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Protein and energy for maintenance and gain of European quail fed different energy sources and housed at two temperatures

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ABSTRACT - The objective of this study was to evaluate whether replacing corn starch (CS) energy with isolated soy protein (ISP) and soybean oil (SO) and the ambient temperature affect the protein and energy requirements for maintenance and gain of European quail. Thus, a total of 432 European quail from 10 to 30 days of age, distributed in a completely randomized design, were used to estimate the protein and energy requirements for maintenance through the comparative slaughter methodology. The treatments consisted of three diets formulated with the replacement of CS, corresponding to 15% of the metabolizable energy in the diet, with ISP and SO, two controlled temperatures (26 and 35 °C), and three levels of feed supply (*ad libitum*, and 70 and 40% of *ad libitum* intake), with four replicates of six birds. Protein and energy requirements for weight gain were determined from 160 European quail, slaughtered every five days at 10, 15, 20, 25, and 30 days of age. Birds were housed in four groups of 40 birds in a room with thermoneutral temperature (26 °C). The energy sources of the feed and temperatures studied affected protein and energy requirements for maintenance and gain of European quail. Replacing CS energy by 15% of dietary energy with SO results in lower protein and energy maintenance requirements for European quail at both temperatures. The protein and energy weight gain requirements of quail fed SO as an energy source is higher than CS and ISP.

Keywords: energy requirements, prediction equations, protein requirement

1. Introduction

Although the economic scenario is going through a challenging time caused by the coronavirus pandemic, world food production has been resilient with an increase in animal protein production to guarantee the demand of the increasing population, according to the United Nations Organization for Agriculture and Food. However, the intensifying greenhouse effect with an increase in the planet's average temperature (Salviano et al., 2016) can also compromise the effort to increase food production, especially animal protein in tropical countries where higher temperatures prevail.

It has been shown in studies that high environmental temperatures influence the performance of broilers (Oba et al., 2012; Silva et al., 2009), heavy dams (Rabello et al., 2004), Japanese quail (Silva et al., 2012; Jordão Filho et al., 2011), and European quail (Sousa et al., 2014; Jordão Filho et al., 2011). Jordão Filho et al. (2011) found that high temperature affects energy maintenance requirements in quail—as temperature increases, maintenance requirements decrease.

The development of nutritional strategies is important to mitigate the negative effects of temperature on animal performance, in addition to helping understand the influence of temperature on energy metabolism and the use of nutrients in feed. Within this context, one strategy can be the use of ingredients that provide less caloric increase, greater welfare, and productivity of the birds.

For van Milgen and Noblet (2003), maintenance energy is, in essence, a requirement of adenosine triphosphate (ATP) and the efficiency of ATP synthesis differs between nutrients; thus, they believe that the metabolizable energy for maintenance is diet-dependent. A study by van Milgen et al. (2001) with growing pigs showed that different nutrients, such as starch, lipids, and proteins, are used with different energy efficiencies.

According to Syafwan et al. (2011), about the same amount of metabolizable energy (ME) is used as ATP when starch and lipids are used for maintenance, and consequently, the heat produced is the same per caloric value of the nutrient for maintenance. In relation to proteins, there is greater heat production per caloric value in ATP production. The same author affirmed that about 66% of the caloric value can be converted to ATP if lipids are used for activity, and the remaining 34% is lost by residual heat. Lipids deposit about 90% of their caloric value in fat production, while only 10% is wasted, which shows the high efficiency of lipids in the deposition.

The estimation of protein requirements for maintenance and weight gain are as important as those for energy, as they comprise several organs and soft structures in the body, thus its adequate and continuous supply throughout the animal's life is necessary. Furthermore, protein is considered one of the main components that increase the cost of feeding commercial birds, so meeting the requirements of this nutrient properly improves quail performance and reduces feed costs. Thus, the objective of this study was to evaluate the influence of replacing corn starch (CS) with protein and lipids in the protein and energy requirement estimates for weight maintenance and gain of European quail housed at two temperatures.

2. Material and Methods

Animal research was conducted in accordance with the institutional committee on animal use (4122150318). The experimental procedures were carried out in Bananeiras, PB, Brazil (6°45'4" S and 35°38'0" W, 544 m of altitude).

A total of 632 European quail (male and female) from 10 to 30 days of age and with an initial weight of 56.75±1.81 g were used, with 432 quail used to estimate the energy and protein requirements for weight maintenance, 160 to estimate the weight gain requirements, and 40 for the reference slaughter.

2.1. Maintenance requirement

The quail used in the maintenance experiment were distributed in galvanized wire cages (33 × 33 × 10 cm) in a completely randomized design. The treatments consisted of three diets formulated with the replacement of CS, corresponding to 15% of the ME in the diet, by the energy of isolated soy protein (ISP) and soybean oil (SO); two temperatures, 26° and 35°C; three feeding levels of 100, 70, and 40% of the *ad libitum* feeding (for maintenance analysis) with four replicates; and six birds per experimental unit. Weight maintenance requirements in energy and protein were estimated by the comparative slaughter methodology. The diets were based on corn and soybean meal, and 15% of the CS energy was replaced with ISP and SO energy (Table 1).

The energy and protein retained in the body of the birds in each plot was calculated by the difference between the amount of energy and protein in the empty body of the birds slaughtered at the end of the experiment and the amount present in the reference slaughter. Maintenance requirements were then determined by the linear relationships of protein and energy retained in the empty body

Table 1 - Composition percentages of ingredients of experimental diet for meat quail (10 to 30 days of age)

Ingredient	Composition of diets			Gain
	Maintenance			
	CS	ISP	SO	
Corn, 8.8% CP	40.950	56.050	38.570	52.560
Soybean meal, 45% CP	25.290	15.560	46.650	38.530
Meat and bone meal	6.871	12.270	5.986	3.290
Corn starch (CS)	12.460	-	-	-
Soybean oil (SO)	-	-	5.000	2.622
Isolated soy protein (ISP)	11.110	12.040	0.772	-
Limestone	1.118	1.130	1.089	1.092
Dicalcium phosphate	0.984	1.038	0.877	0.939
Common salt	0.282	0.238	0.286	0.342
DL-Methionine	0.387	0.431	0.400	0.308
L-Lysine	0.092	0.318	0.051	0.064
L-Threonine	0.016	0.108	0.010	-
L-Arginine	-	0.212	-	-
L-Valine	0.044	0.157	0.036	-
L-Tryptophan	0.142	0.195	0.011	-
Choline chloride	0.060	0.060	0.060	0.060
Vitamin supplement[1]	0.100	0.100	0.100	0.100
Mineral supplement[2]	0.070	0.070	0.070	0.070
Zinc bacitracin	0.015	0.015	0.015	0.015
Butylated hydroxytoluene	0.010	0.010	0.010	0.010
Total	100.000	100.000	100.000	100.000
Nutritional compositions of experimental diets				
Calculated crude protein (%)	27	27	27	23
Crude protein (%)*	26.670	27.760	26.810	22.750
AMEn (Mcal/kg)*	(2.4907)*3 (2.4957)*4	(2.5365)*3 (2.4967)*4	(2.6194)*3 (2.5425)*4	(2.5809)*3 (2.5817)*4
Starch	37.120	37.560	30.040	37.790
Ether extract	2.710	2.380	7.860	5.510
Raw fiber (%)	2.290	3.510	3.310	1.830
Calcium analyzed (%)	0.900	1.320	0.810	0.550
Total phosphorus analyzed (%)	0.600	0.620	0.610	0.450
Digestible arginine (%)	1.660	1.660	1.660	1.400
Digestible met. (%)	0.713	0.737	0.716	0.593
Digestible met. + cyst. (%)	1.050	1.050	1.050	0.890
Digestible lysine (%)	1.350	1.350	1.350	1.140
Digestible threonine (%)	0.870	0.870	0.870	0.747
Digestible tript. (%)	0.300	0.300	0.300	0.881
Digestible valine (%)	1.110	1.110	1.110	0.170
Potassium (%)	0.730	0.642	1.015	0.271
Sodium (%)	0.160	0.170	0.160	0.250
Chlorine (%)	0.249	0.254	0.248	0.932
EB (mEq/kg)	186.090	166.360	259.230	222.700

AMEn - apparent metabolizable energy corrected for nitrogen balance.
1 Basic composition of product: guaranteed levels/kg of product: vitamin A, 10,000,000 IU; vitamin D3, 2,500,000 IU; vitamin E, 6,000 IU; vitamin K, 1,600 mg; vitamin B12, 11,000 mg; niacina, 25,000 mg; folic acid, 400 mg; pantothenic acid, 10,000 mg; selenium, 300 mg; antioxidante, 20 g; vehicle qsp, 1000 g.
2 Basic composition of product: manganese monoxide, zinc oxide, iron sulphate, copper sulphate, calcium iodide, vehicle q.s.p – 1000 g. Guarantee levels per kg of product: Mg, 150,000 mg; Zn, 100,000 mg; Fe, 100,000 mg; Cu, 16,000 mg; I, 1,500 mg.
* - Value analyzed; *3 - Value analyzed room temp 26 °C; *4 - Value analyzed room temp 35 °C.

as a function of both intakes, respectively, through the following model: CP/ME (retained) = a+b* protein/energy (ingested). The ratio of the coefficients (a/b) were interpreted as the CP_m and ME_m requirements and converted to metabolic weight, while the parameter "b" represents the utilization efficiency for gain. The net energy for maintenance (NE_m) was estimated by exponential regression of heat production as a function of ME ingested when extrapolated to zero energy consumption, according to the methodology recommended by Lofgreen and Garrett (1968) and converted into metabolic weight. Heat production was estimated by the difference between ME consumption and energy retention.

2.2. Weight gain requirement

First, 160 birds were distributed into four groups, with four replicates of 10 birds, and then 40 birds were slaughtered every five days (15, 20, 25, and 30 days of age) to estimate the weight gain requirements. The quail were housed in a room at room temperature (26 °C) and fed a control ration (Table 1) *ad libitum*, formulated according to recommendations by Silva and Costa (2009).

Protein and net energy requirements for weight gain were estimated by the regressions of protein and energy retained according to the empty body weight of the quail in five slaughter periods, considering the reference slaughter, carried out at 10 days of age. Parameter "b" of the equation was interpreted as the net protein requirement for weight gain (NP_g) and net energy requirement for weight gain (NE_g), while the dietary requirements for weight gain for both were calculated by the relationship between the NP_g and NE_g requirement and the k_{ng} and k_g (protein and energy utilization efficiencies).

2.3. Slaughter and carcass analysis

The quail were weighed after fasting for 8 h on solid food to determine their empty body weight and then slaughtered by cervical dislocation, avoiding the loss of blood and feathers to enable determining the energy and protein retained in the carcass.

The crude protein (CP) analyzes of the samples were obtained by the Kjeldahl method and the gross energy was determined using a Parr 6100 pump calorimeter.

2.4. Prediction equations

Equations were developed from the daily protein and energy requirements for weight maintenance and gain to predict the protein and energy requirements for the growth of European quail in the 10 to 30-day-old phase, following the prediction models: CP (g/bird/day) = CP_m *$P^{0.75}$ + CP_g *WG; and ME (kcal/bird/day) = ME_m *$P^{0.75}$ + ME_g *WG, in which CP_m = crude protein requirement for maintenance (g/kg$^{0.75}$/d); CP_g = CP requirement for weight gain (g/g); ME_m = ME requirement for maintenance (kcal/kg$^{0.75}$/d); ME_g = ME requirement for weight gain (kcal/g); $P^{0.75}$ = metabolic weight; and WG = weight gain.

3. Results

The CP_m requirements were estimated at 7.73, 8.52, and 6.0 g/kg$^{0.75}$/day in the room at 26 °C and 7.31, 7.91, and 6.55 g/kg$^{0.75}$/day in the room at 35 °C for the CS, ISP, and SO sources, respectively (Table 2). The requirements were higher at a temperature of 26 °C, with the exception of the SO source, which had higher requirements in the 35 °C room. The ISP source provided greater efficiency of use (43%) at the temperature of 35 °C, while the efficiency was higher with the CS source (33%) at the temperature of 26 °C.

The NP_g requirement was estimated at 0.19 g/g. Dietary protein requirements for gain were higher at 26 °C (0.57, 0.59, and 0.51 g/g) when compared with 35 °C (0.50, 0.44, and 0.52 g/g) for CS, ISP, and SO, respectively (Figure 1).

Table 2 - Regression equations for retained crude protein (CP_{ret}) as a function of ingested protein (CP_{ing}), CP requirement for maintenance (CP_m), and protein use efficiencies for gain (K_{ng}) of 10 to 30-day-old European quail fed different sources housed at 26 and 35 °C

T°	Equation	r^2	Metabolic weight ($kg^{0.75}$)	PB_m ($g/kg^{0.75}/d$)	k_{ng} (%)
			Corn starch		
26 °C	CP_{ret}: −0.5114 + 0.3275*CP_{ing}	0.99	0.200	7.73	33
35 °C	CP_{ret}: −0.5542 + 0.3818*CP_{ing}	0.94	0.198	7.31	38
			Isolated soy protein		
26 °C	CP_{ret}: −0.5364 + 0.3243*CP_{ing}	0.96	0.198	8.52	32
35 °C	CP_{ret}: −0.66 + 0.4256*CP_{ing}	0.98	0.194	7.91	43
			Soybean oil		
26 °C	CP_{ret}: −0.3844 + 0.3154*CP_{ing}	0.95	0.198	6.00	31
35 °C	CP_{ret}: −0.46341 + 0.355*CP_{ing}	0.96	0.195	6.55	36

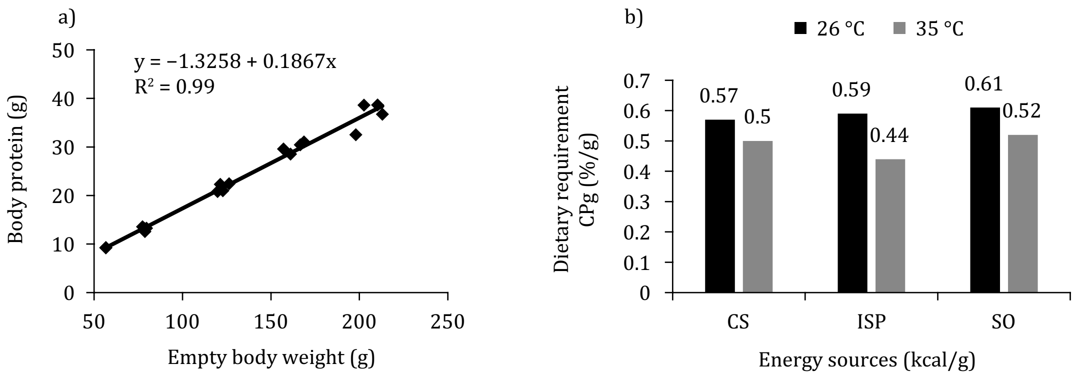

Figure 1 - Body crude protein (CP_b) as a function of empty body weight with estimated net gain requirement of 0.19 g/g (a) and dietary requirement (b) of European quail fed different energy sources and housed at 26 and 35 °C.

The requirements for ME_m, NE_m, and utilization efficiency were influenced by energy sources and temperature (Table 3). The ME_m requirements estimated for quail housed at a temperature of 26 °C were higher (96.48, 102.69, and 93.24 kcal/kg$^{0.75}$/day) than the ME_m estimated at a temperature of 35 °C (85, 68, 85.27, and 70.27 kcal/kg$^{0.75}$/day) respectively, for the CS, ISP, and SO sources. It was observed that replacing corn starch with the ISP source at a temperature of 26 °C caused an increase in the ME_m requirements, while the SO source provided lower requirements at both temperatures.

The NE_m requirements of the quail housed at a temperature of 26 °C were higher than those estimated for the quail housed at 35 °C. Quail housed at 26 °C produced more heat when fed the diet containing ISP compared with other sources, while production in the room at 35 °C was similar. The usage efficiency increased at a temperature of 35 °C and the ISP source provided greater efficiencies among the three sources.

The net gain requirement from the linear regression of body energy as a function of empty body weight was estimated at 1.59 kcal/g. The dietary requirements of ME_g were higher for quail housed at a temperature of 26 °C (5.89, 5.3, and 6.11 kcal/g) when compared with those estimated at the temperature of 35 °C, with requirements of 5.48, 5.13 and 5.89 kcal/g, respectively, for the CS, ISP and SO sources (Figure 2). Birds fed the SO source had higher ME_g requirements at both temperatures than the other sources.

It was then possible to simulate the nutritional plans for European quail aged 10 to 30 days from the estimates of energy and protein requirements for weight maintenance and gain considering metabolic weight, gain, and the effect of temperature and energy sources of the feed (Tables 4, 5, and 6).

Table 3 - Regression equations for retained energy (E_{ret}) as a function of ingested metabolizable energy (ME_{ing}), ME requirement for maintenance (ME_m), net energy for maintenance (NE_m), and energy usage efficiencies for gain (K_g) of 10 to 30-day-old European quail fed different energy sources and housed at 26 and 35 °C

T°	Equation	r^2	Metabolic weight ($kg^{0.75}$)	Energy requirement ($kcal/kg^{0.75}/d$)		K_g (%)
				ME_m	NE_m	
			Corn starch			
26 °C	E_{ret}: −5.2094 + 0.2729*ME_{ing}	0.98	0.200	96.48		27
	CP: 11.626*$e^{0.0266*MEing}$	0.98	0.200		58.15	
35 °C	E_{ret}: −4.9188 + 0.2899*ME_{ing}	0.92	0.198	85.68		29
	CP: 10.037*$e^{0.030*MEing}$	0.96	0.198		50.71	
			Isolated soy protein			
26 °C	E_{ret}: −6.1049 + 0.2994*ME_{ing}	0.89	0.198	102.69		30
	CP: 11.927*$e^{0.0258*MEing}$	0.95	0.198		60.25	
35 °C	E_{ret}: −5.7915 + 0.3498*ME_{ing}	0.94	0.194	85.27		35
	CP: 9.8747*$e^{0.0305*MEing}$	0.96	0.194		50.88	
			Soybean oil			
26 °C	E_{ret}: −4.8002 + 0.2555*ME_{ing}	0.91	0.198	93.24		26
	CP: 11.085$e^{0.0282*MEing}$	0.96	0.198		56.01	
35 °C	E_{ret}: −3.699 + 0.2663*ME_{ing}	0.88	0.195	70.27		27
	CP: 9.8495*$e^{0.0303*MEing}$	0.95	0.195		50.51	

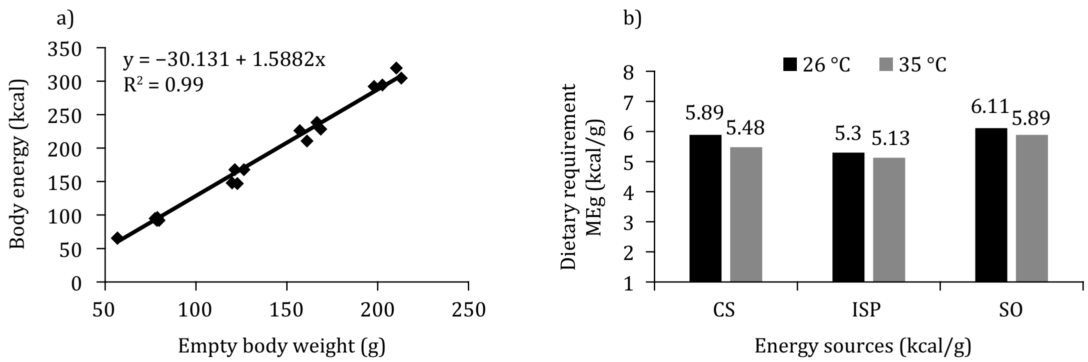

Figure 2 - Body gross energy (GE_b) as a function of empty body weight with estimated net gain requirement of 1.59 kcal/g (a) and dietary requirement (b) of European quail fed different energy sources housed at temperatures of 26 and 35 °C.

The prediction equations to estimate the protein requirements for maintenance and gain of European quail from 10 to 30 days for CS are: CP (g/bird/d) = 7.73*$P^{0.75}$ + 0.57*WG (26°C), CP (g/bird/d) = 7.31*$P^{0.75}$ + 0.50*WG (35 °C); for ISP: CP (g/bird/d) = 9.52*$P^{0.75}$ + 0.59*WG (26 °C), CP (g/bird/d) = 7.91*$P^{0.75}$ + 0.44*WG (35 °C); and for SO: CP (g/bird/d) = 6.00*$P^{0.75}$ + 0.61*WG (26 °C), CP (g/bird/d) = 6.55*$P^{0.75}$ + 0.52*WG (35°C).

The prediction equations for estimating the energy requirements for weight maintenance and gain for CS are: ME (kcal/bird/d) = 96.48*$P^{0.75}$ + 5.89*WG (26 °C), ME (kcal/bird/d) = 85.68*$P^{0.75}$ + 5.48*WG (35 °C); for ISP: ME (kcal/bird/d) = 102.69*$P^{0.75}$ + 5.30*WG (26 °C), ME (kcal/bird/d) = 85.27*$P^{0.75}$ + 5.13*WG (35 °C); and for SO: ME (kcal/bird/d) = 93.24*$P^{0.75}$ + 6.11*WG (26 °C), ME (kcal/bird/d) = 70.27*$P^{0.75}$ + 5.89*WG (35 °C).

Table 4 - Feeding plan for European quail from 10 to 30 days of age fed corn starch as an energy source and housed at 26 and 35 °C at different weight gains depending on the metabolizable energy (ME) and crude protein (CP) requirements

Corn starch										
BW (g)	WG (g/d)	MW (kg$^{0.75}$)	ME requirement (kcal/a/d)			CP requirement (g/a/d)			FI (g/d) - kcal ME (CP%)	
			ME_m[1]	ME_g[2]	Total	CP_m[1]	CP_g[2]	Total	2,800	2,900
26 °C										
60	0	0.121	11.67	0	11.67	0.93	0	0.93	4.17(22)	4.02(23)
100	2	0.178	17.17	11.78	28.95	1.38	1.14	2.52	10.34(24)	9.98(25)
140	4	0.229	22.09	23.56	45.65	1.77	2.28	4.05	16.30(25)	15.74(26)
180	6	0.276	26.63	35.56	61.97	2.13	3.42	5.55	22.13(25)	21.37(26)
35 °C										
60	0	0.121	10.37	0	10.37	0.88	0	0.88	3.70(24)	3.58(25)
100	2	0.178	15.25	10.96	26.21	1.30	1	2.30	9.36(24)	9.04(25)
140	4	0.229	19.62	21.96	41.54	1.67	2	3.67	14.84(25)	14.32(26)
180	6	0.276	23.65	32.88	56.53	2.04	3	5.04	20.19(25)	19.49(26)

CP - crude protein; BW - body weight; WG - weight gain; MW - metabolic weight; FI - feed intake.
[1] Metabolic requirement for maintenance.
[2] Metabolic requirement for gain.
ME_m = 26 °C = 96.48*$P^{0.75}$ and 35 °C = 85.68*$P^{0.75}$; CP_m = 26 °C = 7.73*$P^{0.75}$ and 35 °C = 7.31*$P^{0.75}$.
ME_g = 26 °C = 5.89*WG and 35 °C = 5.48*WG; CP_g = 26 °C = 0.57*WG and 35 °C = 0.50*WG.

Table 5 - Feeding plan for European quail from 10 to 30 days of age fed isolated soy protein as an energy source and housed at 26 and 35 °C at different weight gains, depending on the metabolizable energy (ME) and crude protein (CP) requirements

Isolated soy protein										
BW (g)	WG (g/d)	MW (kg$^{0.75}$)	ME requirement (kcal/a/d)			CP requirement (g/a/d)			FI (g/d) - kcal ME (CP%)	
			ME_m[1]	ME_g[2]	Total	CP_m[1]	CP_g[2]	Total	2,800	2,900
26 °C										
60	0	0.121	12.43	0	12.43	1.03	0	1.03	4.44(23)	4.27(24)
100	2	0.178	18.28	10.60	28.88	1.52	1.18	2.7	10.31(26)	9.96(27)
140	4	0.229	23.52	21.20	44.72	1.95	2.36	4.31	15.97(27)	15.42(28)
180	6	0.276	28.34	31.80	60.14	2.35	3.54	5.89	21.48(27)	20.74(28)
35 °C										
60	0	0.121	10.32	0	10.32	0.96	0	0.96	3.68(26)	3.56(27)
100	2	0.178	15.18	10.26	25.44	1.41	0.88	2.29	9.09(25)	8.77(26)
140	4	0.229	19.53	20.52	40.05	1.81	1.76	3.57	14.30(25)	13.81(26)
180	6	0.276	23.53	30.78	54.31	2.18	2.64	4.82	19.40(25)	18.73(26)

BW - body weight; WG - weight gain; MW - metabolic weight; FI - feed intake.
[1] Metabolic requirement for maintenance.
[2] Metabolic requirement for gain.
ME_m = 26 °C = 102.69*$P^{0.75}$ and 35 °C = 85.27*$P^{0.75}$; CP_m = 26 °C = 9.52*$P^{0.75}$ and 35 °C = 7.91*$P^{0.75}$.
ME_g = 26 °C = 5.30*WG and 35 °C = 5.13*WG; CP_g = 26 °C = 0.59*WG and 35 °C = 0.44*WG.

4. Discussion

The CP_m requirements were close to those found by Nogueira et al. (2019), 6.63 g/kg$^{0.75}$/day for European quail from 15 to 35 days of age. The CP_m requirements in this study show that quail raised in 35 °C environments have a lower CP_m requirement than birds housed at 26 °C, except for the CP_m requirements of quail receiving SO, which increased with heat from 6.00 to 6.55 g/kg$^{0.75}$/day.

Table 6 - Feeding plan for European quail from 10 to 30 days of age fed soybean oil as an energy source and housed at 26 and 35 °C at different weight gains, depending on the metabolizable energy (ME) and crude protein (CP) requirements

Soybean oil										
BW (g)	WG (g/d)	MW ($kg^{0.75}$)	ME requirement (kcal/a/d)			CP requirement (g/a/d)			FI (g/d) - kcal ME (CP%)[3]	
			ME_m[1]	ME_g[2]	Total	CP_m[1]	CP_g[2]	Total	2,800	2,900
26 °C										
60	0	0.121	11.28	0	11.28	0.73	0	0.73	4.02(18)	3.89(19)
100	2	0.178	16.6	12.22	28.82	1.07	1.22	2.29	10.29(22)	9.94(23)
140	4	0.229	21.35	24.44	45.79	1.37	2.44	3.81	16.35(23)	15.79(24)
180	6	0.276	25.73	36.66	62.39	1.66	3.66	5.32	22.28(24)	21.51(25)
35 °C										
60	0	0.121	8.5	0	8.5	0.79	0	0.79	3.04(26)	2.93(27)
100	2	0.178	12.51	11.78	24.29	1.17	1.04	2.21	8.68(25)	8.38(26)
140	4	0.229	16.09	23.56	39.65	1.50	2.08	3.58	14.16(25)	13.67(26)
180	6	0.276	19.39	35.34	54.73	1.81	3.12	4.93	19.55(25)	18.87(26)

BW - body weight; WG - weight gain; MW - metabolic weight; FI - feed intake.
[1] Metabolic requirement for maintenance.
[2] Metabolic requirement for gain.
ME_m = 26°C = 93.24*$P^{0.75}$/35°C = 70.27*$P^{0.75}$; CP_m = 26°C = 6.00*$P^{0.75}$/35°C = 6.55*$P^{0.75}$.
ME_g = 26°C = 6.11*WG/35°C = 5.89*WG; CP_g = 26°C = 0.61*WG/35°C = 0.52*WG.

In a study with heavy dams and with European quail, Rabello et al. (2004) and Silva et al. (2018), respectively, found an increase in CP_m requirements when the birds moved from a cold to a warm environment. However, according to Oliveira et al. (2006), the nutritional requirements of birds change with the temperature of the environment also as a result of the change in the size of the organs and that the larger the size, the greater the animal's requirement. These authors observed a quadratic effect on carcass weight and organ size of broilers housed at different temperatures (16, 20, 25, and 32 °C), pointing out that birds housed at room temperature (25 °C) have higher carcass and organ weights, which suggests that the requirements are higher than in birds housed at higher or lower temperatures, as observed in this work.

The CP_m requirements at both temperatures were higher when the birds were fed the ISP source compared with CS and SO. These values may be the result of the low energy:protein ratio in the diet, which led the birds to use a large part of the protein in the diet as energy, and therefore the requirement is greater. According to Batal and Parsons (2003) and Longo et al. (2005), isolated soy protein has high digestibility, which favors greater use of this nutrient by animals.

The K_{ng} of diets in the 26 °C room with CS, ISP, and SO sources were 33, 32, and 31%, respectively, constituting similar values found by Nogueira et al. (2019) of 39.86% for meat quail from 15 to 36 days reared on the ground. In this study, we found 38, 43, and 36% at the temperature of 35 °C with the CS, ISP, and SO sources, respectively, constituting values close to 38% observed by Jordão Filho (2008) for meat quail from 16 to 36 days old raised in cages at 28 °C.

However, the protein utilization efficiency in other species has been higher, as observed in the study by Albino et al. (1994) and Longo et al. (2001), who found the value of 55.61% for light pullets from 42 to 63 days and 72% for broilers, respectively. According to Silva et al. (2012), the less efficient use of quail when compared with other birds can be explained by the fact that they are more demanding for CP than broilers and laying hens, as they are less efficient in using dietary nitrogen and, therefore, need more protein for maintenance and growth.

Silva et al. (2018) explained that in addition to environmental conditions, activity, and genotype, the efficiency of protein utilization is influenced by age and the type of tissue in formation, with younger birds being more efficient than adult birds due to the predominance of growth muscle, while the older ones prioritize adipose tissue deposition. The greater efficiencies observed at the highest temperature suggest that the birds used most of the dietary protein for weight gain, while the preference at 26 °C was to use protein for maintenance.

Linear regression of body protein as a function of empty body weight indicated net protein requirement for a weight gain of 0.190 g/g. This value is similar to 0.194 g/g of Japanese quail from 15 to 32 days observed by Silva et al. (2004) and 0.211 g/g by Jordão Filho et al. (2012) for European quail.

Estimates of CP_g requirements were similar to the 0.55 g found by Jordão Filho et al. (2012) for European quail aged 16 to 36 days and reared in cages, and 0.52 g for European quail aged 15 to 35 days found by Nogueira et al. (2019). Considering the utilization efficiency of the consumed protein for the net gain of protein in the empty body, higher CP_g requirements were determined for the SO source at both temperatures due to the lower efficiencies when compared with the other sources. The ISP source at a temperature of 35 °C had the lowest CP_g requirement, while starch was more efficient at 26 °C than the other two sources.

There was a reduction in the ME_m and NE_m requirement with increasing temperature. For Silva et al. (2018), this happens due to lower feed intake and, consequently, lesser oxidation of nutrients for heat production and maintenance of body temperature.

Furthermore, according to O'Neill and Jackson (1974), the increase in ambient temperature decreases the energy requirements for maintenance because the birds present better efficiency in the ME conversion into net energy. This fact is also reflected in the usage efficiencies for weight gain in which they were higher at the temperature of 35 °C.

The requirements were higher with ISP at 26 °C. This result confirms the hypothesis that proteins are not efficiently used as an energy source and still entails a greater increase in calories and energy losses due to the excretion of nitrogen compounds (Emmans, 1994). Van Milgen and Noblet (2003) stated that in addition to spending on ATP in protein synthesis and catabolism, there is greater energy loss in eliminating excess nitrogen such as uric acid. For Heinz (1965) and Mitchell et al. (1978), the calorigenic effect of amino acids is due to the high energy demand by the liver for the deamination processes and uric acid formation, in addition to extra energy for subsequent metabolism of the carbon skeletons resulting from this deamination if they are not oxidized to carbon dioxide and water. These authors also stated that more energy would be required if carbon skeletons are converted into glucose, glycogen, or fat.

The NE_m requirement was higher when the ISP source was used. According to reports by Musharaf and Latshaw (1999), protein causes an increase in heat production compared to carbohydrates and fats, and in this case, more energy from the protein is needed to produce an amount of useful energy for the animal, which emphasizes the protein calorigenic effect.

The requirements and heat production were lower at both temperatures with the replacement of CS by the SO source; this effect may be associated with a higher energy density of the oil, causing a smaller amount to meet the maintenance requirement of the quail when compared with the others. Lipid sources provide about 2.25 times more energy and have a lower caloric increase than carbohydrates and proteins. According to Junqueira et al. (2005), they are readily available energy suppliers with an extra-caloric effect, which is reflected in their ME content and, consequently, in the animals' performance.

In studies carried out to estimate the ME_m requirements, such as for laying hens (Sakomura et al., 2005), pullets (Albino et al., 1994), and growing dams (Sakomura et al., 2003), higher requirements were observed when compared with the results of this study, which must be related to the surface and body mass ratio of chickens, hens, and dams, implying that the energy requirements of European quail are different from other species.

The K_g were similar to those found by Jordão Filho et al. (2011), with 27, 26, and 28% at temperatures of 18, 24, and 28 °C, respectively. However, they were lower than those found for other bird species, such as 55% for pullets (Albino et al., 1994), 59% for broilers (Longo et al., 2006), and 69, 69, and 63% for growing heavy dams maintained at temperatures of 15, 22, and 30 °C, respectively (Sakomura et al., 2003). For Silva et al. (2004), the low efficiency of energy use estimated in Japanese quail compared with estimates in other birds reinforces the differences between species in retaining more or less energy and protein efficiency, and this should be used as a criterion in the development of nutritional plans for European quail.

The NE_g requirement of 1.59 kcal/g is below the values found by Jordão Filho et al. (2011) of 2.14 and 2.07 kcal/g for European and Japanese quail aged 16 to 36 days, respectively, while Silva et al. (2004) estimated NE_g of 2.05 kcal/g for Japanese quail from 15 to 32 days of age.

The ME_g requirements were lower than the values presented by Jordão Filho et al. (2011) of 7.64 and 8.28 kcal/g for European and Japanese quail reared in cages, respectively, and 9.32 kcal/g for Japanese quail estimated by Silva et al. (2004).

Bird studies have shown a wide variation for ME_g requirements, with values from 1.91 (Balnave et al., 1978) to 9.32 kcal/g (Silva et al., 2004). According to Sakomura et al. (2005), ME_g requirements are related to differences in body composition, so comparisons between breeds should be cautious, as they have different sizes and body compositions (Scott et al., 1982). Furthermore, according to Rostagno et al. (2017), these differences in requirements may reflect that quail in Brazil are not standardized, which results in a variation of nutritional requirements.

Sakomura et al. (2005) also observed that it is necessary to consider the efficiency with which the energy from the diet is used and deposited in the tissue. The energy use efficiency for weight gain of an average of 29% is different from those found by Silva et al. (2004) and Jordão Filho et al. (2011). According to Groote (1974), the efficiency of energy used for weight gain in growing animals is around 37 to 85%.

Considering the energy sources of the feed, birds fed SO had the highest requirements for ME_g, followed by CS and ISP. This shows that SO is not efficiently used to gain weight in growing quail. The results of this study confirm the hypothesis that the protein source should not be used as an energy source for growing quail due to its thermogenic effect and its cost, and that the energy and protein requirements for weight maintenance and gain decrease as the temperature increases.

In terms of nutrition, it is possible to see that with increased weight gain, more feed and protein should be provided to quail, regardless of temperature and source, and that feeds with higher density should contain more protein due to lower intake.

The nutritional plan simulation enables us to suggest that European quail require a diet containing 2,900 kcal/kg of ME and 26% CP for maximum weight gain at high temperatures, regardless of the source (CS, ISP, and SO).

5. Conclusions

Replacing corn starch energy by 15% of dietary energy with soybean oil results in lower protein and energy maintenance requirements for European quail at both temperatures. The requirement of protein and energy gain of quail fed soybean oil as an energy source is higher than corn starch and isolated soy protein. The use of corn starch and isolated soy protein as energy sources improves the weight gain efficiency in European quail. The energy and protein requirements for weight maintenance and gain of European quail, regardless of the sources, are lower when birds are housed in an environment with 35 °C.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: G.C.C. Pereira, J. Jordão Filho, G.C.A. Santos and J.H.V. Silva. Data curation: G.C.C. Pereira. Formal analysis: J.H.V. Silva. Funding acquisition: J.H.V. Silva. Investigation: G.C.C. Pereira, J. Jordão Filho, L.A.F. Pascoal, G.C.A. Santos, D.R.P. Silva and J.H.V. Silva. Methodology: G.C.C. Pereira, J. Jordão Filho, G.C.A. Santos, D.R.P. Silva and J.H.V. Silva. Supervision: J. Jordão Filho, L.A.F. Pascoal and J.H.V. Silva. Writing – original draft: G.C.C. Pereira. Writing – review & editing: G.C.C. Pereira, J. Jordão Filho, C.F.S. Oliveira and D.T. Cavalcante.

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References

Albino, L. F. T.; Fialho, F. B.; Bellaver, C.; Hara, C. and Paiva, G. J. 1994. Estimativas das exigências de energia e proteína para frangas de postura em recria. Pesquisa Agropecuária Brasileira 29:1625-1629.

Balnave, D.; Farrel, D. J. and Cumming, R. B. 1978. The minimum metabolizable energy requeriment of laying hens. World's Poultry Science Journal 34:149-154. https://doi.org/10.1079/WPS19960035

Batal, A. B. and Parsons, C. M. 2003. Utilization of different soy products as affected by age in chicks. Poultry Science 82:454-462. https://doi.org/10.1093/ps/82.3.454

Emmans, G. C. 1994. Effective energy: a concept of energy utilization applied across species. British Journal of Nutrition 71:801-821. https://doi.org/10.1079/BJN19940188

Groote, G. 1974. Utilization of metabolizable energy. p.113-133. In: Energy requirements of poultry. Morris, T. R. and Freeman, B. M., eds. British Poultry Science, Edinburgh.

Heinz, H. J. 1965. The Heinz handbook of nutrition. 2nd ed. Blakiston Division.

Jordão Filho, J. 2008. Estimativas das exigências de proteína e de energia para mantença, ganho e produção de ovos em codornas. Tese (D.Sc.). Universidade Federal da Paraíba, Areia.

Jordão Filho, J.; Silva, J. H. V.; Costa, F. G. P.; Albino, L. F. T.; Melo, T. S.; Lacerda, P. B.; Dantas, G. M. and Soares, R. P. 2012. Requirement for maintenance and gain of crude protein for two genotypes of growing quails. Revista Brasileira de Zootecnia 41:2048-2054. https://doi.org/10.1590/S1516-35982012000900012

Jordão Filho, J.; Silva, J. H. V.; Silva, C. T.; Costa, F. G. P.; Sousa, J. M. B. and Givisiez, P. E. N. 2011. Energy requirement for maintenance and gain for two genotypes of quails housed in different breeding rearing systems. Revista Brasileira de Zootecnia 40:2415-2422. https://doi.org/10.1590/S1516-35982011001100019

Junqueira, O. M.; Andreotti, M. O.; Araújo, L. F.; Duarte, K. F.; Cancherini, L. C. and Rodrigues, E. A. 2005. Valor energético de algumas fontes lipídicas determinado com frangos de corte. Revista Brasileira de Zootecnia 34:2335-2339. https://doi.org/10.1590/S1516-35982005000700020

Lofgreen, G. P. and Garrett, W. N. 1968. A system for expressing net energy requirements and feed values for growing and finishing beef cattle. Journal of Animal Science 27:793-806. https://doi.org/10.2527/jas1968.273793x

Longo, F. A.; Sakomura, N. K.; Figueiredo, N. A.; Rabello, C. B. V. and Ferraudo, A. S. 2001. Equações de predição das exigências protéicas para frangos de corte. Revista Brasileira de Zootecnia 30:1521-1530. https://doi.org/10.1590/S1516-35982001000600020

Longo, F. A.; Menten, J. F. M.; Pedroso, A. A.; Figueiredo, A. N.; Racanicci, A. M. C.; Gaiotto, J. B. and Sorbara, J. O. B. 2005. Diferentes fontes de proteína na dieta pré-inicial de frangos de corte. Revista Brasileira de Zootecnia 34:112-122. https://doi.org/10.1590/S1516-35982005000100015

Longo, F. A.; Sakomura, N. K.; Rabello, C. B. V.; Figueiredo, A. N. and Fernandes, J. B. K. 2006. Exigências energéticas para mantença e para o crescimento de frangos de corte. Revista Brasileira de Zootecnia 35:119-125. https://doi.org/10.1590/S1516-35982006000100015

Mitchell, H. S.; Rynbergen, H. J.; Anderson, L. and Dibble, M. V. 1978. Nutrición y dieta. 16.ed. Nueva Editorial Interamericana, México.

Musharaf, N. A. and Latshaw, J. D. 1999. Heat increment as affected by protein and amino acid nutrition. World's Poultry Science Journal 55:233-240. https://doi.org/10.1079/WPS19990017

Nogueira, M. F. Z. F.; Marcato, S. M.; Furlan, A. C.; Zancanela, V.; Finco, E. M.; Grieser, D. O.; Stanquevis, C. E. and Oliveira-Bruxel, T. M. 2019. Models for predicting protein requirements for meat quail. Animal Science Journal 90:870-879. https://doi.org/10.1111/asj.13172

Oba, A.; Lopes, P. C. F.; Boiago, M. M.; Silva, A. M. S.; Montassier, H. J. and Souza, P. A. 2012. Características produtivas e imunológicas de frangos de corte submetidos a dietas suplementadas com cromo, criados sob diferentes condições de ambiente. Revista Brasileira de Zootecnia 41:1186-1192. https://doi.org/10.1590/S1516-35982012000500016

Oliveira, G. A.; Oliveira, R. F. M.; Donzele, J. L.; Cecon, P. R.; Vaz, R. G. M. V. and Orlando, U. A. D. 2006. Efeito da temperatura ambiente sobre o desempenho e as características de carcaça de frangos de corte dos 22 aos 42 dias. Revista Brasileira de Zootecnia 35:1398-1405. https://doi.org/10.1590/S1516-35982006000500020

O'Neill, S. J. B. and Jackson, N. 1974. Observations on the effect of environmental temperature and environmental at moult on the heat production and energy requirements of hens and cockerels of a white leghorn strain. Journal of Agriculture Science 82:553-558. https://doi.org/10.1017/S0021859600051455

Rabello, C. B. V.; Sakomura, N. K.; Longo, F. A. and Resende, K. T. 2004. Efeito da temperatura ambiente e do sistema de criação sobre as exigências de energia metabolizável para mantença de aves reprodutoras pesadas. Revista Brasileira de Zootecnia 33:382-390. https://doi.org/10.1590/S1516-35982004000200015

Rostagno, H. S.; Albino, L. F. T.; Hannas, M. I.; Donzele, J. L.; Sakomura, N. K.; Perazzo, F. G.; Saraiva, A.; Teixeira, M. L.; Rodrigues, P. B.; Oliveira, R. F.; Barreto, S. L. T. and Brito, C. O. 2017. Tabelas brasileiras para aves e suínos: composição de alimentos e exigências nutricionais. 4.ed. Departamento de Zootecnia, Universidade Federal de Viçosa, Viçosa, MG.

Salviano, M. F.; Groppo, J. D. and Pellegrino, G. Q. 2016. Análise de tendências em dados de precipitação e temperatura no Brasil. Revista Brasileira de Meteorologia 31:64-73. https://doi.org/10.1590/0102-778620150003

Sakomura, N. K.; Basaglia, R.; Sá-Fortes, C. M. L. and Fernandes, J. B. K. 2005. Modelos para estimar as exigências de energia metabolizável para poedeiras. Revista Brasileira de Zootecnia 34:575-583. https://doi.org/10.1590/S1516-35982005000200027

Sakomura, N. K.; Silva, R.; Couto, H. P.; Coon, C. and Pacheco, C. R. 2003. Modeling metabolizable energy utilization in broiler breeder pullets. Poultry Science 82:419-427. https://doi.org/10.1093/ps/82.3.419

Scott, M. L.; Nesheim, M. C. and Young, R. J. 1982. Nutrition of the chicken. 3rd ed. M.L. Scott, Ithaca.

Silva, J. H. V.; Silva, M. B.; Jordão Filho, J.; Silva, E. L.; Andrade, I. S.; Melo, D. A.; Ribeiro, M. L. G.; Rocha, M. R. F.; Costa, F. G. P. and Dultra Júnior, W. M. 2004. Exigências de mantença e de ganho em proteína e energia em codornas japonesas (*Coturnix coturnix japonica*) na fase de 15 a 32 dias. Revista Brasileira de Zootecnia 33:1220-1230. https://doi.org/10.1590/S1516-35982004000500014

Silva, J. H. V. and Costa F. G. P. 2009. Tabela para codornas japonesas e europeias. 2.ed. FUNEP, Jaboticabal.

Silva, J. H. V.; Jordão Filho, J.; Costa, F. G. P.; Lacerda, P. B.; Vargas, D. G. V. and Lima M. R. 2012. Exigências nutricionais de codornas. Revista Brasileira de Saúde e Produção Animal 13:775-790.

Silva, J. H. V.; Jordão Filho, J. and Santos S. C. L. 2018. Produção de codornas - recentes avanços na nutrição de codornas: modelagem da energia e proteína. p.71-91. In: Produção de não ruminantes. Costa, F. G. P. and Silva, J. H. V., org. Editora Universitária-UFPB, João Pessoa.

Silva, V. K.; Silva, J. D. T.; Gravena, R. A.; Marques, R. H.; Hada, F. H. and Moraes, V. M. B. 2009. Desempenho de frangos de corte de 1 a 21 dias de idade alimentados com rações contendo extrato de leveduras e prebiótico e criados em diferentes temperaturas. Revista Brasileira de Zootecnia 38:690-696. https://doi.org/10.1590/S1516-35982009000400015

Sousa, M. S.; Tinoco, I. F. F.; Barreto, S. L. T.; Amaral, A. G.; Pires, L. C. and Ferreira, A. S. 2014. Determinação de limites superiores da zona de conforto térmico para codornas de corte aclimatizadas no Brasil de 22 a 35 dias de idade. Revista Brasileira de Saúde e Produção Animal 15:350-360.

Syafwan, S.; Kwakkel, R. P. and Verstegen, M. W. A. 2011. Heat stress and feeding strategies in meat-type chickens. World's Poultry Science Journal 67:653-674. https://doi.org/10.1017/S0043933911000742

van Milgen, J. V. and Noblet, J. 2003. Partitioning of energy intake to heat, protein, and fat in growing pigs. Journal of Animal Science 81:E86-E93.

van Milgen, J. V.; Noblet, J. and Dubois S. 2001. Energetic efficiency of starch, protein and lipid utilization in growing pigs. Journal of Nutrition 131:1309-1318. https://doi.org/10.1093/jn/131.4.1309