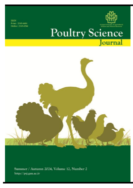

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Estimation of Dietary Metabolizable Energy Requirement of Growing Japanese Quail Using Broken Line Regression

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Abstract

A dose-response experiment with seven dietary energy levels (2500, 2650, 2800, 2950, 3100, 3250 and 3400 kcal of MEn/Kg) was implemented to study the effects of dietary energy level on growth performance and carcass characteristics of Japanese quails from 2 to 5 weeks of age. Three hundred and thirty-six 14-day-old Japanese quails were randomly divided into 7 dietary treatments, containing six replicates with eight males and females per each, and the birds were grown up to 5 weeks of age. At 35 d of age, weight gain, feed intake and feed conversion ratio (FCR) of quails from each pen were measured or calculated, and one quail (male one) that had similar body weight to the average of the replication weight was selected and slaughtered to evaluate the yields of carcass parts. The results showed that with an increase in dietary MEn levels feed intake, crude protein intake, FCR and crude protein intake:gain (g/g) of quails decreased significantly ($P < 0.05$). The highest and the lowest dietary MEn levels resulted in a decrease in body weight gain and metabolizable energy intake (kcal/b). The highest rate of weight gain belonged to moderate dietary energy levels (2800 and 2950 kcal/kg). The results of the experiment revealed that metabolizable energy intake to weight gain, as well as some carcass characteristics such as edible carcass, thighs and breast percentages and giblets (liver, heart and gizzard percentages), were not affected by different dietary energy levels. With increasing dietary energy from 2500 to 2950 kcal MEn/Kg, the weight gain of quail increased and above 2950 kcal/Kg decreased significantly ($p=0.0058$). Based on broken line regression analysis, between two and four weeks of age, the metabolizable energy requirement of growing quails was 2831 and 2799 Kcal/kg for optimal weight gain and FCR, respectively, when protein level in the diet was 24 percent.

Introduction

Usually, the first step in the preparation of poultry feed formulation is to choose the appropriate energy level of the diet because the lowest production cost is achieved through the selection of the appropriate energy level of the diet (National Research Council, 1994). McDonald and Evans (1977) reported that, as a general rule, the selection of an appropriate dietary energy level would be related to the metabolizable energy cost of the diet compared to the benefit gained from that level. In quail rations, energy-containing dietary ingredients are the primary cost and the optimal level of energy is important to reduce feed cost per unit of quail production. Many studies were found examining the effects of dietary energy levels on the growth of growing quail. Some studies related to the determination of the nutritional requirements of quail are carried out using the dose-response method and are not based on dietary energy partition mechanisms necessary for the maintenance, growth and production of quail (Zancanela *et al.*, 2015). Currently, although

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workers reported on the response of quail to dietary energy (Angulo *et al*., 1993, Elangovan *et al*., 2004, Kaur *et al*., 2008, Mosaad and Iben, 2009, Attia *et al*., 2012, Ghazaghi *et al*., 2012, Sheikh *et al*., 2012, Mahmood *et al*., 2014, Dowarah *et al*., 2014, Reda *et al*., 2015, Muniz *et al*., 2016, Omidiwura *et al*., 2016, Yazarloo *et al*., 2017, Taheri *et al*., 2017, Muniz *et al*., 2018, Ashour *et al*., 2022), however, the results of these experiments were somewhat controversial according to the differences among the age of experimental birds, dietary energy level used by authors, criteria measured and different methodology which used in their experiments. For instance, it has been reported that increasing the energy level of the diet can improve the feed conversion rate of quail by reducing feed consumption (Attial *et al*., 2012, Kaur *et al*., 2008, Muniz *et al*., 2016). However, some studies showed that dietary energy levels didnot have any significant effect on the body weight and feed conversion ratio of quails (Ghazaghi *et al*., 2012, Dowarah *et al*., 2014). According to the knowledge of the authors, there was not any dose response study to investigate the energy requirement of growing Japanese quails with wider ranges of dietary metabolizable energy at the age between 3-5 weeks of age. Therefore, considering weight gain and feed conversion ratio (FCR) as the main growth performance criteria in the modern quail production system, our research aimed to study the effects of dietary energy levels on growth performance and carcass characteristics of Japanese quails and then the determine of metabolizable energy requirements of quails with broken line regression method.

Materials and Methods

The number of 500-day-old Japanese quail chicks was obtained from a local commercial hatchery, and the birds were reared from hatching to 14 days of age in wire pens with a common starter diet (Table 1). During this time, food and water were provided freely and lighting was continuous. The temperature was kept at 35℃ from 1 to 3 days and then gradually decreased to room temperature until 14 days. A dose-response experiment with seven dietary energy levels (2500, 2650, 2800, 2950, 3100, 3250 and 3400 kcal of ME/Kg) was carried out with 15-d-old quails. At 15 days old, all birds were weighed separately, and some quails with the lowest or highest weights were removed. Three hundred and thirty-six birds were selected based on average body weight and were allotted 48 raised wire-floor pens with eight pieces per pen. Along with the MEn values of feed ingredients for chickens (National Research Council, 1994), seven dietary treatments were provided to contain 2500, 2650, 2800, 2950, 3100, 3250 and 3400 Kcal of MEn/Kg respectively, and each treatment applied to 6 replicate pens. At 28 and 35 d of age, weight gain, feed intake and feed conversion ratio (FCR) were calculated or measured. Average feed intake (g/bird) and FCR were altered according to time of death and weight of mortality. Metabolizable energy and protein intakes were calculated based on the average feed intake of quails in each replicate multiplied by their corresponding dietary metabolizable energy (Kcal/kg) and crude protein (%). Metabolizable energy and crude protein intake to gain were obtained by dividing metabolizable energy and crude protein intakes by the weight gain of birds in each replicate. At the end of the experiment (35 days of age) and after feed withdrawal for 3 h, one quail (male) was selected based on the resemblance to the average body weight of every pen, slaughtered, and eviscerated by hand. Edible carcass, breast meat and leg meat were detached manually from carcasses and weighed with a digital balance with an accuracy of 0.01 g. Breast and leg meat were all skinless but with bones. All carcass portions were expressed as a percentage relative to live body weight at the time of processing.

The calculated economic traits were production index (Tandoğan and Cicek, 2016), feed cost per quail (Rials /bird), feed cost: gain (Rials/kg) (Moradi *et al*., 2013) and monetary returns (Rials/bird) (McCoy *et al*., 1994), which is the price of feed ingredients at the start of the experiment and the selling price of quails (Rials/Kg) at marketing were used. In brief, relationships for calculating feed cost per quail (Rials/bird), feed cost: gain (Rials/kg) and monetary returns per each quail (Rials/b) are summarized below:

Feed cost (Rials/b) = [∑ (feed price (Rials/Kg) in the same period × feed intake (Kg) of each period)]

Feed cost: gain (Rials/Kg) = Feed cost (Rials/b)/Weight gain (Kg)

Monetary Returns (Rials/b) = [weight gain (Kg) × 160000) - feed cost (Rials/b)], which 160000 was the Rials Live weight price of quails at the time of marketing.

$$\text{Production Index} = \frac{\text{Weight gain (g)} \times \text{Viability (\%)}}{\text{FCR} \times \text{Growth period (days)}}$$

Viability (%) = 100- mortality (%)

Data were analyzed as a completely randomized design (CRD) by the ANOVA procedure of SAS software (SAS Institute, 2004). When the effects of dietary treatments were significant ($P < 0.05$), means were compared using Duncan's multiple range test comparison procedure of SAS software (SAS Institute, 2004). In this study, a broken-line regression investigation (Robbins *et al*., 2006) was used to assess the MEn requirement of growing quails.

Table 1. Experimental diets and their chemical composition

Feed ingredients (%)	Diet-1	Diet-2	Diet-3	Diet-4[6]	Diet-5	Diet-6	Diet-7
Corn (CP=8.5%)	42.09	47.23	51.82	48.74	45.66	42.57	39.5
Soybean (CP=44%)	45.8	44.8	43.92	44.51	45.11	45.71	46.3
Soy oil	0.5	0.5	0.67	3.15	5.63	8.12	10.6
Di-calcium phosphate	0.76	0.75	0.74	0.75	0.75	0.76	0.76
Oyster shell	1.29	1.3	1.31	1.3	1.3	1.29	1.29
Salt	0.35	0.35	0.34	0.35	0.35	0.35	0.35
DL-methionine	0.02	0.02	0.02	0.02	0.02	0.02	0.02
L-lysine Hydrochloride	0.02	0.02	0.02	0.02	0.02	0.02	0.02
L-threonine	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Vitamin Premix[1]	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Mineral Premix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vit E Premix[3]	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Filler[4]	8.51	4.37	0.5	0.5	0.5	0.5	0.5
Nutrients of diets (%)[5]							
Metabolizable energy(kcal/kg)	2500	2650	2800	2950	3100	3250	3400
Crude protein (%)	24	24	24	24	24	24	24
Lysine (%)	1.36	1.36	1.35	1.35	1.36	1.37	1.38
Methionine+ Cysteine (%)	0.76	0.77	0.77	0.77	0.77	0.76	0.77
Threonine (%)	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Calcium (%)	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Available Phosphorus (%)	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Crude fiber (%)	6.71	5.51	4.39	4.36	4.34	4.31	4.29
Ether extract (%)	2.29	2.48	2.81	5.16	7.50	9.85	12.19
Sodium (%)	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Cost (Rials/Kg)[7]	31753	32210	32756	34539	36323	38106	39890

[1] Every 1 kg of vitamin supplements included: Vitamin A: 5000000 IU, vitamin D_3: 2000000 IU, vitamin E: 32,000 mg, vitamin K: 1280 mg, vitamin B_1: 1750 mg, B_2: 3440 mg, Niacin: 25,000 mg, Pantothenic Acid: 7,400 mg, Vitamin B_6: 1950 mg, Vitamin B_9: 880mg, Vitamin B_{12}: 8mg, Biotin: 100 mg, and Antioxidant: 1000 mg.

[2] Every 1 kg of vitamin supplements included: Mn: 48000 mg, Fe: 8,000 mg, Cu: 6,400 mg Se: 120 mg, I: 500 mg, and Zn: 44000 mg.

[3] Each Kg of Vit E supplement included 5500 IU DL-α tocopheryl acetate.

[4] The filler was a mixture of fine-washed sands and sawdust (50%:50%) as an inert ingredient.

[5] All feeds were formulated to meet at least NRC 1994 nutrients level for growing Japanese quail recommendations and nutrients of composed diets were calculated according to NRC (1994) feed analysis tables.

[6] This diet was also fed to all birds from 1-14 days of age.

[7] The cost of feed ingredients at the time of start of the experiment were (Rials/Kg), Corn: 18500, Soybean meal: 47500, Vegetable oil: 83330, Dicalcium phosphate: 55000, Oyster-shell: 1100, Salt: 4400, DL-Methionine: 320000, L-Lysine Hydrochloride: 600000, L-Threonine: 180000, Vitamin Premix: 140000, Mineral Premix: 140000, Vit E Premix: 70000 and Filler: 500.

Based on the relationship between the predictor variable and dependent variable, suitable broken-line regression models can be different combinations of simple linear model, zero-slope model (plateau) and quadratic model. In this study, according to the scatter plots, two straight lines were fitted to the data as a final model (Equation 1). Where f(x)= weight gain or feed:gain; x= dietary energy level (kcal/Kg); d = requirement of dietary energy and a_i and b_i are the intercept and slope of the model, respectively. All regression analyses were performed using R version 4.1.2.

$$f(x) = \begin{cases} a_1 + b_1 x & x < d \\ a_2 + b_2 x & x \geq d \end{cases} \quad \text{Equation 1}$$

Results and Discussion

Production traits

The effect of dietary energy levels on feed intake (FI), weight gain (WG) and feed conversion ratio (FCR) of quails at 15-28 and 15-35 days are shown in Table 2. As well the optimum dietary ME levels for production traits of growing Japanese quails at different ages by broken line method is shown in Table 6. The results of the experiment showed that the effect of dietary metabolizable energy on feed intake at 15-28 and 15-35 was highly significant ($P < 0.0001$). It means that an increase in dietary energy levels resulted in a decrease in feed intake. , The linear and quadratic effects of dietary metabolizable energy on feed intake of growing quails, were not significant. The results of some experiments also showed that an increase in dietary energy levels resulted in a decrease in the feed intake of growing quails (Kaur *et al*.,2008; Mosaad and Iben, 2009; Attia *et al*., 2012; Muniz *et al*., 2016 and 2018; Omidiwura *et al*., 2016; Taheri *et al*., 2017) which was similar to the results of present study. Sheikh *et al*. (2012) and Dowarah *et al*. (2014) showed that an increase in dietary energy levels had no significant effect on the feed intake of growing quails and

Mahmood *et al*. (2014) showed that higher dietary energy level resulted in a more feed intake than lower dietary energy level which is not in accordance with the results of this experiment. These discrepancies may be due to the range of dietary metabolizable energy used at different experiments, the age of growing quails, the basal diet used in each experiment and other managerial practices in the rearing of quails. The effect of dietary energy level on weight gain of quail at 15-28 days was highly significant ($P < 0.001$), as dietary energy levels from 2500 to 2950 kcal/kg resulted in an increase in body weight gain and beyond that, resulted in a decrease in body weight gain. Different dietary energy levels didnot show any significant effect on weight gain at 15-35 days of age (p=0.136). The quadratic effect of dietary energy levels on the weight gain of quails was significant at 15-28 and 15-35 days of age. The broken line method revealed that the optimum dietary energy level for weight gain at 15-28 and 15-35 days of age for growing quails were 2831 and 2854 kcal/Kg, respectively (See Figures 1). Effect of dietary energy levels on feed: gain at 15-28 and 15-35 days was significant. As increase in dietary energy levels improved the feed: gain ratio at these periods. The quadratic effect of dietary energy effect on feed: gain ratio was significant only at 15-28 days of age. The broken line method showed dietary energy for the best feed: gain ratio at this period was 2799 kcal ME/Kg. Elangovan *et al*. (2004), Kaur *et al*. (2008), Attia *et al*. (2012) Reda *et al*. (2015), Muniz *et al*. (2016), showed that an increase in dietary metabolizable energy resulted in a decrease in feed conversion ratio which is similar to the results obtained in the present study. Sheikh *et al*. (2012) showed that a diet with 3000 kcal/Kg metabolizable energy resulted in a lower feed-to-gain ratio than diets with 2800 and 2900 kcal/kg metabolizable energy, but the difference between diets with 2800 and 2900 kcal ME/kg was not significant. Taheri *et al*. (2017) also showed that 3050 and 3200 kcal ME/kg resulted in a similar FCR in growing quails and both of them resulted in lower FCR than diet with 2900 kcal ME/kg. Mosaad and Iben (2009) reported the effect of dietary energy level on FCR was related to the age of quails, as a diet with 3000 kcal ME/kg resulted in a lower feed: gain ratio but the difference between 2600 and 2800 Kcal/kg ME diets on FCR were not significant, at the age of 1-3 weeks. However, at 3-6 weeks of age, differences among 2600, 2800 and 3000 Kcal ME/kg diets on FCR were significant and diet with 3000 Kcal ME/Kg resulted in a minimum FCR and diet with 2600 Kcal ME/Kg resulted in a maximum FCR in growing Japanese quails. Ghazaghi *et al*. (2012), Dowarah *et al*. (2014) and Omidiwura *et al*. (2016) cited that dietary energy levels didnot show any significant effect on feed conversion ratio. Dowarah *et al*. (2014) cited crude fiber digestibility increased linearly with an increase in dietary energy level and nitrogen retention and ether extract digestibility was highest on the feeding of 3000 kcal ME/Kg (having medium energy) diets. However, this improvement in nutrient digestibility is not reflected at FCR. Omidiwura *et al*. (2016) concluded the dry matter (DM) digestibility was the highest in the medium protein-medium energy (MP-ME) fed group of growing quails. Ash, ether extract and crude protein digestibility were also the highest in birds fed with MP-ME combination as compared with other combinations. In other words, they found that the MP-ME-fed quails were able to digest and utilize their nutrients better than the birds fed with other energy-protein combinations. Similarly, Yazarloo *et al*. (2017), in their study, showed that medium levels of dietary energy (2850 Kcal ME/Kg) resulted in better feed efficiency than higher (2950) and lower (2750) dietary metabolizable energy levels. They showed quails under dietary regimens of 2850 Kcal ME/Kg had higher plasma levels of growth hormone than those fed with 3200 Kcal ME/Kg diets. Ghazaghi *et al*. (2012) showed 2878 Kcal ME/Kg diet resulted in the lowest FCR by regression analysis in young growing quails, which was very close to the value obtained in this study. It should be noted in the studies of dietary metabolizable energy requirements of birds, that the environmental temperature has a significant effect on the metabolizable energy requirement, and experimental conditions of studies may cause differences in the results. On the other hand, breeding companies continuously are improving the commercial strains, and part of these differences in metabolizable energy requirement may be related to the genetic potential of modern Japanese quails (Ghazaghi *et al*., 2012) at the time of nutritional experiments. Besides this, amino acids quality and quantity of diet can affect performance as well as metabolizable energy requirement of the birds. Experimental methodology and type of statistical analysis are other important sources of discrepancies among the results observed in experiments for the discovery of metabolizable energy requirements of the quails. In most experiments for determination of dietary requirement of ME and CP in Japanese quail, Duncan’s multiple range has been used (Shim and Vohra, 1984; Elangovan *et al*., 2004; Siyadati *et al*., 2011), which may influence the results. In fact, in dose-response experiment, we are searching for an estimation of a dietary nutrient that optimized performance using the appropriate model. Regression analysis could estimate the optimal point, but the mean comparison approach makes it impossible. The age of quails used in different experiments and the ratio between dietary energy levels and other nutrient densities may be relatively important other factors affecting various results obtained by dietary energy levels on quail performance as well metabolizable energy requirement of the quails.

Table 2. Effect of dietary energy on weight gain, feed intake and feed: gain of growing Japanese quails from 15-28 and 15-35 d of age

Dietary Energy (Kcal of AME/kg)	Weight gain (g)		Feed intake (g)		Feed: gain	
	15-28 d	15-35d	15-28d	15-35d	15-28d	15-35d
2500	87.2 [ab]	124.0	254.0 [a]	420.0 [a]	2.91 [a]	3.38 [a]
2650	87.6 [ab]	125.6	241.4 [b]	389.1 [b]	2.76 [b]	3.10 [b]
2800	91.2 [a]	129.8	229.4 [bc]	399.9 [b]	2.51 [c]	3.08 [b]
2950	89.1 [a]	127.1	226.9 [c]	368.2 [c]	2.55 [c]	2.90 [c]
3100	82.1 [bc]	127.4	219.4 [c]	358.1 [c]	2.63 [c]	2.80 [cd]
3250	80.4 [c]	124.7	202.1 [d]	335.2 [d]	2.51 [c]	2.68 [de]
3400	76.6 [c]	119.8	191.3 [d]	313.3 [e]	2.50 [c]	2.61 [e]
SEM	1.85	2.37	4.35	5.85	0.04	0.05
P values						
ANOVA	<0.0001	0.136	<0.0001	<0.0001	<0.0001	<0.0001
L	0.004	0.007	0.887	0.450	0.001	0.038
Q	0.002	0.006	0.493	0.174	0.003	0.120

a-e: Means with different superscripts within the same column differ significantly ($P < 0.05$).
Results are means with n=6 per treatment, ME: dietary metabolizable energy effect, L: Linear effect of ME, Q: Quadratic effect of ME.

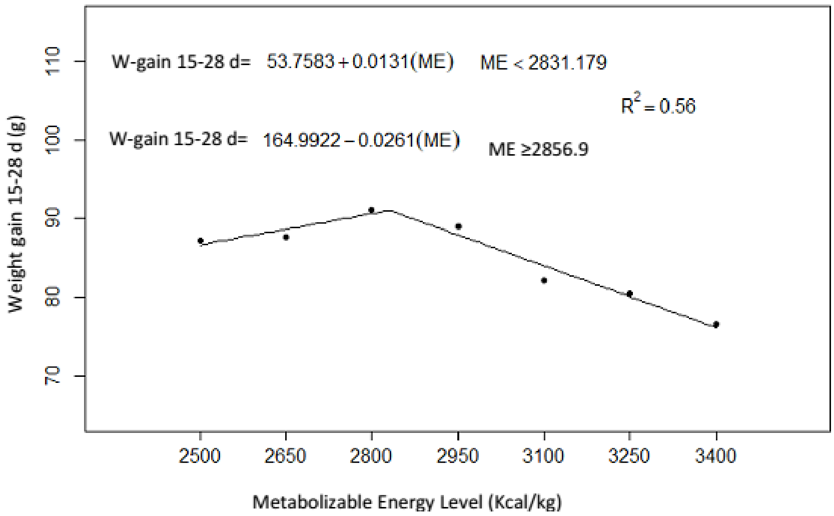

Figure 1. Metabolizable energy requirement of growing Japanese quails based on weight gain (15-28 days of age).

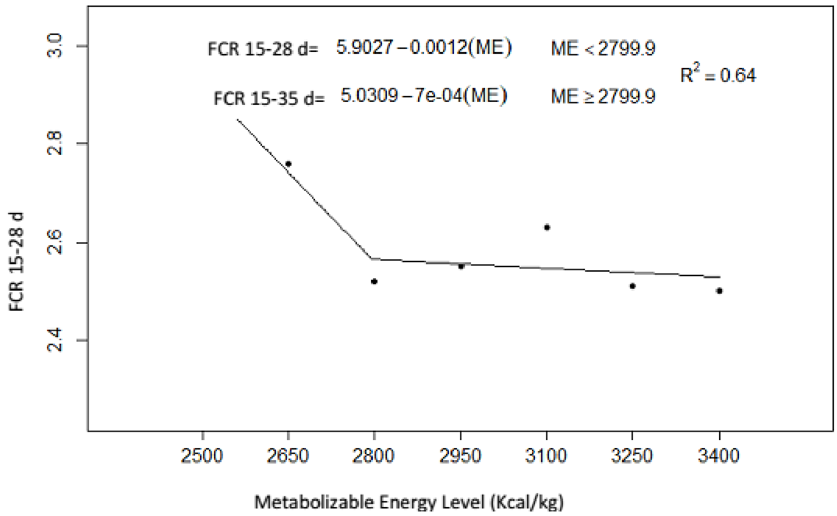

Figure 2. Metabolizable energy requirement of growing Japanese quails based on feed conversion ratio (FCR) (15-28 days of age).

The effect of dietary energy levels on metabolizable energy and crude protein intakes and their efficiencies is shown in Table 3. Dietary energy levels and their quadratic effect on metabolizable energy intake (MEI) of quails at 15-35 days was significant. A dietary energy level of around 2823 kcal ME/kg resulted in the highest metabolizable energy intake by growing quails as obtained by broken line regression. Metabolizable energy intake: gain was not affected by dietary energy level at 15-35 days of age. The effect of dietary metabolizable energy on crude protein intake at 15-28 and 15-35 was highly significant ($P <$ 0.0001). It means that an increase in dietary energy levels resulted in a decrease in crude protein intake. However, the Linear and quadratic effects of dietary metabolizable energy on crude protein intake of growing quails were not significant. Effect of dietary metabolizable energy levels on crude protein intake: gain at 15-28 and 15-35 days was significant. Quadratic effect of dietary energy levels on crude protein intake: gain at 15-28 days was significant. Mosaad and Iben (2009) reported at 1-3 weeks of age, metabolizable energy intake: gain (MEI: gain) was not affected by dietary energy levels; however, lower dietary energy level resulted in a higher crude protein intake: gain (CPI: gain), which was similar to the results of the present experiment. These researchers reported increase in dietary energy levels resulted in a significant decrease in CPI: gain and MEI: gain at 4-6 weeks of age, which was in accordance to present results of this experiment. Kaur *et al*. (2008) showed that an increase in dietary energy level resulted in a significant improvement in protein efficiency ratio and nitrogen retention to ME ratio. Omidiwura *et al*. (2016) reported effect of dietary energy levels on CPI and protein efficiency ratio was not significant; however, an increase in dietary energy level resulted in a higher ether extract digestibility.

Table 3. Effect of dietary energy on metabolizable energy and crude protein intakes and metabolizable energy and crude protein to gain ratios of growing Japanese quails from 15-35 d of age

Dietary Energy (Kcal MEn/kg)	Metabolizable energy intake (kcal/b)		Metabolizable energy intake: gain (kcal/kg)		Crude protein intake (g/b)		Crude protein intake: gain (g/g)	
	15-28 d	15-35 d	15-28 d	15-35 d	15-28 d	15-35 d	15-28 d	15-35 d
2500	634.9	1050.1^{cd}	7.28^{bc}	8.50	60.96^{a}	100.8^{a}	0.70^{a}	0.81^{a}
2650	639.8	1031.1^{d}	7.30^{bc}	8.22	57.98^{b}	93.4^{b}	0.66^{b}	0.75^{b}
2800	642.2	1119.7^{a}	7.05^{c}	8.65	55.05b^{c}	96.0^{b}	0.60^{d}	0.74^{b}
2950	669.4	1086.1^{abc}	7.51^{b}	8.55	54.45^{c}	88.4^{c}	0.61c^{d}	0.70^{c}
3100	679.9	1110.1^{ab}	8.28^{a}	8.73	52.63^{c}	85.9^{c}	0.64b^{c}	0.68^{cd}
3250	656.9	1089.2^{abc}	8.15^{a}	8.75	48.504^{d}	80.4^{d}	0.60^{d}	0.65^{de}
3400	650.4	1065.1^{cd}	8.50^{a}	8.90	45.93^{d}	75.2^{e}	0.60^{d}	0.63^{e}
SEM	12.67	16.54	0.13	0.14	1.03	1.39	0.011	0.012
P values								
ANOVA	0.150	0.0058	<0.0001	0.058	<0.0001	<0.0001	<0.0001	<0.0001
L	0.057	0.006	0.107	0.776	0.892	0.456	0.006	0.041
Q	0.066	0.007	0.052	0.675	0.503	0.177	0.011	0.127

a-e: Means with different superscripts within the same column differ significantly (P < 0.05).
Results are means with n=6 per treatment, ME: dietary metabolizable energy effect, L: Linear effect of ME, Q: Quadratic effect of ME.

Carcass characteristics

The effect of dietary energy levels on carcass characteristics of Japanese quails is shown in Table 4. Dietary energy levels didnot show any significant effects on percentages of carcass, thighs and breast+wings. Dietary energy levels also didnot have significant effects on percentages of edible viscera parts such as the liver, heart and gizzard. Linear and quadratic effects of dietary energy on carcass characteristics and edible viscera were also insignificant. Muniz *et al*. (2016) reported that dietary energy levels in the range of 2850-3250 KcalME/Kg didnot show significant effects on carcass characteristics, which was similar to the results of this experiment. Ashour *et al*. (2022) also cited that dietary energy levels at 2800-3000 kcal ME/Kg didnot have a significant effect on carcass parts percentages to live weight in quails grown up during summer season. Attia *et al*. (2012) also showed that dietary energy levels in the range of 2800-3000 Kcal ME/Kg had no significant effect on carcass characteristics of growing quails. Mahmood *et al*. (2014) and Taheri *et al*. (2017) showed that dietary metabolizable energies at the levels of 3100 and 3200 Kcal/Kg, respectively, resulted in a higher percentage of liver to live weight, which was not in accordance with the results obtained in the present study. Albeit quails used 2950 kcal ME/Kg diet had numerically higher percentages of edible carcass to live weight, however, it seems that other environmental and genetic factors rather than dietary energy levels may have more significant effects on carcass characteristics changes of growing Japanese quails.

Table 4. Effect of dietary energy on carcass characters of growing Japanese quails at 35 d of age

Dietary Energy (Kcal of AME/kg)	Carcass parts to live weight (%)			Edible viscera to live weight (%)		
	Edible Carcass	Tighes	Breast + wings	Liver	Heart	Gizzard
2500	71.99	8.44	36.75	1.59	0.788	2.105
2650	72.47	8.26	38.40	1.63	0.758	2.23
2800	73.03	8.62	38.27	1.73	0.733	2.11
2950	74.26	8.54	37.84	1.46	0.860	1.78
3100	73.24	8.64	37.52	1.53	0.803	1.99
3250	72.41	8.60	36.47	1.44	0.778	2.08
3400	73.77	8.69	37.38	1.63	0.815	1.93
SEM	0.53	0.21	0.62	0.07	0.03	0.12
P-values						
ANOVA	0.0605	0.988	0.262	0.123	0.341	0.256
L	0.153	0.855	0.182	0.490	0.893	0.469
Q	0.176	0.878	0.171	0.519	0.925	0.506

Results are means with n=6 per treatment, ME: dietary metabolizable energy effect, L: Linear effect of ME, Q: Quadratic effect of ME.

Production index and economic traits

The effect of dietary energy levels on the production index and economic traits of growing Japanese quails during 15-28 and 15-35 days has been shown in Table 5 and optimum dietary ME levels for production index and economic traits of growing Japanese quails at different ages by broken line method is shown in Table 6. Effect of dietary energy levels on feed cost: gain (Rials/Kg) and production index at 15-28 and 15-35 days were significant ($P < 0.05$). The effect of dietary energy levels on monetary returns (Rials/bird) was significant ($P < 0.0001$) only at 15-28 days. The quadratic effect of dietary energy levels on all economic traits was significant at 15-28 and 15-35 days of age. Generally, the results showed that both the lower and higher dietary energy levels at the range of 2500-3400 kcal ME/kg resulted in a relatively higher feed cost: gain and lower monetary returns and production indices at different ages, especially at 15-28 days of age. The broken line method showed that optimum dietary energy levels for production indices at 15-28 and 15-35 days were 2800 and 3028 kcal ME/Kg and for best feed cost: gain (Rials/Kg live weight) were 2800 and 2648 kcal ME/Kg at 15-28 and 15-35 days and for the best monetary returns (Rials/bird) at 15-28 and 15-35 days were 2800 and 2703 Kcal ME/Kg respectively. These results showed that considering a shorter time of growth period (15-28 days) dietary metabolizable energy levels around 2800 Kcal/kg resulted in optimum production and economic traits, but at longer growth periods (15-35 days), albeit higher dietary energy levels around 3028 Kcal/kg resulted in a higher production index but lower dietary energy levels 2648 and 2703 Kcal ME/kg diets resulted in a lower feed cost: gain and higher monetary returns for growing quails and therefore they were more economic. It is believed that under the appropriate situation, the Japanese quail starts laying eggs almost at day 35-45 days, and Narinc *et al*. (2013) stated the exact time of the first egg was 38.9 days by non-linear models. Also, rapid and increasing development of pubic spread occurred between 38 to 59 d (Satterlee and Marin, 2004).

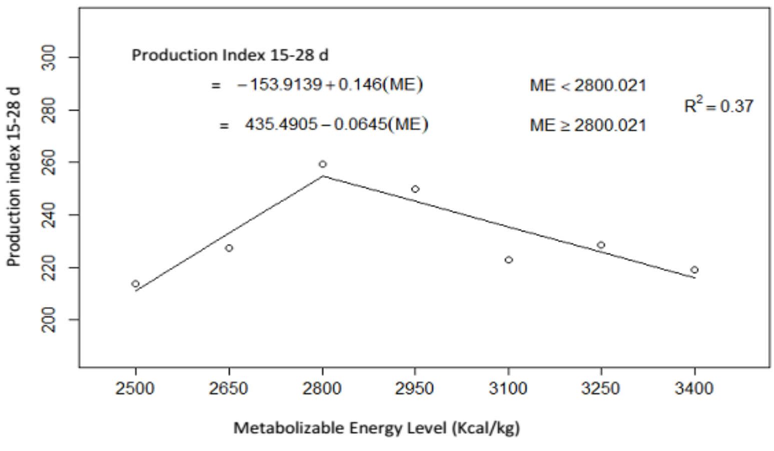

Figure 3. Metabolizable energy requirement of growing Japanese quails based on Production Index (15-28 days of age).

It was shown that quails were prepared for lay and high-energy diets may be used as a precursor for follicle growth. Elangovan *et al*. (2004) also concluded that the highest dietary energy level in their experiment (2900 Kcal ME/Kg) was the optimum dietary energy level for the general performance of growing quails, which was similar to the results of the present study. Muniz *et al*. (2018) reported that during the starter phase of growing quails (1-14 d), 2820 Kcal ME/Kg warranted adequate performance which was very similar results of this experiment at 15-28 days of age.

Table 5. Effect of dietary energy levels on production index and economic traits of growing Japanese quails at different ages

Dietary Energy (Kcal of AME/kg)	Feed cost: gain (Rials/kg)		Monetary returns (Rials/kg)		Production Index	
	15-28 d	15-35d	15-28d	15-35d	15-28d	15-35d
2500	92542 [bc]	107631 [a]	5884.7 [b]	4495.8	213.8 [c]	174.45 [c]
2650	88939 [c]	99985 [b]	6340.0 [b]	7559.7	227.5 [c]	192.97 [bc]
2800	82502 [d]	101183 [b]	7070.6 [a]	7651.7	256.6 [a]	200.93 [ab]
2950	88087 [c]	100185 [b]	6412.5 [ab]	7617.3	250.0 [ab]	209.07 [ab]
3100	97143 [ab]	102162 [b]	5168.4 [c]	7373.7	223.0 [c]	216.18 [a]
3250	95808 [ab]	102478 [ab]	5164.3 [c]	7178.6	228.6 [bc]	221.13 [a]
3400	99814 [a]	104411 [ab]	4619.4 [c]	6670.3	219.2 [c]	218.27 [a]
SEM	1563.9	1714.6	230.0	321.9	7.805	6.503
P values						
ANOVA	<0.0001	0.0430	<0.0001	0.0769	0.0015	0.0001
L	0.0007	0.0033	0.0007	0.0017	0.0009	0.0187
Q	.0004	0.0034	0.0003	0.0016	0.0009	0.0351

Results are means with n=6 per treatment, ME: dietary metabolizable energy effect, L: Linear effect of ME, Q: Quadratic effect of ME.

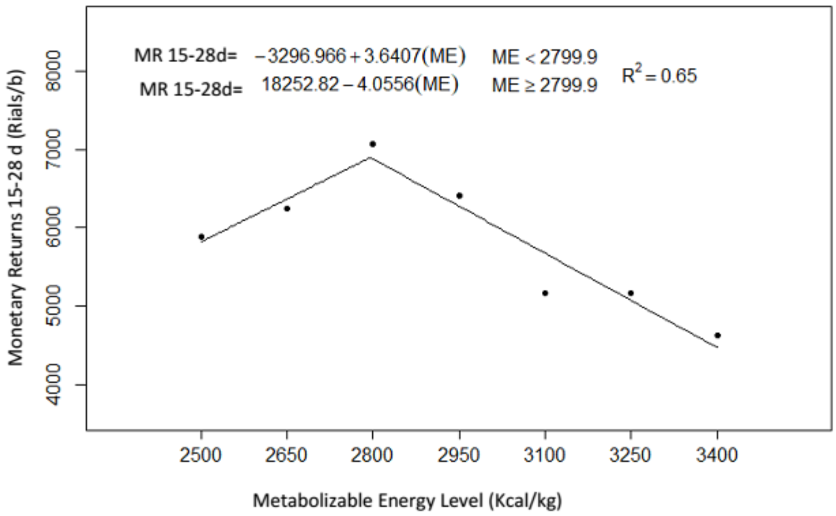

Figure 4. Metabolizable energy requirement of growing Japanese quails based on Monetary Returns (15-28 days of age).

Table 6. Estimated optimum dietary ME levels for some production and economic traits of growing Japanese quails at different ages by broken line regression method

Production or economic trait	Optimum Dietary ME level (Kcal/kg)	Marginal Error (Kcal/kg)	P value	R^2
Weight gain (g) 15-28 d	2831.9	145.1	<0.0001	0.56
Weight gain (g)15-35 d	2854.3	204.9	0.034	0.20
FCR 15-28 days	2799.9	0.0000002	<0.0001	0.64
Production index 15-28 days	2800.0	116.4	0.0004	0.37
Production index 15-35 days	3028.6	299.4	<0.0001	0.51
Feed cost: gain (Rials/g) 15-28 d	2799.9	0.0007	<0.0001	0.63
Feed cost: gain (Rials/g) 15-35 d	2647.5	0.0007	0.005	0.28
Monetary returns (Rials/b) 15-28 d	2799.9	48.6	<0.0001	0.65
Monetary returns (Rials/b) 15-35 d	2702.8	122.6	0.010	0.25

Conclusion

Moderate dietary metabolizable energy levels in the range of 2500-3400 kcal/kg resulted in higher performance and economic traits of growing Japanese quails between 15-35 days of age. Based on broken line regression analysis, between two and four weeks of age, the metabolizable energy requirement of growing quails was 2831 and 2799 Kcal/kg for optimal weight gain and FCR, respectively, when the protein level in the diet was 24 percent.

References

Angulo E, Brufau J, Miquel A, & Esteve-garcia E. 1993. Effect of diet density and pelleting on productive parameters of Japanese quail. Poultry Science, 72: 607-610. DOI:10.3382/ps.0720607

Ashour EA, Alabdali AYM, Aldhalmi AK, Taha AE, Swelum AA & Abd El-Hack ME. 2022. Impacts of varying dietary energy and crude protein levels on growth, carcass traits and digestibility coefficients of growing Japanese quail (Coturnix Coturnix Japonica) during the summer season. Italian Journal of Animal Science, 21 (1): 1402-1410. DOI: 10.1080/1828051X.2022.2118625

Attia, AI, Mahrose KHM, Ismail IE & Abou-Kasem DE. 2012. Response of growing Japanese quail raised under two stocking densities to dietary protein and energy levels. Egyptian Journal of Animal Production, 49 Suppl: 159-167. DOI: 10.21608/EJAP.2012.100945

Dowarah R, Sethi APS & Brah GS. 2014. Effect of dietary energy and protein on growth performance and carcass characteristics of white plumage Japanese quails during summer season. Animal Nutrition and Feed Technology, 14: 461-470. DOI: 10.5958/0974-181X.2014.01348.1

Elangovan AV, Mandal AB, Tyagi PK, Tyagi PK, Toppo S & Johri TS. 2004. Effects of enzymes in diets with varying energy levels on growth and egg production performance of Japanese quail. Journal of the Science of Food and Agriculture, 84: 2028–2034. DOI: 10.1002/jsfa.1910

Ghazaghi M, Mehri M, Yousef-Elahi M & Rokouei M. 2012. Response surface of dietary energy and protein in Japanese quail from 7-14 days of age. Poultry Science, 91: 2958-2962. DOI: 10.3382/ps.2012-02170

Kaur S, Mandal AB, Singh, KB, & Kadam MM. (2008). The response of Japanese quails (heavy body weight line) to dietary energy levels and graded essential amino acid levels on growth performance and immuno-competence. Livestock Science, 117(2-3): 255–62. DOI: 10.1016/j.livsci.2007.12.019

Mahmood M, Abdur Rahman, Saima, Muhammad Akram, Pasha TN & Abdul Jabbar M. 2014. Effect of dietary energy levels on growth performance and feed cost analysis in Japanese quail. Pakistan Journal of Zoology, 46(5): 1357-1362.

McCoy RA, Behnke KC, Hancock JD, & McEllhiney RR. 1994. Effect of maximum uniformity on broiler chick performance. Poultry Science, 73: 443-451. DOI: 10.3382/ps.0730443

McDonald MW & Evans M. 1977. A simulation study of the effects of dietary metabolizable energy on the economics of broiler production. Poultry Science 56(3), 997-1003. DOI: 10.3382/ps.0560997

Moradi, M, Maghsoudlou S, Rostami F & Mostafalu Y. 2013. Effect of different substitution levels of extruded soybean with soybean meal and different dietary vitamin E levels on production index and economic traits of broilers. Animal Production Research, 1 (4): 15-25. (In Persian).

Mosaad GMM and Iben C. 2009. Effect of dietary energy and protein levels on growth performance, carcass yield and some blood constituents of Japanese quails (Coturnix coturnix Japonica). Die Bodenkultur: Journal of Land Management Food and Environment, 60(4):39-46.

Muniz JCLI, Barreto SLT, Mencalha R, Viana GS, Reis RS, Ribeiro CLN, Hannas MI, Luiz Albino FT. 2016. Metabolizable energy levels for meat quails from 15 to 35 days of age. Ciência Rural, Santa Maria, 46(10): 1852-1857. DOI: 10.1590/0103-8478cr20141666

Muniz JCL, Barreto SLT, Viana GS, Mencalha R, Reis RS, Hannas M, Barbosa LMR & Maia RC. 2018. Metabolizable energy levels for meat-type quails at starter phase. Brazilian Journal of Poultry Science, 20 (2): 197-202. DOI: 10.1590/1806-9061-2017-0496

Narinc D, Karman E, Aksoy T & Zia Firat M. 2013. Investigation on non-linear models to describe long term egg production in Japanese quail. Poultry Science, 92: 1676-1682. DOI: 10.3382/ps.2012-02511

NRC (National Research Council). 1994. Nutrient Requirements of Poultry. 9th Rev. Ed. National Academy Press. Washington, DC. 176 Pages.

Omidiwura BRO, Odu O, Agboola AF, Akimbola DD & Lyayi EA. 2016. Crude protein and energy requirements of Japanese quail (Coturnix coturnix Japonica) during rearing period. Journal of World Poultry Research, 6(2): 99-104. pii: S2322455X1600014-6

Reda, FM, Ashour EA, Alagawany M & Abd El-Hack ME. 2015. Effect of dietary protein, energy and lysine intake on growth performance and carcass characteristics of growing Japanese quails. Asian Journal of Poultry Science, 9(3): 155-164. DOI: 10.3923/ajpsaj.2015.155.164

Robbins KR, Saxton AM & Southern LL. 2006. Estimation of nutrient requirements using broken-line regression analysis. Journal of Animal Science, 84(E Suppl): E155-E165. DOI: 10.2527/2006.8413_supplE155x

SAS (Statistical Analysis System). 2004. SAS/STAT® 9.1.3. User's Guide. SAS Institute Inc. Cary, North Carolina.

Satterlee DG & Marin RH. 2004. Pubic spread development and first egg lay in Japanese quail. Journal of applied poultry research, 13: 207-212. DOI: 10.1093/japr/13.2.207

Sheikh N, Moravej H, Shivazad M & Towhidi A. 2012. The effects of different levels of dietary energy and protein on performance and carcass characteristics of Japanese quails. Animal Production Research, 1(2): 55- 63. (In Persian).

Shim KF & Vohra, P. 1984. A review of the nutrition of Japanese quail. World's Poultry Science Journal, 40 (3): 261-274. DOI: 10.1079/WPS19840022

Siyadati SA, Irani M, Ghazvinian K, Mirzaei-Aghsaghali A, Rezaipoor V, Fathi H, Alipoor K & Zamanzad-Ghavidel S, 2011. Effect of varying dietary energy to protein ratio on productive performance and carcass characteristics of Japanese quail. Annals of Biological Research, 2: 149-55.

Taheri HR, Abbasi M & Tanha N. 2017. Effect of different dietary levels of energy and protein on performance of Japanese quail during grower phase. Research on Animal Production, 8 (15): 11-17. DOI: 10.29252/rap.8.15.11

Tandoğan M & Cicek H. 2016. Technical performance and cost analysis of broiler production in Turkey. Brazilian Journal of Poultry Science, 18 (1): 169-174. DOI: 10.1590/18069061-2015-0017

Yazarloo M, Sharifi SD, Shariatmadari F, Salehi A& Malaki M. 2017. The effect of different levels of dietary metabolizable energy and crude protein on performance and nitrogen and energy metabolism in Japanese quail (coturnix coturnix japonica). Journal of Animal Production, 19 (1): 145-157. (In Persian). DOI: 10.22059/jap.2017.60104

ZancanelaV, Marcato SM, Furlan AC, Grieser DO & Ton APS. 2015. Models for prediction energy requirements in meat quail. Livestock Science, 171: 12-19. DOI: 10.1016/j.livsci.2014.10.002