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METABOLIZABLE ENERGY AND CRUDE PROTEIN REQUIREMENTS OF TWO QUAIL SPECIES (*Coturnix japonica* and *Coturnix ypsilophorus*)

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ABSTRACT

The present study aimed to investigate the effects of different levels of dietary metabolizable energy (ME) and crude protein (CP) on performance and carcass characteristics of Japanese (*Coturnix japonica*) and Brown (*Coturnix ypsilophorus*) quails during a 42 d feeding trial. A total of 720 (360 per each species) one week-old quail chicks were randomly (by species) distributed between 72 cages according to a 3 × 3 × 2 factorial arrangement of treatments (3 dietary ME levels: 2800, 2900 and 3000 kcal/kg of diet; 3 different CP levels: 22, 24 and 26%; and 2 quail species: Japanese and Brown) with 4 replicates of 10 birds each. Performance parameters were recorded biweekly. Results showed that except 22-35 d period, average daily feed intake (ADFI) was affected ($P<0.01$) by dietary ME level with the lowest ADFI assigned to those fed diets containing 3000 kcal ME/kg. Japanese quails consumed ($P<0.01$) more feed than Brown quails during 22-35 and 36-49 d of age. Increase in dietary ME and CP levels to 2900 kcal/kg and 26%, respectively, increased ($P<0.01$) average daily weight gain (ADWG), and Japanese quails had the greater ADWG compared with Brown quails. Feed conversion ratio (FCR) was improved by incremental levels of dietary ME ($P<0.01$) and CP ($P<0.05$) throughout the trial period. Japanese quails showed the better ($P<0.01$) FCR values compared with Brown quails during 22-49 d of age. Increase in dietary ME and CP levels increased ($P<0.01$) carcass and breast yields. Highly positive correlations were found among daily ME/CP intakes and ADWG, ADFI, and carcass yield. The present findings indicate that Japanese quails need the diets containing 3000 kcal ME/kg and 26% CP during the first weeks of age to achieve optimum growth performance. Dietary CP level can be reduced to 24% CP at the older ages. The nutritional demands of Brown quails were determined to be 2900 kcal ME/kg and 24% CP during the starter period and 2900 kcal/kg ME and 22% CP at the remaining growth period.

Key words: Quail, *Coturnix japonica*, *Coturnix ypsilophorus*, Dietary protein requirements, Metabolizable energy, Performance, Carcass characteristics

INTRODUCTION

The quail is a small bodied bird belonging to the species galliformes, which is a native to Asia and Europe and have been farmed since ancient times (Wakasugi, 1984). The commercial production of Japanese quails (*Coturnix japonica*) has increased during the recent years. Few reports on the nutritional requirements of metabolizable energy (ME) and crude protein (CP) for quails have been published (Lepore and Marks, 1971; Vohra and Roudybush, 1971; Sakurai, 1981; Marks, 1993; Ri *et al.*, 2005); however, the reported values are limited and contradictory. For instance, as the interest in the study of Japanese quail developed, the maintenance of intensive quail populations on diets containing about 28% CP was adopted (Woodard *et al.*, 1965); however, later studies indicated that Coturnix can be reared on 25-26% CP-diets during the first weeks (Weber and Reid, 1967; Lepore and Marks, 1968; Svacha *et al.*, 1970) and dietary CP content can be reduced to 20% after 3 weeks of age (Vogt, 1967; Gropp and Zucker, 1968).

Like other species the energy is the principal nutritional component of the diets, which determines the quail performance. The ME requirements of quails are variable depending on a number of factors including body weight gain, amino acid balance, feed efficiency, breed, house condition and stocking density (Lepore and Marks, 1971). Sakurai (1981) obtained optimum performance with 58 kcal ME/day in a smaller species. Comparing the energy utilization by quails and broiler chickens, Begin (1968) did not find any clear difference in feed: gain ratio between low or high energy diets (2200 and 3400 kcal ME/kg), concluding that quails can utilize the diets with varying energy contents similar to broilers. On the other hand, dietary CP requirement of Japanese quail is relatively high and depends on body weight gain, breed, age, diet composition and environmental condition. Woodard *et al.* (1965) suggested a dietary protein level of 28% for intensively-raised quails, while Whyte *et al.* (2000) suggested a dietary protein level of 18-24% for better performance.

Brown or swamp quail (*Coturnix ypsilophorus*) is another quail species with a good potential for growth; to our knowledge, however, studies on the nutritional requirements of this species are scanty. The objectives of the present study was to investigate the influence of feeding diets containing different levels of ME and CP on growth performance and carcass characteristics of

Japanese and Brown quails during different growth stages.

MATERIALS AND METHODS

Birds, diets and management: The present study was carried out in the Poultry Research Station of Isfahan University of Technology (Isfahan, Iran), and all experimental procedures were approved by Animal Care and Use Committee of Isfahan University of Technology. Day-old quail chicks were hatched from eggs of 2 random-bred lines (Japanese and Brown quails). The random-bred populations had been housed in the separately stainless steel batteries. The chicks were raised on the litter during the 1st week of age and on 7th day, 720 mixed-sex chicks (360 per each species) were weighed and randomly distributed among 72 cages of 10 chicks each. The birds were reared in groups, in stainless steel cages, at a density of 220 cm^2/bird in an environmentally-controlled room. A 20 light: 4 dark lighting schedule was provided throughout the trial period. Each cage was equipped with one tube feeder and two adjacent cages with one tube drinker. Temperature was set on 36˚C during the 1st week of age and was reduced by 3˚C per week until the birds were 5 weeks old. Feed and water were provided for *ad libitum* consumption. A commercial corn-soybean meal-based diet containing 25% crude protein (by analysis) and 2900 kcal ME/kg was fed during the 1st week and the experimental diets were offered from the 2nd week of age. A completely randomized design was employed to test 3 dietary CP (22, 24 and 26% of diet) and 3 ME levels (2800, 2900 and 3000 kcal ME/kg of diet) for 2 different quail species (Japanese and Brown quails) based on a 3 × 3 × 2 factorial arrangement of treatments. The selected levels of dietary CP and ME were based on the NRC (1994) recommended values. Prior to formulating the diet, the ingredients used were analyzed for moisture by the oven-drying method (934.01), CP by the Kjeldahl (976.06), ether extract by Soxhlet fat analysis (954.02), crude fiber by manually (978.10) and total ash by muffle furnace (942.05) according to the standard procedures of AOAC (2002). All of the samples were analyzed in triplicate. The ME content of feedstuffs was measured using chromic oxide marker method (Roudybush *et al.*, 1974). The diets were then formulated using the determined ME and CP values. The experimental diets were balanced to me*et al*l of the nutrient requirements as specified by National Research Council (NRC, 1994). The diets were formulated to contain similar quantities of calcium and non-phytate phosphorus and to maintain similar proportions of key essential amino acids in each protein group (Table 1).

Measurements and chemical analysis Average daily weight gain (ADWG) and feed intake (ADFI) were recorded on the cage basis at biweekly intervals (8-21 d as starter, 22-35 d as grower, and 36-49 d as finisher periods). Mortality was recorded daily. Any bird that died was weighed and the weight was used to adjust feed: gain ratio. The chromic oxide marker method (Roudybush *et al.*, 1974) was used to measure the ME content of experimental diets. Chromic oxide-containing diets (supplemented with 0.5% trivalent chromic oxide) were fed for 5 d during 32 to 36 d of age and a 24-h excreta collection was made on 5th day. Excreta samples were frozen immediately at −20˚C and than freeze-dried. Feed samples and freeze-dried excreta were ground prior to chemical analysis. The samples were analyzed for gross energy (measured by adiabatic bomb calorimeter, Parr instrument Co., Moline, IL). Chromic oxide was determined using the procedure proposed by Williams *et al.* (1962).

At d 49 of age, 6 quails from each cage replicate (3 males and 3 females) were randomly selected to evaluate the carcass traits. Feed and water were withdrawn 3 h prior to slaughter. The birds were weighed, exsanguinated, feathers removed and eviscerated. Abdominal fat, which consisted of fat surrounding the gizzard, proventriculus, and in the abdominal cavity, was exactly removed and weighed. After the eviscerated weight had been obtained, the leg quarters and breast meat were cut and weighed separately on a digital sensitive scale.

Statistical analysis: All data were subjected to analysis of variance using the General Linear Models procedures of SAS statistical software (SAS Institute, 1999) based on a 3 × 3 × 2 factorial arrangement with dietary ME and CP levels and quail species as the main effects and respective 2- and 3-way interactions. For carcass measurements, the mean values of 6 birds were used in the analysis of variance, because no significant differences were found between 2 sexes (except abdominal fat percentage, which tended to be greater in female chicks; data not shown). Percentage data were subjected to arc sin transformation prior to statistical analysis, because the transformed distributions were consistent with normality. Whereas the differences were determined from the transformed data, only non-transformed data are presented for relevance. Least Significant Difference test was used to compare treatment means. All statements of statistical significance were based on $P<0.05$ unless otherwise stated. The analyses of correlation were made among the ME/CP intakes and main performance parameters for each quail species.

RESULTS

Significant ($P<0.001$) decreases in ADFI were observed at 8-21 and 22-35 d of age as the result of increasing dietary ME content (Table 2). With the exception of 36-49 d of age, in that ADFI was increased as the result of increase in dietary CP, feed intake wasn't affected by dietary CP level during the remaining experimental periods. Feed intake was also influenced (P<0.001) by quail species, thus the Japanese quails consumed more feed than Brown quails during 22-35, 36-49 and 8-49 d of age. Except CP × species interaction at 8-21 and 36-49 d of age, in which Brown quails decreased their ADFI as the response to increase in dietary CP content from 24 to 26%, other 2- and 3-way interactions between dietary ME, CP, and quail species were not significant for ADFI.

Increase in dietary ME level up to 2900 kcal/kg was associated (P<0.01) with increase in ADWG throughout the experimental period (Table 2). However, the ADWG of birds fed diets containing 2900 and 3000 kcal ME/kg was not statistically different (P>0.05). Increase in dietary CP level from 22 to 24% improved ADWG of both species, however, this effect was more pronounced for Japanese quails than for Brown ones, resulting in the significant (P<0.05) CP × species interactions throughout the experimental period.

Table 1. Composition and nutritive value of experimental diets containing different metabolizable energy (ME) and crude protein (CP) levels, fed to quail chicks from 8 to 49 d of age

ME (kcal/kg)	**2800**	**2800**	**2800**	**2900**	**2900**	**2900**	**3000**	**3000**	**3000**
CP (%)	**22**	**24**	**26**	**22**	**24**	**26**	**22**	**24**	**26**
Ingredients (%)									
Corn, yellow	58.20	54.42	48.05	58.83	52.47	46.10	56.88	50.52	44.16
Soybean meal	30.04	35.10	40.59	29.93	35.42	40.91	30.26	35.74	41.23
Fish meal	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Alfalfa meal	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sunflower oil	0.12	0.23	1.13	0.97	1.86	2.75	2.59	3.49	4.38
Limestone	1.12	1.08	1.04	1.12	1.08	1.05	1.12	1.08	1.04
Common salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin premix[†]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mineral premix[‡]	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
DL- Methionine	0.05	0.07	0.09	0.05	0.07	0.09	0.05	0.07	0.09
Sand	1.37	—	—	—	—	—	—	—	—
Nutrient composition[§]									
Calculated ME (kcal/kg)	2800	2800	2800	2900	2900	2900	3000	3000	3000
Determined ME by Japanese quails (kcal/kg)	2785	2845	2773	2907	2958	2943	2985	3074	3091
Determined ME by Brown quails (kcal/kg)	2802	2858	2698	2888	2936	2902	3018	3059	3030
Crude protein (%)	22.00	24.00	26.00	22.00	24.00	26.00	22.00	24.00	26.00
Calcium (%)	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Non-phytate P (%)	0.31	0.32	0.33	0.31	0.32	0.33	0.31	0.32	0.33
Sodium (%)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Methionine (%)	0.46	0.50	0.54	0.46	0.50	0.54	0.46	0.50	0.54
Methionine + cysteine (%)	0.80	0.87	0.94	0.80	0.87	0.94	0.80	0.87	0.93
Lysine (%)	1.28	1.41	1.54	1.28	1.41	1.54	1.28	1.42	1.55
Arginine (%)	1.43	1.57	1.72	1.43	1.58	1.72	1.43	1.58	1.73
Tryptophan (%)	0.29	0.33	0.37	0.29	0.33	0.37	0.29	0.33	0.37
Threonine (%)	0.86	0.94	1.02	0.86	0.94	1.02	0.86	0.94	1.02

[†]Provided per kilogram of diet: vitamin A (retinyl acetate), 6,500 IU; cholecalciferol, 1,800 IU; vitamin E (DL-α-tocopheryl acetate), 8.5 IU; vitamin K (menadione sodium bisulfate), 5 mg; riboflavin, 4.4 mg; niacin, 40 mg; pantothenic acid, 14 mg; choline (choline chloride), 560 mg; vitamin B_{12}, 5 µg; folic acid, 0.8 mg; biotin; 0.1 mg; pyridoxine, 10 mg; thiamin, 3 mg; ethoxyquin, 125 mg.

[‡]Provided per kilogram of diet: manganese, 80 mg; zinc, 65 mg; iron, 50 mg; copper, 8 mg; iodine, 1.8 mg; selenium, 0.3 mg; cobalt, 0.15 mg; molibdenium, 0.16 mg.

[§]All values were calculated except of dietary ME and CP contents that were determined by bioassay (chromic oxide marker method; Roudybush *et al.*, 1974) and analysis (Kjeldahl), respectively.

Table 2. Effect of different levels of dietary metabolizable energy (ME) and crude protein (CP) on daily feed consumption and body weight gain of Japanese and Brown quails

ME (kcal/kg)	CP (%)	Feed consumption (g/d per bird)				Body weight gain (g/d per bird)			
		8-21 d	22-35 d	36-49 d	8-49 d	8-21 d	22-35 d	36-49 d	8-49 d
Japanese quail									
2800	22	9.32	18.13	24.20	17.22	3.64	4.52	4.86	4.34
	24	9.27	18.38	24.01	17.22	3.80	4.70	4.93	4.48
	26	9.52	18.45	24.65	17.54	3.84	4.78	5.02	4.55
2900	22	8.75	18.17	24.44	17.12	3.66	4.66	5.06	4.46
	24	8.90	18.13	24.66	17.23	3.94	4.86	5.18	4.66
	26	8.89	18.13	25.17	17.40	4.08	4.94	5.31	4.78
3000	22	8.61	17.25	24.00	16.62	3.76	4.60	5.15	4.50
	24	8.52	18.09	24.14	16.92	4.02	5.01	5.27	4.77
	26	8.53	17.93	24.96	17.14	4.14	5.08	5.39	4.87
Brown quail									
2800	22	9.46	17.14	22.31	16.30	3.64	4.20	4.41	4.08
	24	9.16	16.87	22.41	16.15	3.77	4.25	4.49	4.17
	26	9.10	17.06	21.93	16.03	3.61	4.13	4.36	4.03
2900	22	8.89	16.88	21.93	15.90	3.72	4.34	4.54	4.20
	24	8.88	16.62	22.32	15.94	3.91	4.42	4.68	4.34
	26	8.65	16.86	22.36	15.96	3.93	4.38	4.63	4.31
3000	22	8.84	16.26	21.94	15.68	3.81	4.29	4.61	4.24
	24	8.38	16.32	22.14	15.61	3.88	4.46	4.74	4.36
	26	8.42	16.67	22.09	15.73	3.97	4.53	4.70	4.40
Pooled SEM		0.111	0.229	0.234	0.182	0.064	0.063	0.057	0.059
ME level (kcal/kg)									
2800		9.31[a]	17.67[a]	23.25	16.74[a]	3.72[b]	4.43[b]	4.68[b]	4.28[b]
2900		8.83[b]	17.47[a]	23.48	16.59[a]	3.87[a]	4.60[a]	4.90[a]	4.46[a]
3000		8.55[c]	17.09[b]	23.21	16.28[b]	3.93[a]	4.66[a]	4.98[a]	4.52[a]
CP level (%)									
22		8.98	17.31	23.14[b]	16.47	3.71[b]	4.44[b]	4.77[b]	4.30[b]
24		8.51	17.40	23.28[ab]	16.51	3.89[a]	4.62[a]	4.88[a]	4.46[a]
26		8.51	17.52	23.53[a]	16.63	3.93[a]	4.64[a]	4.90[a]	4.49[a]
Quail species									
Japanese		8.92	18.07[a]	24.47[a]	17.16[a]	3.88[a]	4.79[a]	5.13[a]	4.60[a]
Brown		8.86	16.74[b]	22.16[b]	15.92[b]	3.80[b]	4.33[b]	4.57[b]	4.24[b]
Probability									
ME		***	***	NS	***	**	**	**	**
CP		NS	NS	*	NS	***	**	***	**
Species		NS	***	***	***	*	**	***	**
ME × CP		NS	NS	NS	NS	NS	*	NS	NS
ME × species		NS	NS	NS	NS	NS	NS	NS	NS
CP × species		**	NS	**	NS	*	**	**	**
ME × CP × species		NS	NS	NS	NS	NS	NS	NS	NS

[abc]Means with no common superscripts within the column of each classification (ME and CP levels and quail species) are significantly (P<0.05) different. NS: not significant at P<0.05; *P<0.05; **P<0.01; ***P<0.001.

Feed conversion ratio (FCR) was improved (P<0.01) by increase in dietary ME content throughout the trial period (Table 3). Similarly, dietary CP level had a significant effect (P<0.05) on FCR values (except 36-49 d of age). The FCR values were decreased (P<0.05) when dietary CP level was increased to 24%; however, additional increase in dietary CP level to 26% had no further effect on FCR values. Mortality was significantly (P<0.05) greater in the birds fed diets containing 26% CP compared with other CP groups (Table 3).

Carcass percentage was influenced (P<0.01) by dietary ME and CP levels, quail species and also by ME × CP interaction (Table 4). Increase in dietary ME content to 2900 kcal/kg caused significant (P<0.01) increase in carcass yield. The same response was observed when dietary CP level was increased to 24% (P<0.01). Japanese quails had the greater (P<0.05) carcass and breast yields compared with Brown quails. Moreover, breast and thigh percentages were influenced (P<0.05) by dietary CP and ME levels, with the lowest values assigned to the birds fed diets containing 22%

CP and 2800 kcal ME/kg. Increase in dietary ME level increased (P<0.05) abdominal fat deposition.

Correlation coefficients among performance parameters of Japanese and Brown quails are shown in Tables 5 and 6, respectively. The highly positive correlations were observed among daily ME intake and most performance traits. Similarly, daily CP intake was positively correlated with ADWG, ADFI and carcass yield. Correlation coefficients among daily ME/and or CP intakes and performance parameters were higher in Japanese quails than those of Brown quails.

Table 3. Effect of different levels of dietary metabolizable energy (ME) and crude protein (CP) on feed conversion ratio and mortality of Japanese and Brown quails

ME (kcal/kg)	CP (%)	Feed conversion ratio (g feed: g gain)				Mortality (%)			
		8-21 d	22-35 d	36-49 d	7-49 d	8-21 d	22-35 d	33-49 d	8-49 d
Japanese quail									
2800	22	2.56	4.01	4.98	3.97	2.50	2.50	2.50	7.50
	24	2.44	3.91	4.87	3.84	2.50	0.00	0.00	2.50
	26	2.48	3.86	4.91	3.85	5.00	2.50	5.00	12.50
2900	22	2.39	3.90	4.83	3.84	0.00	0.00	2.50	2.50
	24	2.26	3.73	4.76	3.70	0.00	0.00	0.00	0.00
	26	2.18	3.67	4.74	3.64	2.50	2.50	0.00	5.00
3000	22	2.29	3.75	4.66	3.69	2.50	2.50	2.50	7.50
	24	2.12	3.61	4.58	3.55	5.00	2.50	2.50	10.00
	26	2.06	3.53	4.63	3.52	2.50	2.50	5.00	10.00
Brown quail									
2800	22	2.60	4.08	5.06	4.00	0.00	2.50	0.00	2.50
	24	2.43	3.97	4.99	3.87	2.50	0.00	2.50	5.00
	26	2.52	4.13	5.03	3.98	7.50	2.50	5.00	15.00
2900	22	2.39	3.89	4.83	3.79	2.50	0.00	2.50	5.00
	24	2.27	3.76	4.77	3.67	2.50	2.50	2.50	7.50
	26	2.20	3.85	4.83	3.70	5.00	2.50	2.50	10.00
3000	22	2.32	3.79	4.76	3.70	2.50	2.50	2.50	7.50
	24	2.16	3.66	4.67	3.58	2.50	2.50	2.50	7.50
	26	2.12	3.68	4.70	3.58	5.00	2.50	5.00	12.50
Pooled SEM		0.052	0.058	0.060	0.056	2.381	2.125	2.307	3.298
ME level (kcal/kg)									
2800		2.51[a]	3.99[a]	4.97[a]	3.92[a]	3.33	1.67	2.50	7.50
2900		2.28[b]	3.80[b]	4.79[b]	3.72[b]	2.08	1.25	1.67	5.00
3000		2.18[c]	3.67[c]	4.67[c]	3.60[c]	3.33	2.50	3.33	9.17
CP level (%)									
22		2.43[a]	3.90[a]	4.85	3.83[a]	1.67	1.67	2.08	5.42[b]
24		2.28[b]	3.77[b]	4.77	3.70[b]	2.50	1.25	1.67	5.42[b]
26		2.26[b]	3.79[b]	4.81	3.71[b]	4.58	2.50	3.75	10.83[a]
Quail species									
Japanese		2.31	3.77[b]	4.77[b]	3.73	2.50	1.67	2.22	6.39
Brown		2.33	3.87[a]	4.85[a]	3.76	3.33	1.94	2.78	8.06
Probability									
ME		**	**	**	**	NS	NS	NS	NS
CP		*	*	NS	*	NS	NS	NS	*
Species		NS	**	**	NS	NS	NS	NS	NS
ME × CP		NS	NS	NS	NS	NS	NS	NS	NS
ME × species		NS	NS	NS	NS	NS	NS	NS	NS
CP × species		NS	*	NS	NS	NS	NS	NS	NS
ME × CP × species		NS	NS	NS	NS	NS	NS	NS	NS

[abc]Means with no common superscripts within the column of each classification (ME and CP levels and quail species) are significantly (P<0.05) different.

NS: not significant at P<0.05; *P<0.05; **P<0.01.

Table 4. Effect of different levels of dietary metabolizable energy (ME) and crude protein (CP) on carcass characteristics of Japanese and Brown quails at d 49 of age

ME (kcal/kg)	CP (%)	Carcass	Breast	Thigh	Abdominal fat
Japanese quail		------------------------------ (% of live body weight)		------------------------------	
2800	22	68.74	31.88	22.68	0.39
	24	69.67	32.04	23.39	0.36
	26	67.24	31.67	22.91	0.51
2900	22	68.13	32.18	23.45	0.59
	24	70.65	33.52	25.27	0.47
	26	71.29	33.91	24.93	0.39
3000	22	67.58	32.54	22.84	0.67
	24	70.90	34.26	25.09	0.58
	26	71.81	34.83	25.80	0.52
Brown quail					
2800	22	65.56	29.09	23.89	0.28
	24	65.90	29.58	24.53	0.25
	26	64.28	28.56	23.92	0.35
2900	22	65.39	30.12	24.12	0.42
	24	67.11	32.29	25.68	0.30
	26	66.87	31.68	25.95	0.26
3000	22	65.45	29.52	24.71	0.48
	24	66.92	31.95	25.73	0.43
	26	66.73	32.41	26.27	0.32
Pooled SEM		0.759	0.760	0.734	0.077
ME level (kcal/kg)					
2800		66.90^{b}	30.47^{b}	23.55^{b}	0.36^{b}
2900		68.24^{a}	32.28^{a}	24.90^{a}	0.41^{b}
3000		68.23^{a}	32.59^{a}	25.07^{a}	0.50^{a}
CP level (%)					
22		66.81^{b}	30.89^{b}	23.62^{b}	0.47
24		68.53^{a}	32.27^{a}	24.95^{a}	0.40
26		68.04^{a}	32.18^{a}	24.96^{a}	0.39
Quail species					
Japanese		69.56^{a}	32.98^{a}	24.04^{b}	0.50^{a}
Brown		66.02^{b}	30.58^{b}	24.98^{a}	0.34^{b}
Probability					
ME		**	*	*	*
CP		**	**	*	NS
Species		**	*	**	**
ME × CP		**	NS	NS	NS
ME × species		NS	NS	NS	NS
CP × species		NS	NS	NS	NS
ME × CP × species		NS	NS	NS	NS

[ab]Means with no common superscripts within the column of each classification (ME and CP levels and quail species) are significantly (P<0.05) different.

NS: not significant at P<0.05; *P<0.05; **P<0.01.

DISCUSSION

The significant decreases in ADFI were observed at 8-21 and 22-35 d of age as a result of increase in dietary ME level. These observations were in agreement with reports by Golian and Maurice (1992) and Leeson *et al.* (1993), who concluded that birds consume feed to primarily meet energy requirements. Although ADFI was decreased by increasing dietary ME content, however, ADFI of birds fed diets containing 2800 and 2900 kcal ME/kg were not statistically different except starter period (8-21 d). It seems that the older birds consume more feed, and in turn, more ME from the diets with the higher energy levels (Lepore and Marks, 1971). Compared with dietary ME content, increase in dietary CP level had no marked effect on ADFI, except of 36-49 d of age (finisher period). Likewise, Erakpotobor *et al.* (2004) reported that ADFI of Japanese quails were increased with increasing dietary CP level.

Table 5. Correlation coefficients among major economic traits in Japanese quails fed diets different in metabolizable energy (ME) and crude protein (CP) levels

	CPI-2	CPI-3	TCPI	TMEI	TBWG	TFI	TFCR	Carcass	Breast	Thigh	Abd. fat[9]
CPI-1[1]	0.91^{***}	0.84^{***}	0.92^{***}	0.12	0.25	0.67^{***}	0.11	0.22	0.01	0.14	–0.21
CPI-2[2]		0.96^{***}	0.99^{***}	0.39^{*}	0.57^{***}	0.65^{***}	–0.21	0.47^{**}	0.23	0.38^{*}	–0.12
CPI-3 [3]			0.98^{***}	0.48^{**}	0.66^{***}	0.54^{***}	$–0.35^{*}$	0.50^{**}	0.32	0.42^{*}	–0.09
TCPI[4]				0.40^{*}	0.57^{***}	0.61^{***}	–0.23	0.46^{**}	0.24	0.37^{*}	–0.13
TMEI[5]					0.67^{***}	0.40^{*}	$–0.42^{**}$	0.70^{***}	0.45^{**}	0.53^{***}	0.48^{**}
TBWG[6]						0.15	$–0.86^{***}$	0.74^{***}	0.53^{***}	0.51^{**}	0.22
TFI[7]							0.37^{*}	0.45^{**}	–0.05	0.17	0.09
TFCR[8]								$–0.45^{**}$	$–0.53^{***}$	$–0.39^{*}$	–0.17
Carcass									0.55^{***}	0.53^{***}	0.14
Breast										0.48^{**}	0.18
Thigh											–0.15

[1]CPI-1: daily CP intake during 8-21 d of age; [2]CPI-2: daily CP intake during 22-35 d of age; [3]CPI-3: daily CP intake during 36-49 d of age; [4]TCPI: daily CP intake during 8-49 d of age; [5]TMEI: daily ME intake during 8-49 d of age; [6]TBWG: daily body weight gain during 8-49 d of age; [7]TFI: daily feed intake during 8-49 d of age; [8]TFCR: feed conversion ratio during 8-49 d of age; [9]Abd. fat: Abdominal fat percentage. $^{*}P<0.05$; $^{**}P<0.01$; $^{***}P<0.001$.

Table 6. Correlation coefficients among major economic traits in brown quails fed diets different in metabolizable energy (ME) and crude protein (CP) levels

Traits	CPI-2	CPI-3	TCPI	TMEI	TBWG	TFI	TFCR	Carcass	Breast	Thigh	Abd. fat[9]
CPI-1[1]	0.90^{***}	0.84^{***}	0.91^{***}	–0.15	–0.23	0.42^{*}	0.39^{*}	0.06	–0.04	0.08	–0.26
CPI-2[2]		0.97^{***}	0.99^{***}	0.07	0.11	0.30	0.07	0.26	0.18	0.24	–0.24
CPI-3 [3]			0.99^{***}	0.13	0.26	0.18	–0.10	0.34^{*}	0.29	0.35^{*}	–0.23
TCPI[4]				0.07	0.13	0.28	0.05	0.27	0.20	0.27	–0.24
TMEI[5]					0.53^{***}	0.36^{*}	–0.23	0.74^{***}	0.30	0.39^{*}	0.36^{*}
TBWG[6]						–0.17	$–0.87^{***}$	0.70^{***}	0.59^{***}	0.47^{**}	0.10
TFI[7]							0.64^{***}	0.46^{**}	–0.23	–0.04	–0.01
TFCR[8]								–0.32	$–0.58^{***}$	$–0.38^{*}$	–0.07
Carcass									0.41^{*}	0.26	0.12
Breast										0.21	–0.12
Thigh											0.28

[1]CPI-1: daily CP intake during 8-21 d of age; [2]CPI-2: daily CP intake during 22-35 d of age; [3]CPI-3: daily CP intake during 36-49 d of age; [4]TCPI: daily CP intake during 8-49 d of age; [5]TMEI: daily ME intake during 8-49 d of age; [6]TBWG: daily body weight gain during 8-49 d of age; [7]TFI: daily feed intake during 8-49 d of age; [8]TFCR: feed conversion ratio during 8-49 d of age; [9]Abd. fat: Abdominal fat percentage. $^{*}P<0.05$; $^{**}P<0.01$; $^{***}P<0.001$.

In general, there was no significant difference between ADWG of birds fed diets containing 2900 and 3000 kcal ME/kg. It seems that dietary ME requirement of both quail species is a value between 2900 and 3000 kcal/kg during the first weeks of growth period and 2900 kcal/kg at the older ages. However, NRC (1994) suggests the constant value of 2900 kcal ME/kg for the nutritional requirements of ME for Japanese quails throughout the growing and breeding periods. Current findings indicated that dietary ME demand is close to NRC (1994) recommendations for Japanese quails.

Increase in dietary CP level to 24% improved (P<0.001) ADWG of both quail species, but this effect was more obvious for Japanese quails. These findings are in agreement with the results of Vohra and Roudybush (1971) and Erakpotobor *et al.* (2004), who reported the greater weight gains for quail chicks with diets higher in CP level. Increase in dietary CP level from 24 to 26% improved (P<0.001) ADWG of Japanese chicks, while had no or sometimes negative effect on ADWG of Brown quails. This output caused significant (P<0.05) CP × quail species interaction. Incremental levels of dietary CP had more effect on ADWG during early growth stages compared with finisher periods. The maintenance of intensive Japanese quail populations on diets containing about 28% CP was adopted (Woodard *et al.*, 1965); however, the later studies indicated that Coturnix can be reared on diets containing 25-26% CP during early weeks

(Weber and Reid, 1967; Lepore and Marks, 1968; Svacha *et al.*, 1970) and dietary CP level can be reduced to 20% after 3 weeks of age (Vogt, 1967; Gropp and Zucker, 1968). The experimental diets in the present study were formulated to maintain constant level of critical amino acids to dietary CP; consequently the diets with higher CP levels had a higher density of amino acids. Increased ADFI and ADWG in chicks fed on higher CP diets may be, in part, related to the higher amino acid density, because the birds appear to respond to amino acid concentration rather than dietary CP level (Straznicka, 1990). Excessive concentrations of most amino acids decrease feed intake and subsequent growth (Straznicka, 1990), probably due to amino acid interactions. In the present study, maintaining constant levels of most essential amino acids to dietary CP don't appear to could result in amino acid imbalance.

Average FCR values were reduced (P<0.01) by increase in dietary ME content throughout the experimental period. These findings are in agreement with those of Lepore and Marks (1971), who reported the value of 3080 kcal ME/kg compared with the lower ME levels for optimum feed efficiency for 2 quail lines. Feed conversion ratio was decreased (P<0.05) when dietary CP level increased to 24%; however, further increase in dietary CP level had no additional effect on FCR values. Increase in dietary CP level during early growth stages had greater effect on FCR values than in the later periods, indicating the nutritional demands of dietary CP would decrease with age (Vogt, 1967; Gropp and Zucker, 1968).

In contrast to periodical mortality, total mortality during 8-49 d of age was significantly (P<0.05) greater in the birds fed diets containing 26% CP. A reasonable explanation for this observation remains to be elucidated. It seems that, however, the greater mortality rate in high-CP groups may be resulted from excesses nitrogen-related metabolic disorders. In addition, high-CP diets have greater levels of soybean meal, and in turn, more potassium content. The higher potassium levels in high-CP diets may impair dietary cation-anion balance, causing a part of mortality occurred. Most mortality in the birds fed on 26% CP-diets were allotted to Brown quails, indicating this quail species don't require high CP levels and may not tolerate excesses nitrogen.

Increase in dietary ME level to 2900 kcal/kg caused significant increase in carcass yield, but further increase in ME level was not associated with additional improvements. Consistent with our findings, Waldroup *et al.* (1990) reported that female broilers fed on high energy diets had significantly greater dressing percentage than females fed the low energy diets. Japanese quails had the greater (P<0.01) carcass yield than Brown quails. On the other hand, thigh percentage of Brown quails was significantly (P<0.01) greater than that of Japanese quails which was in good agreement with the report by Vali *et al.* (2005), who also observed that Brown quails had the heavier thigh muscle compared with Japanese ones.

Excess energy from ME-enriched diets will normally be stored as fat. Increase in dietary ME level in the study here was associated with increased (P<0.05) abdominal fat deposition. Probably, the higher fat deposition is related to the higher growth rate in birds fed on higher ME-diets compared with those on diets containing 2800 kcal ME/kg. Consistent with this, Marks (1990) reported that the faster growing birds deposit more fat than their slower growing counterparts. Abdominal fat percentage was greater in Japanese quails than in Brown quails, probably because of more feed intake and faster growth rate of former species.

As noted, there were highly positive correlations among daily ME intake (and also daily CP intake) and most performance traits. Correlations among dietary ME/ and or CP intakes and these traits indicate that these two cost components of diets play an important role in the production economics. There were high correlations among ADWG and carcass components (positive correlation), as well as between FCR and these traits (negative correlation). Similarly, Nahashon *et al.* (2005) noted the positive and highly significant correlations between the live weight and weights of carcass, breast, thigh, drumstick, and wing of French guinea fowl. Also, Wang *et al.* (1991) reported positive but small to moderate correlations between carcass weight and weight gain. Correlation coefficients were higher for Japanese quails than those for Brown ones. Japanese quails appear to be more responsive to dietary modifications of CP and ME levels than Brown quails. These findings suggest that the nutritional requirements for dietary CP are lower in Brown quails compared to Japanese ones.

Based on the results obtained, Japanese quails seems to utilize more efficiently diets containing 3000 kcal ME/kg and 26% CP during the first weeks of age. These levels can be reduced to 2900 kcal ME/kg and 24% CP (or even less than 24%) in the older ages. With Brown quails, the nutritional demands for dietary ME and CP were determined to be 2900 kcal ME/kg and 24% CP in the starter period, and 2900 kcal/kg ME and 22% CP in the remaining growth stage. Although increase in dietary CP (and in some cases dietary ME) level improved the growth performance of both quail species, but Japanese quail utilized more efficiently high-CP diets, and achieve better ADWG and FCR values.

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