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The Performance of Japanese Quail (White Breasted Line) to Dietary Energy and Amino Acid Levels on Growth and Immuno-competence

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Abstract

The response of growing Japanese quails (White Breasted line-CARI UJJWAL, n=900, divided into 36 subgroups) to three dietary levels of essential amino acids (EAA) at three different metabolizable energy (ME) levels (3×3 factorial design) on growth and immunity was investigated. Nine diets including three levels of ME (2700, 2900 and 3100 kcal/kg) each at three levels of EAA (low, medium and high) were formulated. Each diet was offered to 4 replicated groups of 25 Japanese quails up to 5 weeks of age. The ratio of lysine to protein and the level of methionine and threonine to lysine, as specified by NRC (NRC, 1994), remained almost similar in all the diets. Body weight gain, feed intake and feed conversion ratio did not differ statistically due to the treatments i.e. interaction of ME and EAA levels. However, there was linear increase in body weight gain with increased EAA levels during 0-3 or 0-5 weeks of age. Feed intake increased linearly with the decreased ME ($P<0.01$) and increased EAA ($P<0.01$) in diets. Feed conversion ratio (FCR) improved ($P<0.01$) linearly with increase in dietary ME concentration from 0-3, 3-5 or 0-5 weeks of age. Protein efficiency (PE) improved ($P<0.01$) with decreased EAA levels and also with the increase in dietary ME level during 0-3, 3-5 and 0-5 weeks of growing age, whereas energy efficiency is influenced by EAA levels during 0-3 and 3-5 weeks of age ($P<0.01$). Maximum performance index during 0-5 weeks of age was observed in diet with 3100 kcal ME/Kg and 115% EAA. Nitrogen retention per unit energy intake was increased ($P<0.01$) with the increased EAA levels and decreased energy levels. Humoral (SRBC) and cellular (PHA-P) immune response did not differ due to ME, EAA or ME x EAA. Thus, it was concluded that the optimum level of dietary ME is 2700 kcal/kg with CP 25.83%, lysine 1.49%, methionine 0.58% and threonine 1.17% on dry matter basis during 0-5 weeks of age was optimum for gain. However for optimum feed conversion, the growing quails required diet with ME 3100 kcal/kg with CP 23.23%, lysine 1.30%, methionine 0.50% and threonine 1.02% for 0-5 weeks of age.

Keywords: Japanese quail; Essential amino acids; Metabolizable energy; Growth; Immunity

Introduction

Japanese quail (*Coturnix coturnix japonica*) is one of the diversified poultry species reared for commercial egg and meat production. It is blessed with the unique characteristics of fast growth, early sexual maturity, high rate of egg production, short generation interval and shorter incubation period that makes it suitable for diversified animal agriculture. They are fairly resistant to diseases, and impart less worry for vaccination. Because of low volume, low weight, less feed input and space requirements, the commercial quail farming for table egg and meat production can be started with much lower capital investment as compared to chicken and duck with almost the same profit margin. With shorter reproduction cycle and earlier marketing age, it offers fast monetary circulation ultimately yielding quicker returns. The meat production performance of Japanese quails has also been improved during recent years due to genetic selection. Therefore, there is need of updating optimal nutritional requirements of Japanese quails with the improvement in genetic makeup to exploit production potentiality.

Precise nutrient supply reduces feed cost, wastage of nutrients, environmental pollution, and bad aroma in poultry house, and thus improves animal welfare. Establishing requirements of limiting amino acids and accordingly supplementing their synthetic form in diet matching the requirements provides scope to reduce dietary protein (CP) content. In low protein maize-soya bean meal based diets of growing Japanese quails, methionine, threonine and lysine are the first, second and third limiting amino acids, respectively. Generally the CP content in diets of growing quails ranges from 24 to 27% [1,2] that can be reduced through supplementation of the limiting amino acids as their synthetic forms.

Few works have been conducted on amino acid requirements taking individual amino acids [3,4]. However, the ratio of lysine to CP and ratio of other essential amino acids in relation to lysine is important rather than studying individual amino acids to achieve optimum growth and feed efficiency [5-7]. The ideal protein concept used in formulation of amino acid levels was based on the Illinois Ideal Chick Protein (IICP) concept, developed at Illinois University in 1950s to 1960s. The Agricultural Research Council in the United Kingdom was the first to propose an ideal protein for pigs in which lysine was used as the reference amino acid. Giving digestible lysine of diet a value of 100%, the concentration of other digestible amino acids was ranked accordingly [8]. The information on the amino acid nutrition of Japanese quail, as a whole, is scanty [1,2,9]. The literature is also silent on the digestible amino acid values in different feedstuffs and their requirements for quails. In chickens as well as in mammals, it has been shown that deficiency or excess of dietary protein [10-12] or amino acids [13-15] alters immune responses. Therefore, the present study was conducted to elucidate the response of growing Japanese quail to different levels of essential amino acid (EAA) at reduced dietary CP content with different levels of energy for optimum growth

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performance, feed utilization efficiency and immunity under tropical climate. The ratios of the most limiting amino acids (methionine and threonine) in relation to lysine calculated from NRC (1994) specification were taken as base for formulation of diets and setting experimental design.

Materials and Methods

Selection and rearing of chicks

Day-old quail chicks (n=900) of white breasted line were weighed and randomly distributed into 9 treatments with four replicates of 25 chicks each. All the chicks were reared in groups in electrically heated battery brooders with wire-mesh floor. All the groups were subjected to similar management practices (brooding, lighting, feeding and watering) throughout the experiment except the diets offered. Lighting regime was 24 h and brooding temperature gradually decreased from 34°C during the initial 7 days to 26°C by 21 days of age. Water and experimental diets were supplied *ad libitum*. No vaccination was performed.

Feed ingredients and experimental diets

Nine corn-soya based diets were formulated with three levels of energy (2700, 2900 and 3100 kcal ME per kg) and three levels of essential amino acids (EAA) viz. low, medium and high levels of limiting amino acids (lysine, methionine and threonine) in 3 × 3 factorial design (Table 1). The values of amino acids as suggested by NRC (1994) on 90% dry matter basis were translated at each energy level on 100% dry matter basis. The feed ingredients were ground; micro-ingredients were premixed and then thoroughly mixed through a mixer to have mash diets. Each diet was offered to 100 chicks in 4 replicated groups. The level of energy and EAA, and the ratios of limiting amino acids (methionine and threonine) in relation to lysine, as suggested by NRC (1994) were taken as base. The lysine requirement was met by increasing CP content through soya bean meal. Dietary methionine and threonine were adjusted by supplementing their synthetic forms (LR grade and 99% purity of DL-methionine and L-threonine). The levels of other EAA were also increased with the increasing level of CP in the diet. Moreover, irrespective of the levels of essential amino acids, the profile of total limiting amino acids (methionine and threonine) in relation to lysine (100) remained almost similar in all the diets (Table 2), while the ratios of other EAA to lysine varied slightly depending upon the CP content and the proportion of different feedstuffs used to meet energy requirements. However, the ratios for other EAA to lysine were higher and in no case can be defined as deficient.

	2700 Kcal			2900 Kcal			3100 Kcal		
	85%	100%	115%	85%	100%	115%	85%	100%	115%
Ingredient composition (on DM basis)									
Maize, Yellow	48.0	45.5	43.2	62.18	59.7	57.0	68.5	60.49	52.54
Rice bran, deoiled	25.6	20.74	16.0	9.3	4.34	0	0	0	0
Soyabean meal, solvent extracted	23.73	31.0	38.0	25.85	33.2	40.16	27.24	33.98	40.59
Veg.Oil	0	0	0	0	0	0	1.6	2.8	4.0
Limestone	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0
Dicalcium phosphate	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1
Trace mineral premix *	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Vitamin Premix *	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Salt	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
DL-Methionine	0.051	0.099	0.147	0.051	0.100	0.147	0.055	0.106	0.156
L-Threonine	0.021	0.062	0.108	0.020	0.063	0.107	0.023	0.066	0.116
Nutrient composition (on DM basis)									
ME, kcal/kg##	2702	2701	2703	2902	2902	2898	3100	3102	3104
CP, %**	20.54	23.23	25.83	20.67	23.39	25.99	20.66	23.23	25.75
ME:CP	131.6	116.3	104.7	140.4	124.1	111.5	150.0	133.5	120.5
Lys, %#	1.10	1.30	1.49	1.10	1.30	1.49	1.11	1.30	1.50
Lys: CP	0.054	0.056	0.058	0.053	0.056	0.058	0.053	0.056	0.058
Met, %#	0.43	0.50	0.58	0.42	0.50	0.57	0.42	0.50	0.57
Thr, %#	0.87	1.02	1.17	0.87	1.02	1.17	0.87	1.02	1.17
Cys, %#	0.40	0.44	0.47	0.40	0.44	0.47	0.39	0.43	0.46
Arg, %#	1.56	1.80	2.03	1.53	1.76	1.99	1.50	1.75	1.99
Ile, %#	0.92	1.06	1.20	0.94	1.08	1.22	0.95	1.08	1.21
Leu, %#	2.00	2.21	2.41	2.12	2.33	2.52	2.17	2.32	2.47
Phe, %#	1.14	1.30	1.44	1.17	1.32	1.47	1.17	1.31	1.45
Val, %#	1.10	1.23	1.36	1.10	1.23	1.35	1.09	1.21	1.34
His, %#	0.65	0.73	0.81	0.65	0.74	0.82	0.65	0.73	0.81
Ca, %**	0.85	0.87	0.88	0.83	0.85	0.86	0.82	0.84	0.86
Available.P, %##	0.40	0.40	0.41	0.40	0.40	0.41	0.39	0.40	0.40
Potassium, %	1.09	1.16	1.22	0.91	0.98	1.06	0.81	0.93	1.05
Crude fibre, %	6.16	5.92	5.69	4.30	4.06	3.87	3.22	3.52	3.81

*Trace mineral premix supplied Mg- 300, Mn- 55, I- 0.4, Fe- 56, Zn- 30 and Cu- 4 mg/kg diet. The vitamin premix supplied vitamin A, 8250 IU; vitamin D_3, 1200 ICU; vitamin K, 1 mg; vitamin E, 40 IU; vitamin B_1, 2 mg; vitamin B_2, 4 mg; vitamin B_{12}, 10 mcg; niacin, 60 mg; pantothenic acid, 10 mg; choline, 500 mg/kg diet. **Analysed values #Calculated based on analyzed ingredient values ##Calculated from tabulated values
Percent of EAA values specified by NRC (1994)

Table 1: Ingredient (%) and nutrient composition of experimental diets.

	2700 kcal			2900 kcal			3100 kcal		
	85%	100%	115%	85%	100%	115%	85%	100%	115%
Met	38.48	38.43	38.52	38.43	38.43	38.44	38.43	38.44	38.43
Cys	36.55	33.78	31.82	36.07	33.35	31.45	35.52	32.87	30.94
Met+Cys	75.03	72.21	70.34	74.50	71.78	69.89	73.95	71.31	69.37
Thr	78.45	78.22	78.51	78.46	78.36	78.48	78.44	78.15	78.45
Arg	141.5	138.1	135.7	138.2	135.3	133.3	136.1	134.3	132.9
Ile	83.55	81.52	80.09	85.43	83.11	81.43	86.18	83.09	80.84
Leu.	181.4	169.7	161.4	191.9	178.5	168.9	196.0	178.4	165.5
Phe	103.5	99.50	96.64	105.6	101.2	98.10	106.2	100.9	97.07
Val	99.91	94.76	91.10	99.19	94.11	90.54	98.26	93.23	89.57
His	58.61	56.06	54.25	59.18	56.52	54.64	59.20	56.23	54.07

Table 2: Essential amino acid profiles in dietary treatments (in relation to lysine as 100).

Recording of data

The data of body weights and feed intake were recorded at weekly intervals. Mortality was recorded as and when it occurred. Daily recording of temperature and relative humidity was carried out. The maximum and minimum temperature in the experimental shed was 33.2±0.35 and 25.6±0.30°C and the dry and wet bulb temperature were 29.0±0.24 and 27.9±0.22, respectively. Feed conversion (feed, g: gain, g) ratio (FCR), energy efficiency (EE-energy intake, KJ: gain, g), protein efficiency (PE-CP intake, g: gain, g) and performance index (FCR: gain) were calculated.

Metabolism trial

A metabolism trial was carried out for a 3-day collection period during the third week of age. During this period besides offering weighed quantity of feed, the total excreta voided during a 24-hour period were collected daily and weighed. A representative sample of excreta was pooled for 3 consecutive days and dried in a hot air oven with an exhaust facility at 60°C till a constant weight was obtained. The dried excreta, feed and residue samples were ground and processed for nitrogen, calcium and phosphorus analysis to calculate their retention.

Immunity traits and immune organs

The cellular immune response was assessed by cutaneous basophilic hypersensitivity test using PHA-P (Phytohaemagglutinin, lectin from Phaseolus vulgaris). At 33rd day of age, ten birds from each treatment were selected and the toe thickness of both left and right foot at 3rd and 4th inter-digital spaces was measured by micrometer. Immediately after measurements, 0.05 ml PHA-P (2 mg PHA-P ml-1 of phosphate buffer saline-PBS) and 0.05 ml of PBS was injected intra-dermally in foot web of 3rd and 4th digits of right and left foot (acted as control), respectively. The web swelling of both feet was measured 24 h after injection. The response was determined by subtracting the skin thickness of first measurement from the second and values of left foot (control) from the right foot [16].

Humoral immune response was evaluated through estimation of haemagglutination (HA) antibody titre estimation. Suspension of sheep red blood cell-SRBC (1% and 2.5% v/v) in PBS was prepared and stored in refrigerator at 4°C until its use. At 29th day of age, 0.2 ml of 2.5% sheep-RBC suspension was injected intravenously per bird and a total of 10 birds were injected per treatment to study the primary antibody response to SRBC. At 35th day, 2 ml blood was collected during sacrifice. The blood was allowed to clot; the serum was collected, and frozen (-70°C) until analyzed for the antibody titres to SRBC (1% v/v). The antibody titre was determined by HA test [17,18]. The titres were expressed as log 2. After 5 weeks of age 8 quails were randomly picked up from each treatment and sacrificed to study the relative weight (as % of live weight) of immune organs (thymus and spleen).

Biochemical analysis

The representative samples of feed ingredients were analyzed for crude protein (CP), phosphorus [19] and calcium [20]. The amino acid contents of the feed ingredients were analyzed [21], while that for mixed feed were calculated (Table 1). The excreta samples were also analyzed for nitrogen content [19].

Statistical analysis

The data obtained from the experiment was analyzed to study the effect of dietary treatments using analysis of variance (3 × 3 factorial CRD) as per Snedecor and Cochran [22]. The treatment means for the traits found significant (Pb0.05) in analysis of variance were compared for significance using Duncan's multiple range tests [23].

Results and Discussion

Live weight gain

The live weight gain (Table 3) during 0-3 or 0-5 weeks of age did not differ (P>0.05) due to interaction of EAA and ME levels, while differed significantly due to EAA levels. The quails received diet with high EAA level (with 25.8 to 26% CP) grew faster (P<0.01) than those reared on medium (23.2 to 23.4% CP) or low EAA (20.5 to 20.7% CP) levels during 0–3 or 0–5 weeks of age. The dietary ME levels did not influence the live weight gain at any growth phase. Therefore, a dietary level of 2700 kcal/kg and high EAA (25.8-26.0% CP) during the 0–5 weeks of age was found optimum for body weight gain. Live weight gain also did not differ among diets with 2900 or 2700 kcal ME/kg during 0-5 weeks [24] or 11.72-13.39 MJ ME/kg during 0–6 weeks of age [25]. The quails responded beneficially to high EAA level (25.8–26.0% CP) which was in line with the earlier feeding trial with heavy body weight line of quails [7]. A dietary CP level of 26% was also suggested [26] for 0–5 weeks of age for better growth and feed efficiency in growing Japanese quails. In this study, the optimum levels of critical amino acids were Lys 1.49–1.50%, Met 0.57–0.58%, Met+Cys 1.03-1.05% and Thr 1.17 at 25.8-26.0% CP on DM basis.

Feed intake

The feed intake (FI, g per bird) did not differ due to the treatments i.e. interaction between EAA and ME levels at any growth phase (Table 3). The Feed intake of white breasted quail line during 0-3 and 0-5 weeks of age remained similar (P<0.01) in groups received 100% or 115% levels of EAA, but decreased (P<0.01) at lower EAA (85%). It was highest (P<0.01) in lowest energy level. These results were in line with those of other workers [24]. A higher FI with decrease in dietary

	Live weight Gain		Feed Intake		FCR	
	0-3 weeks	0-5 weeks	0-3 weeks	0-5 weeks	0-3 weeks	0-5 weeks
Interaction effect (MExEAA)						
2700, 85	77.76	151.98	193.77	461.61	2.74	3.23
2700, 100	88.02	163.73	217.79	514.99	2.56	3.25
2700, 115	91.60	164.21	227.57	526.97	2.51	3.28
2900, 85	71.88	143.81	172.65	417.74	2.78	3.17
2900, 100	87.68	160.84	203.72	473.17	2.40	3.02
2900, 115	95.94	170.17	219.59	502.58	2.37	3.01
3100, 85	69.24	146.74	169.42	403.93	2.55	2.86
3100, 100	80.21	159.27	184.87	431.96	2.38	2.79
3100, 115	93.32	168.60	205.42	462.82	2.22	2.77
Pooled SEM	1.706	1.744	4.39	8.145	0.033	0.037
Main effects						
AMEn, kcal/kg						
2700 kcal	85.79^{p}	159.97	213.04^{p}	501.19^{p}	2.60^{p}	3.25^{p}
2900 kcal	85.17^{pq}	158.27	198.66^{pq}	464.50^{q}	2.51^{p}	3.07^{q}
3100 kcal	80.93^{q}	158.20	186.57^{q}	432.90^{r}	2.38^{q}	2.81^{r}
EAA levels						
85% AA	72.96^{y}	147.51^{y}	178.61^{x}	427.76^{x}	2.69^{w}	3.09
100% AA	85.30^{x}	161.28^{x}	202.13^{w}	473.37^{w}	2.45^{x}	3.02
115% AA	93.62^{w}	167.66^{w}	217.53^{w}	497.46^{w}	2.36^{x}	3.02
Probability						
ME x EAA	NS	NS	NS	NS	NS	NS
ME levels	NS	NS	P<0.0001	P<0.0001	P<0.0001	P<0.0001
EAA levels	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P<0.0001	NS

^{pqr}(energy level), ^{wxy}(EAA levels) Values bearing different superscripts differ significantly(P<0.05). NS=Non-significant (P>0.05). The values are means.

Table 3: Live weight gain (g/bird), feed intake (g/bird) and feed conversion ratio (feed: gain) of growing quails at different growth phases.

energy concentration was to compensate energy intake. The higher FI with increased EAA levels in this study corroborated well with the earlier observations [7]; and the higher feed intake was to compensate energy requirement for growth as the live weight increased with the EAA levels.

Feed conversion ratio

The interaction of EAA and energy levels did not influence feed conversion ratio (FCR) at any growth phase (Table 3). However, FCR differed significantly during 0-3 weeks of age due to EAA levels, and during 0-3 and 0-5 weeks of age due to ME levels. The FCR emerged at medium or high EAA levels remained statistically similar but was poor (P<0.01) in low EAA level during 0-3 weeks of age. The FCR improved (P<0.01) during 0-5 weeks with increase in dietary energy level, and the best (P<0.01) FCR was emerged from diet with 3100 kcal ME/ kg during 0-3 and 0-5 weeks of age. An improvement in FCR in growing quails with increasing dietary energy level was also reported earlier [24]. FCR improved with increase in EAA level during 0-3 weeks of age. This was in line with earlier findings [7]. It indicated that the EAA levels influenced FCR at early growth phase only.

Protein and energy efficiency

Protein efficiency (CP intake per unit gain-PE) and energy efficiency (ME intake, KJ per unit gain-EE) did not differ due to interaction of energy and EAA levels (Table 4). The birds under high EAA level or 2700 and 2900 kcal/kg energy levels consumed more (P<0.01) protein per unit gain than those on medium or low EAA levels and 3100 kcal/kg energy level during 0-3 and 0-5 weeks of age. Birds fed with medium or high EAA level utilized energy more efficiently (P<0.01) during early (0-3 weeks) growth phase, while during overall phase EE did not differ due to EAA level. Dietary energy levels affected energy intake per unit gain during 0-3 weeks that too is higher in highest energy level. The EAA levels that resulted more growth had higher energy efficiency. An improved FCR and EE with the increased level of CP or amino acids were also observed in guinea fowls during initial growth period [27]. The EE or energy intake in Japanese quails also did not differ due to diets with variable ME concentration during 4-7 weeks of age [28]. The improved EE might be due to the ability of Japanese quails to retain more energy as protein than fat in body tissues in comparison to broiler chickens [9], which was supported by high EAA level.

Performance Index

As the gain and feed conversion ratio showed different trend due to EAA or energy level the performance index (PI, gain: FCR) that takes into consideration of both these parameters were calculated. PI was influenced (P<0.01) due to EAA and ME levels as well as their interaction. An increment in performance of growing quails was recorded with increased energy and EAA level being highest in 3100 kcal ME and at 115% EAA during 0-5 weeks of age. Interaction revealed highest PI in diet with 3100 kcal ME and 115% EAA in comparison to any other diet, and thus a dietary energy level of 3100 Kcal ME with 115% EAA was found to be optimum for economic performance for white breasted growing Japanese quails.

Utilization of nitrogen, calcium and phosphorus

The retention of N (% of intake or g per unit ME intake) were non-significant due to interaction of EAA and energy levels but significant (P<0.01) when individual effects of EAA and energy levels were considered (Table 5). Percent N retention increased (P<0.01) with the increased energy levels and decreased with increased EAA levels.

The retention of Ca and P, as percent of intake, (Table 5) was non-significant due to interaction of EAA and energy levels. Ca registered

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	Protein efficiency		Energy Efficiency		Performance Index
	0-3 weeks	0-5 weeks	0-3 weeks	0-5 weeks	0-5 weeks
Interaction effect (MExEAA)					
2700, 85	0.515	0.609	6.79	8.03	46.97ef
2700, 100	0.542	0.688	6.31	8.01	50.41de
2700, 115	0.592	0.775	6.21	8.12	50.14de
2900, 85	0.521	0.594	7.30	8.33	45.50f
2900, 100	0.513	0.646	6.36	8.01	53.44cd
2900, 115	0.562	0.715	6.26	7.97	56.50bc
3100, 85	0.486	0.545	7.28	8.16	51.35d
3100, 100	0.508	0.596	6.80	7.97	57.18b
3100, 115	0.525	0.657	6.32	7.90	60.82a
Pooled SEM	0.006	0.012	0.083	0.051	0.867
Main Effects					
AMEn, kcal/kg					
2700 kcal	0.550^{p}	0.691^{p}	6.44^{q}	8.05	49.17^{r}
2900 kcal	0.532^{p}	0.652^{q}	6.64^{pq}	8.10	51.82^{q}
3100 kcal	0.507^{q}	0.599^{r}	6.80^{p}	8.01	56.45^{p}
EAA levels					
85% AA	0.507^{x}	0.583^{y}	7.12^{w}	8.17	47.94^{y}
100% AA	0.521^{x}	0.643^{x}	6.49^{x}	8.00	53.68^{x}
115% AA	0.560^{w}	0.716^{w}	6.26^{x}	8.00	55.82^{w}
Probability					
ME x EAA	NS	NS	NS	NS	P<0.029
ME levels	P<0.001	P<0.0001	P<0.025	NS	P<0.0001
EAA levels	P<0.0001	P<0.0001	P<0.0001	NS	P<0.0001

^{pqr}(energy level), ^{wxy}(EAA levels) Values bearing different superscripts differ significantly(P<0.05). NS=Non-significant (P>0.05). The values are means.

Table 4: Protein (g/g gain) and energy (kcal/g gain) efficiency of growing quails at different growth phases.

	% N retention intake	N retention(gm)/100Kcal ME intake	% Ca retention intake	% P retention intake
Interaction effect (ME x EAA)				
2700, 85	47.43	0.577	29.90	34.75
2700, 100	46.18	0.636	34.82	41.52
2700, 115	45.68	0.698	36.21	42.42
2900, 85	49.04	0.559	34.68	41.41
2900, 100	47.15	0.608	38.82	45.11
2900, 115	46.11	0.662	38.15	45.40
3100, 85	50.11	0.534	36.28	41.41
3100, 100	48.12	0.577	41.08	47.18
3100, 115	47.37	0.629	42.97	48.68
Pooled SEM	0.314	0.009	0.723	0.747
Main Effects				
AMEn, kcal/kg				
2700 kcal	46.43^{q}	0.637^{p}	33.65^{r}	39.57^{q}
2900 kcal	47.43^{pq}	0.610^{q}	37.22^{q}	43.98^{p}
3100 kcal	48.53^{p}	0.580^{r}	40.11^{p}	45.76^{p}
EAA levels				
85% AA	48.86^{w}	0.557^{y}	33.62^{x}	39.19^{x}
100% AA	47.15^{x}	0.607^{x}	38.24^{w}	44.61^{w}
115% AA	46.38^{x}	0.663^{w}	39.11^{w}	45.50^{w}
Probability				
ME x EAA	NS	NS	NS	NS
ME levels	P<0.006	P<0.0001	P<0.0001	P<0.0001
EAA levels	P<0.001	P<0.0001	P<0.0001	P<0.0001

^{pqr}(energy level), ^{wxy}(EAA levels) Values bearing different superscripts differ significantly(P<0.05). NS=Non-significant (P>0.05).The values are means.

Table 5: Nitrogen, calcium and phosphorus retention in growing quails at 3rd week of age.

	Foot index	HA-titre	Bursa	spleen	Thymus
Interaction effect (MExEAA)					
2700, 85	0.195	4.50	0.091	0.046	0.150
2700, 100	0.178	4.50	0.112	0.053	0.132
2700, 115	0.200	5.00	0.089	0.052	0.129
2900, 85	0.168	4.25	0.115	0.051	0.132
2900, 100	0.163	5.25	0.088	0.049	0.136
2900, 115	0.245	5.50	0.112	0.051	0.140
3100, 85	0.170	4.25	0.110	0.044	0.143
3100, 100	0.150	4.75	0.079	0.071	0.165
3100, 115	0.238	5.75	0.103	0.059	0.138
Pooled SEM	0.013	0.204	0.004	0.003	0.004
Main Effects					
AMEn, kcal/kg					
2700 kcal	0.191	4.67	0.097	0.050	0.137
2900 kcal	0.192	5.00	0.105	0.050	0.136
3100 kcal	0.186	4.92	0.097	0.058	0.149
EAA levels					
85% AA	0.178	4.33	0.105	0.047	0.142
100% AA	0.163	4.83	0.093	0.058	0.144
115% AA	0.228	5.42	0.101	0.054	0.136
Probability					
ME x EAA	NS	NS	NS	NS	NS
ME levels	NS	NS	NS	NS	NS
EAA levels	NS	NS	NS	NS	NS

NS=Non-significant (P>0.05). The values are means.

Table 6: Cellular and humoral immune-response and relative weight (g/100 g live weight) of immune organs in different dietary treatments.

linearly higher retention (P<0.01) due to increase in ME levels in diet while P retention remains statistically similar in 2900 and 3100 kcal/kg diets. However, both Ca and P retention were higher in higher EAA levels and did not differ between the groups fed 100 and 115% EAA diets.

Immune-response and yield of immune organs

The humoral (SRBC) and cellular (PHA-P) immune responses, and the relative weights (g per 100 g live weight) of immune organs did not differ statistically due to energy, EAA levels or their interaction (Table 6). In an earlier experiment with fixed dietary energy level (2900 kcal/kg), the immune response did not differ due to EAA levels [7]. However, high antibody titre to SRBC in low CP diet in chickens was observed [29]. In contrary, chickens fed diets deficient in amino acids had lower secondary responses to SRBC, a T-dependent antigen [11].

Conclusion

It can be concluded that the optimum level of dietary ME is 2700 kcal/kg with CP 25.83%, lysine 1.49%, methionine 0.58% and threonine 1.17% on dry matter basis during 0–5 weeks of age for gain. However, for optimum feed conversion, the growing quails require diet with ME 3100 kcal/kg with CP 23.23%, lysine 1.30%, methionine 0.50% and threonine 1.02% for 0-5 weeks of age.

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