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EFFECT OF HIGH ENERGY DIET WITH DIFFERENT PROTEIN LEVELS ON THE GROWTH PERFORMANCE AND CARCASS TRAITS OF JAPANESE QUAILS

(With 6 Tables)

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**مدى تأثير عليقه عالية في الطاقة مع مستويات مختلفة من البروتين
على كفاءة الأداء وخواص الذبيحة في طيور السمان**

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أجريت هذه التجربة لدراسة تأثير تغذية عليقة عالية في الطاقة مع مستويات مختلفة من البروتين على كفاءة الأداء وخواص الذبيحة وبعض التغيرات البيوكيميائية في مصل دم طيور السمان لمدة ٤٢ يوم. تم استخدام عدد ٦٠ من كتاكيت السمان في عمر يوم قسمت عشوائيا إلى خمس مجموعات متساوية بكل منها عدد ١٢ كتكوت. غذيت طيور السمان في المجموعات الخمس على علائق عالية في الطاقة (٣٢٠٠ ك كالورى طاقة ممثلة/كجم عليقه) وتحتوي على ١٨، ٢٠، ٢٢، ٢٤، ٢٦ % بروتين خام. قدرت المقاييس الخاصة بتقييم كفاءة الأداء وخواص الذبيحة وبعض التغيرات البيوكيميائية وقد تم التوصل إلى النتائج الآتية: سجلت المجموعتين الثالثة والرابعة المغذاة على علائق بها مستوى عالي من الطاقة وتحتوي على ٢٢، ٢٤ % بروتين خام احسن نتائج وأعلى معدلات في النمو (١٨٨ & ١٨٩,٤ جم) وأدى ذلك إلى تحسن في معدل التحويل الغذائي (٢,٧١ & ٢,٨٤) بالمقارنة بالمجموعات المختبرة الأخرى. لوحظ أن مستوى بروتين العليقة أثر على معدل التصافي حيث سجلت طيور السمان في كل من المجموعتين الرابعة والخامسة أعلى معدل للتصافي (٧٣,٢١ & ٧٣,٠٦ %) مقارنة بالمجموعات الثلاثة الأولى التي سجلت اقل المعدلات (٦٨,١٢، ٦٨,٤٥، ٦٨,١٩ %) بالترتيب في حين لا توجد فروق معنوية بين المجموعات المختبرة في الصفات الأخرى للذبيحة. زاد التركيز الكلي لحامض اليوريك والكالسيوم والفوسفور الغير عضوي في مصل دم طيور السمان المغذاة على علائق بها نسب عالية من البروتين في حين لم يتأثر تركيز كل من الدهون الثلاثية والكوليسترول والسكر في الدم باختلاف نسبة البروتين في العليقة. نستخلص من هذه الدراسة أن تغذية طيور السمان على عليقه تحتوي على ٣٢٠٠ ك كالورى طاقة ممثلة/كجم عليقة مع نسبة ٢٢ % بروتين خام أدى إلى تحسن كفاءة الأداء ومعدل النمو ومعامل التحويل الغذائي بالإضافة إلى تحسين الجدوى الاقتصادية.

SUMMARY

The chick performance, carcass traits and some blood biochemical parameters of Japanese quails fed high energy diet containing different

protein levels were studied for 42 days. Sixty quail chicks at hatch (average weight 7.02 g \pm 0.12) were randomly distributed into five experimental groups (12 chicks/each). Quails in the five groups were fed ad libitum on the respective isocaloric experimental diets (3200kcal ME/kg diet) containing five dietary protein levels (18, 20, 22, 24, 26 %). The growth performance, carcass characteristics and some blood biochemical parameters were assessed. The results showed that, quails fed on high energy diets containing 22, 24 % protein in the third and fourth groups achieved significantly ($P < 0.05$) better results, and recorded highest gains (188.0 & 189.4 g, respectively) with lowest feed intake. Highest weight gain averages with greatest values of feed conversion (2.84 & 2.71) were recorded in the third and fourth groups of quails, respectively. Dressed carcass as a percentage of live body weight was maximum in quails offered high protein diets in the fourth and fifth groups (73.21 & 73.06%), while the lowest were recorded in the first three groups fed low protein diets (68.12, 68.45 & 68.19 %, respectively). Dietary protein levels had no significant ($P < 0.05$) effect on the internal organ weights. Uric acid, calcium and inorganic phosphorous were increased significantly ($P < 0.05$) with increasing dietary protein levels, while had no significant effect on serum triglycerides, cholesterol and glucose. It could be concluded that, quails fed on diet having 3200kcal ME/kg with 22 % crude protein, supplemented with limiting amino acids, recorded the best results in weight gain and feed conversion, in addition to economical feed efficiency.

Key words: *Quails, performance, carcass traits, protein levels*

INTRODUCTION

Japanese quails (*Coturnix coturnix japonica*) 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 chickens and ducks with almost the same profit margin (Kaur *et al.*, 2008). 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 make up to exploit production potentiality. The protein quantity and quality are the main factor limiting the animal performance. Traditionally, the levels of crude protein and total essential amino acids are criteria for least-cost feed formulation for monogastrics. In recent years, the model for ideal protein (Baker & Han, 1994; Emmert & Baker, 1997; Baker, 2003) is more widely applied by the poultry nutritionists. Establishing requirements of limiting amino acids and supplementing those accordingly in diet through their synthetic form matching the requirements provides scope to reduce dietary protein content. In low protein maize-soybean meal based diets of growing Japanese quails, methionine and lysine are the most limiting amino acids. Generally the crude protein content in diets of growing quails ranges from 24 to 27 % that can be reduced through supplementation of the limiting amino acids as their synthetic forms (Weber & Ried, 1967; Vohra & Roudybush, 1971; NRC, 1994; Baldini *et al.*, 1995; Shrivastava & Panda, 1999). Protein level in the ration of quails is considered as an important factor for the efficient growth but recent studies have shown that besides the protein level, the amino acid profile of feed is more important. The total protein needed for growth actually is based upon the requirement for the dietary essential amino acids and the amount of nitrogen necessary for the biosynthesis of dietary non essential amino acids in the body (Riaz & Alam, 2006). The main factors determining the production cost of quails are growth rate and feed cost per unit of growth. Feed contributes to about 60-70 % of the total cost of bird production (Vohra, 1993). One of the most expensive major nutrients in a poultry diet is its energy content. Energy alone contributes to about 70 % of the total cost of poultry diets (Skinner *et al.*, 1992). The recommended energy level for growing quail was 2900 kcal/kg diet (NRC, 1994). High-energy broiler diets are recommended to achieve maximum weight gain and optimal feed conversion ratio (Saleh *et al.*, 2004). Indeed, feed efficiency is influenced by changes in dietary energy concentration in two partially dependent pathways. Firstly, as dietary energy increases, less feed is taken in to satisfy the energy need. Secondly, growth rate is promoted by increasing levels of dietary energy (Palvnik *et al.*, 1997 and Duplecz *et al.*, 1999). The present study was conducted to evaluate the effect of high-energy diet containing different levels of crude protein on the growth performance, carcass traits and some blood constituents in Japanese quails.

MATERIALS and METHODS

Experimental chicks and housing:

Sixty quail chicks at hatch (average weight 7.02 g ± 0.12) were randomly distributed into five experimental groups (12 chicks/each), housed in battery cages and kept under similar environmental and managerial conditions during the experimental period. Temperature was set at 35°C during the first week and gradually reduced by 2.5°C per week to reach 25°C at 6th weeks of age. Each cage was equipped with feed and conical water troughs. This experiment was carried out at Faculty of Veterinary Medicine, Assiut University.

Diets and Feeding:

Five isocaloric experimental diets (3200 kcal ME/kg) included corn-soybean meal basal were formulated to contain five dietary protein levels (18, 20, 22, 24, 26 %) and fed to the quails throughout the experimental period which extended for 6 weeks. Synthetic methionine and lysine were used to balance their contents in the diets. The physical and chemical composition of the experimental diets is shown in Table 1.

Table 1: Physical and chemical composition of the experimental diets

Diets Composition	% CP				
	18	20	22	24	26
Physical composition (%):					
Corn, ground	61.60	54.05	46.60	39.30	32.65
Soybean meal	27.65	34.10	40.54	46.79	52.64
Vegetable oil	05.73	07.10	08.40	09.70	10.80
Ground limestone	02.30	02.30	02.25	02.20	02.10
Sod monobasic PO ₄	01.61	01.52	01.45	01.37	01.20
Common salt	00.30	00.30	00.30	00.30	00.30
Premix*	00.20	00.20	00.20	00.20	00.20
Methionine	00.22	00.19	00.17	00.14	00.11
Lysine	00.39	00.24	00.09
Chemical composition (%)					
Dry matter	89.67	89.83	89.98	90.11	90.23
Crude protein	18.00	20.00	22.00	24.00	26.00
ME (Kcal/kg diet)	3200	3200	3200	3200	3200
Cal/protein ratio	178.0	160.0	145.0	133.0	123.0
Ether extract	08.26	09.43	10.59	11.56	12.46
Crude fiber	03.20	03.57	03.86	04.13	04.40
Calcium	00.90	00.92	00.91	00.91	00.90
Total phosphorus	00.71	00.70	00.71	00.71	00.70
Methionine	00.50	00.50	00.50	00.50	00.50
Lysine	01.30	01.30	01.30	01.36	01.50

* Each Kg of premix contained vit. A 8,000,000 IU; vit. D₃ 1,600,000 IU; vit. E 7 mg; vit. K₃ 1.5 mg; vit. B₁ 1.0 mg; vit. B₂ 3.5 mg; vit. B₆ 1.0 mg; vit. B₁₂ 10.0 mg; Nicotinic acid 20.0 mg; Pantothenic acid 7.0 mg; Folic acid 1,000,000 IU; Biotin 40,000 IU; Choline chloride 350.0 mg; Mn 40.0 mg; I 0.3 mg; Co 0.75 mg; Zn 40.0 mg; Cu 3.0 mg; Fe 25.0 mg; Se 0.1 mg; Ethoxyquin 5.0 mg and Ascorbic acid 500 mg.

The leg-banded quails in the five groups were fed ad libitum on the respective diets in mash form and given free access to water throughout the experimental period.

Measurements:

Body weight development (g) and feed intake (g) of quails were recorded on 7-day interval until 42 days of age. Mortality rate was also monitored on group basis. Feed conversion ratio (g feed/g gain), protein efficiency (g protein intake/g gain) and energy efficiency (kcal ME intake/g gain) were calculated every other week. The proximate analysis of the experimental feeds was performed using procedures detailed by the Official Analytical Chemistry (AOAC, 1990).

Carcass traits:

At the end of the experiment three birds from each group were slaughtered after fasting overnight, processed and the weight of carcass, liver, intestine, proventriculus, gizzard and heart were recorded. Dressed carcass is the weight of the slaughtered birds after removal of feathers, head and feet but including all edible offals. The organ weights were expressed as relative weight proportionate to pre-slaughter live body weight.

Blood samples:

Blood samples were collected from each bird. Serum was separated by centrifugation at 3000 rpm for 10 minutes and stored at -18°C till further analysis. Total serum protein, total lipids, total cholesterol, glucose and uric acid were determined using standard kits supplied by Bio-Merieux (Baines/France). Inorganic phosphorous was determined in serum according to the method of Yee (1968) at 650 nm, while serum calcium was determined after the method described by Lehman & Henry (1984) at 550 nm by using spectrophotometer and test kits supplied by Sentinel Chemistry Co. (Milan, Italy).

Economical evaluation:

Total feed cost, total production cost, price of body weight, net revenue and economical feed efficiency were calculated.

Statistical analysis:

Statistical analysis of the obtained data was carried out according to procedures of completely random design SAS (1995).

RESULTS

Body weight development and mortality rate of the experimental chicks fed high-energy diets containing different levels of protein are shown in Table 2. Groups fed on 22 & 24 % crude protein were recorded highest values in body weight (194.9 & 196.6 g/bird) compared with other treated groups.

Table 2: Body weight development (g) and mortality rate (%) of the Japanese quails.

Weeks	Protein levels (%)				
	18	20	22	24	26
0	7.12±0.06	6.94±0.03	6.95±0.05	7.22±0.07	6.85±0.06
1	23.30±1.32 ^{b*}	24.10±1.19 ^b	29.40±1.86 ^a	31.10±1.66 ^a	26.20±1.43 ^{ab}
2	42.30±2.36 ^b	43.90±2.95 ^b	51.00±3.14 ^a	53.70±3.46 ^a	50.80±3.62 ^a
3	71.80±3.18 ^b	74.80±5.12 ^b	81.60±4.86 ^a	89.20±5.10 ^a	85.60±5.17 ^a
4	121.0±3.68 ^b	125.3±5.26 ^b	133.8±6.09 ^{ab}	139.8±6.23 ^a	127.3±5.78 ^b
5	153.7±5.44 ^c	160.8±6.12 ^b	171.8±5.11 ^a	174.3±4.32 ^a	165.4±5.11 ^b
6	176.3±6.28 ^c	185.6±7.10 ^b	194.9±4.87 ^a	196.6±6.09 ^a	184.6±4.82 ^b

* Figures in the same row having the same superscripts are not significantly different (($P < 0.05$))

The performance characteristics of quails include feed consumption, body weight gain, feed conversion ratio, energy and protein efficiency are cleared in Table 3. Feed intake was increased in group fed on 18 % protein diet (575g/quail) and decreased gradually till reached 509 g/quail in the group fed high protein diet (26%). Weight gain was increased with chick groups fed on 22 & 24 % protein (188.0 & 189.4 g)/bird), while the low protein diet (18%) recorded the lowest gain (169.2g/bird). Protein efficiency ratio was increased with group fed high level of protein (26%), while energy efficiency ratio increased with low level of protein (18%) compared with other treated groups.

Table 3: Chick performance of Japanese quails fed different levels of protein

Item	Protein levels (%)				
	18	20	22	24	26
Feed intake (g)					
0-2 week	93.60	87.70	93.30	99.50	98.70
2-4 week	254.2	232.1	232.3	216.3	198.8
4-6 week	227.2	220.9	207.0	205.0	211.2
0-6 week	575.0	541.0	533.0	521.0	509.0
Weight gain (g)					
0-2 week	35.18±2.14 ^{b*}	36.96±1.17 ^b	44.05±2.28 ^a	46.48±1.92 ^a	43.95±2.08 ^a
2-4 week	78.70±3.72 ^b	81.4±2.94 ^{ab}	82.8±3.16 ^{ab}	86.10±3.45 ^a	76.50±2.16 ^b
4-6 week	55.30±3.11	60.30±2.35	61.15±2.68	56.80±2.29	57.30±2.26
0-6 week	169.2±5.23 ^c	178.7±4.12 ^b	188.0±5.22 ^a	189.4±3.46 ^a	177.8±3.78 ^b
Feed conversion					
0-2 week	2.66	2.36	2.11	2.14	2.26
2-4 week	3.14	2.82	2.75	2.47	2.58
4-6 week	4.17	3.73	3.50	3.53	3.82
0-6 week	3.32	2.97	2.84	2.71	2.88
Protein efficiency (g protein intake/g gain)					
0-2 week	0.48	0.47	0.47	0.51	0.58
2-4 week	0.58	0.57	0.62	0.60	0.68
4-6 week	0.74	0.75	0.75	0.87	0.76
0-6 week	0.61	0.61	0.62	0.66	0.74
Energy efficiency (kcal ME intake/g gain)					
0-2 week	8.51	7.60	6.78	6.85	7.19
2-4 week	10.34	9.12	8.98	8.04	8.28
4-6 week	13.15	11.67	10.84	11.54	11.78
0-6 week	10.88	9.69	9.07	8.80	9.16

*Figures in the same row having the same superscripts are not significantly different (P<0.05).

Carcass traits including carcass weight, dressing percentages, weights of internal organs proportionate to pre-slaughter live body weight are revealed in Table 4. Level of protein had effect on dressing percentage which increased with high protein level (24 & 26%) in comparison with other groups. Dressed carcass as a percentage of live body weight was maximum in quails offered high protein diets (24 & 26%) in the fourth and fifth groups (73.21 & 73.06%). The lowest dressed carcass percentages were recorded in the first three groups fed low protein diets (68.12, 68.45 and 68.19 %, respectively).

Table 4: Carcass traits of Japanese quails fed different levels of protein

Parameters	Protein levels (%)				
	18	20	22	24	26
LBW (g)	176.3±6.65 ^{a*}	185.6±7.36 ^b	194.9±5.97 ^a	196.6±7.12 ^a	184.6±5.86 ^b
Dressed carcass weight (g)	120.1±5.18 ^c	127.0±6.25 ^b	132.9±4.72 ^b	143.9±5.49 ^a	134.9±4.94 ^b
Dressing (%)	68.12±0.27 ^b	68.45±0.19 ^b	68.19±0.38 ^b	73.21±0.28 ^a	73.06±0.20 ^c
Intestine (%)	5.76±0.06	5.63±0.05	5.92±0.05	6.15±0.09	6.12±0.07
Proventriculus (%)	0.311±.003	0.319±.002	0.331±.005	0.348±.003	0.356±.004
Gizzard, %	1.82±0.06	1.82±0.03	1.87±0.07	1.93±0.04	1.95±0.06
Liver, %	2.13±0.03	2.17±0.05	2.16±0.04	2.39±0.03	2.20±0.05
Heart, %	1.25±0.02	1.28±0.03	1.32±0.05	1.36±0.04	1.36±0.03

* Figures in the same row having the same superscripts are not significantly different (P<0.05)

Serum biochemical parameters (total serum protein, triglycerides, total cholesterol, glucose, uric acid, calcium and inorganic phosphorous are presented in Table 5. Uric acid, calcium and phosphorous levels in the serum of quails were increased with increasing level of protein.

Table 5: Serum biochemical parameters in Japanese quails fed different levels of protein.

Parameters	Protein levels (%)				
	18	20	22	24	26
Total protein, g/l	27.7±0.52	28.32±0.16	29.70±0.32	30.4±0.12	30.6±0.80
Triglycerides, mmol/l	7.32±1.6	6.24±1.11	7.12±0.58	6.78±0.47	5.92±0.37
Cholesterol, mmol/l	6.12±0.24	5.98±0.37	6.33±0.21	5.96±0.46	6.03±0.52
Glucose, mmol/l	16.23±0.6	15.99±0.57	17.22±0.40	16.07±0.32	16.11±0.56
Uric acid, mmol/l	0.39±0.03 ^b	0.35±0.05 ^b	0.45±0.03 ^a	0.52±0.06 ^a	0.47±0.03 ^a
Calcium, mmol/l	1.92±0.18 ^b	2.01±0.27 ^b	2.39±0.21 ^a	2.35±0.18 ^a	2.65±0.28 ^a
Phosphorus, mmol/l	1.29±0.06 ^b	1.38±0.13 ^b	1.79±0.08 ^a	1.68±0.11 ^a	1.65±0.07 ^a

* Figures in the same row having the same superscripts are not significantly different (P<0.05)

Economical evaluation of quail performance in the different experimental groups are presented in Tables 6. The economical evaluation of quail performance fed diets containing 22 and 24 % protein had more economic feed efficiency (82.1 & 83.2%) compared with the other experimental groups (62.9, 77.7, 65.5%).

Table 6: Economical evaluation of chick performance in the different experimental groups

Parameters	Protein levels (%)				
	18	20	22	24	26
Body weight (g)	176	186	192	197	185
Price of feed (LE/Kg)	1.83	1.90	1.98	2.06	2.15
Feed intake (g)	575	541	533	520	510
Total feed cost (LE)	1.05	1.03	1.06	1.07	1.10
Total production cost (LE)	1.45	1.43	1.46	1.47	1.50
Price of body weight	2.11	2.23	2.30	2.36	2.22
Net revenue, LE	0.66	0.80	0.87	0.89	0.72
Economic feed efficiency	62.9	77.7	82.1	83.2	65.5
Relative economic feed efficiency	100	124	131	132	104

DISCUSSION

Growth performance:

There was significant ($P < 0.05$) difference in the body weight and weight gain between the different experimental groups and the chick groups fed on the dietary protein levels of 18, 20 & 26 % had significant the lower values. The body weight and weight gain of the groups fed 22 & 24 % protein levels increased significantly ($P < 0.05$) as compared to the other groups. These agreed with that found by Ozek et al. (2003) and Ozek (2006) who reported progressive growth rates with increasing dietary protein concentration. Satisfactory growth rates were obtained between 24 and 27 % crude protein levels as found in the earlier studies by (Weber & Ried, 1967; Vohra & Roudybush, 1971; NRC, 1994; Baldini *et al.*, 1995; Shrivastava & Panda, 1999). Poultry fed commercial diet with a reduction of 2 units of protein perform as well as better than poultry fed diets containing higher protein levels if the low protein diets are supplemented with the most limiting amino acids (Han *et al.*, 1992; Moran *et al.*, 1992 and Lippens *et al.*, 1997). Concerning the feed intake, there were no differences between the experimental groups during the first two weeks of age, while in the last four weeks of the experiment, feed consumption was clearly reduced in groups fed diets containing 24 & 26 % protein. For the whole period (0-6 weeks), the lowest and highest feed consumption was found in quails fed the diets containing 26 and 18 % protein, respectively. These results of feed intake are supported by the work of Ozek *et al.* (2003) and Ozek (2006) who reported that quails fed a diet containing 20% protein consumed significantly ($p < 0.01$) more feed than others fed on 22, 24, 26 and 28% dietary protein. In contrast, Woodard *et al.* (1977) reported that there

was linear relationship between feed consumption of pheasant and dietary protein content. The protein content of the diet had a significant ($P < 0.05$) effect on the feed conversion ratio for the 0-2, 2-4 and 4-6 weeks periods. The feed and energy efficiency of the first group fed low protein diet (18%) was significantly ($P < 0.05$) poorer than other groups fed high protein diets at the same period. Angulo *et al.* (1993), Djouvinov & Mihailov (2005), Hashiguchi & Yamamoto (2006) and Tarasewicz *et al.* (2006) found that total body weight gain and feed conversion were not affected by dietary protein levels in growing quails. On the other hand, Annaka *et al.* (1993), Marks (1993) and Hashiguchi *et al.* (1998) indicated that body weight gain decreased linearly with low dietary protein level in quails. Energy efficiency (kcal ME intake/g gain) was enhanced in the third and fourth groups (9.07 & 8.8) fed on 22 & 24% protein. Improvement of energy efficiency resulted in an increasing of body weight gain and feed conversion in quails in these groups. Protein efficiency calculated as g protein intake/g gain was similar amongst the quail chicks fed different protein levels and group fed 26 % protein tended to be more optimally efficient.

Carcass traits:

The level of dietary protein significantly affect the dressing percentages and the groups fed on the high dietary protein (24 & 26 %) recorded the highest values. In this respect, Kul *et al.* (2006) and Seker *et al.* (2009) found that the dressing percentages of Japanese quails slaughtered on 45 days old were 67.23 and 70.67 %, respectively. Among the internal organ weights, there were no significant difference among groups in weights of intestine, proventriculus, gizzard, liver and heart. The internal organ weights were slightly highest in the fourth and fifth groups fed high protein diets (24 & 26 %) compared with groups fed low protein diets (18, 20, 22 %). Similar results have been reported by Adeyemo, (2000) who found that increasing CP level in the diets of pullets improved dressing percentage. Also Aggoor *et al.* (2000) and Ismail *et al.* (2006) found that high energy diet produced carcass of higher dressing percentage in quails, whilst had no effect on the internal organs. On the contrary Kassim & Suwanpradit (1996) found that increasing dietary energy or protein did not affect dressing and internal organ percentages.

Serum biochemical parameters:

Serum biochemical values revealed that uric acid, calcium and inorganic phosphorous increased significantly ($P < 0.05$) with increasing dietary protein levels. A direct relationship between uric acid and dietary

protein concentration agreed with Belay & Teeter (1996) and Odunsi *et al.* (1999). Different protein levels had no significant ($P < 0.05$) effect on serum triglycerides, cholesterol and glucose of Japanese quails. This may be due to that quails in all groups fed on the same diet have 3200kcal ME/kg diet.

Economical evaluation:

The data of economical evaluation of quail performance revealed that feeding diets containing 22 and 24 % protein had improved economic feed efficiency compared with other experimental groups. Priority of economical feed efficiency in the third and fourth groups may be due to better feed and energy utilization and conversion.

It could be concluded that, quails fed on diet containing 3200kcal ME/kg with 22 % crude protein, supplemented with limiting amino acids, recorded the best results in weight gain, feed conversion, in addition to economical feed efficiency.

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