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Research Article
Effect of Dietary Energy and Protein on Growth Performance and Carcass Traits of Mamourah Cockerels

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Abstract
Background: Dietary energy and protein are the most important determinants of least-cost feed formulation. So, the concurrent increase in feed prices and demand on animal proteins for humans necessitate an urgent need to define the optimal dietary protein and energy levels for growing poultry. **Materials and Methods:** A study with a factorial arrangement of treatments (2×3) was done to investigate the effects of two dietary protein levels (18 and 20% CP), each with three metabolizable energy levels (3100, 3000 and 2900 kcal ME kg^{-1}) on growth performance, nutrient digestibility, carcass traits and blood parameters of Mamourah cockerels. One hundred eighty birds were randomly allocated to 6 experimental groups, each with three replications and kept in floor pens in an open-sided house. Thus, six diets were formulated and fed to the experimental birds and managed similarly from 6-14 weeks of age. **Results:** Feeding the 20% CP diets throughout the experiment positively affected feed intake and weight gain of cockerels and negatively affected protein efficiency ratio and economic efficiency compared with the 18% CP diets but feed conversion ratio and efficiency of energy utilization were not affected. Conversely, birds fed the 18% protein diets exhibited significantly higher digestibility of dry matter, organic matter, crude protein and ether extract than those fed the 20% protein diets but digestibility of other nutrients were not altered. Dietary protein level had no effect on almost all carcass traits and blood parameters examined. However, decreasing dietary ME level did not affect feed intake or nutrient digestibility but positively affected growth performance. Carcass traits were not affected by decreasing dietary ME level but when it reached 2900 kcal kg^{-1} percent abdominal fat was significantly reduced and the percentages of carcass yield, total edible parts and liver were negatively affected. Dietary energy level had no effect on plasma constituents of birds but cholesterol concentration decreased when ME level reduced to 3000 or 2900 kcal kg^{-1}. The interactions between dietary protein and energy levels were not significant for most variables examined. **Conclusion:** Taking the economic aspect into account, optimal dietary CP and ME levels for growing Mamourah cockerels are suggested to be 20% CP and 3000 kcal kg^{-1}.

Key words: Dietary energy, protein, growth and carcass traits, Mamourah cockerels, metabolizable energy

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In most developing countries, including Egypt, there is an urgent need for improving animal and poultry production to meet the ongoing demand on animal protein. Nowadays, the prices of animal proteins are progressively increased due to two main reasons, the first is the gradual increase in human population and the second is related to the high cost of production. One of possible solutions of this problem is activating the ignored sector of poultry production by smallholders and rural poor poultry keepers. On the other hand, the price of poultry meat, particularly chickens is considerably lower than other types of meat (veal, beef and mutton) produced by cattle, buffalos, sheep and goats.

In Egypt, Mamourah is one of the modern developed strains of native chickens for the production of eggs and meat. Mamourah chickens were produced by crossing Alexandria cocks with Dokki-4 hens[1]. Mamourah cockerels are primarily raised as sires for the breeder hens to produce the hatching eggs. These Mamourah cockerels (or cocks) can also be kept for meat production. For Egyptians, there is a general perspective that the meat of native chickens is perceived to be tastier than that of their exotic counterparts. Thus, the price of live native chicken at the Egyptian market is considerably more than that of the commercial broiler chicks, suggesting a potential favorable market for keeping the native chickens, particularly for smallholders and rural poor poultry keepers.

On the other hand, there is no doubt that dietary protein and energy requirements of the growing poultry are widely variable due to many factors such as species, genotype (breed or strain), gender, growth phase, environmental temperature, housing system, plane of nutrition, diet nutrient digestibility, amino acid bioavailability, dietary amino acid balance and type and level of dietary fat[2,3]. Thus, there is some difficulty in the choice of optimal dietary crude protein and energy levels for the growing chickens that match their actual requirements in order to achieve optimal growth, superior feed conversion and the best economic efficiency and profitability[4,5]. In addition, limited information are available on the recommended dietary crude protein and energy levels for the Egyptian growing chickens. For economical and environmental considerations, however, there is a tendency among some poultry nutritionists and producers to lower the dietary protein and/or energy levels for growing poultry below the recommendations and to supplement their diets with the most critical essential amino acids methionine and lysine. The present study was undertaken, to evaluate the effects of dietary protein and energy interaction on growth performance, nutrient digestibility, carcass traits and some blood profiles of Mamourah cockerels.

MATERIALS AND METHODS

The present study was performed at El-Serw Poultry Research Station, Animal Production Research Institute, Ministry of Agriculture, Egypt. The feeding trial was carried out during the period from May-July, 2014. The response of male Mamourah chickens to feeding the experimental diets was evaluated as growth performance, nutrient digestibility, carcass traits and some blood parameters.

A total number of 180, 6 weeks old birds of male Mamourah chickens were used in this study. The birds were randomly allocated to six equal experimental groups, each with three replications and kept in floor pens (10 birds per pen measuring 2.5×1.5 m) within an open-sided laying house. Six experimental diets containing three Metabolizable Energy (ME) levels (3100, 3000 and 2900 kcal ME kg^{-1} which were referred to as high, intermediate and low energy diets) and two Crude Protein (CP) levels (20 and 18% CP) were formulated and used. The proposed dietary ME levels for the local Mamourah cockerels were intended to define the optimal level of dietary energy which can optimize their growth performance and maintain the best economic efficiency and feed conversion ratio. The experimental groups of birds were fed their respective experimental diets from 6-14 weeks of age. All birds were exposed to a daily photoperiod of 22 h light:2 h darkness. Birds had free access to feed and water and managed similarly throughout the experimental period. Composition and chemical analysis of the experimental diets are given in Table 1.

Feed intake and live body weight for each replicate group of birds were determined at the beginning of experiment and on a weekly basis thereafter. Thus, body weight gain, feed conversion ratio (g feed:g gain), efficiency of energy utilization (kcal ME consumed:g gain) and protein efficiency ratio (g CP eaten:g gain) were calculated throughout the experiment (6-14 weeks of age). The Economic Efficiency of Feeding (EEF) was also calculated for the whole experimental period as follows:

$$\text{EEF} = \frac{\text{Sale price per total gain} - \text{Total feed cost}}{\text{Total feed cost}} \times 100$$

Mortality of birds was monitored and recorded daily.

At 13 weeks of age, three Mamourah cockerels were randomly selected from each treatment, around its average body weight and kept at individual cages, equipped with feeders and drinkers and underneath galvanized metal trays for droppings collection. Each group of birds were fed with its respective diet for a 3 days pretest adaptation period, followed by a 3 days test period in which daily feed intake and total

Table 1: Ingredients and chemical composition of the experimental diets

	Grower diets of Mamourah cockerels (6-14 weeks of age)					
Ingredients (%)	1	2	3	4	5	6
Yellow corn, ground	69.45	66.75	64.25	73.47	71.00	67.92
Soybean meal (44% CP)	15.00	22.70	30.00	14.30	21.12	27.00
Corn gluten meal (62% CP)	11.50	6.60	2.00	8.10	3.80	0.00
Wheat bran	0.00	0.00	0.00	0.00	0.00	1.20
Dicalcium phosphate	1.50	1.50	1.50	1.50	1.50	1.50
Limestone	1.50	1.50	1.50	1.50	1.50	1.50
Sodium chloride	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin Min. Premix[§]	0.30	0.30	0.30	0.30	0.30	0.30
L-lysine-HCl	0.40	0.25	0.05	0.43	0.33	0.10
DL-methionine	0.05	0.10	0.10	0.10	0.15	0.18
Total	100.00	100.00	100.00	100.00	100.00	100.00
Cost per kg diet (LE)	3.36	3.34	3.29	3.22	3.21	3.16
Determined analysis (As DM basis), (%)[7]						
DM	91.00	90.80	90.85	90.90	91.00	90.80
OM	83.53	83.20	83.47	83.75	83.42	83.31
Crude protein	22.02	22.08	22.03	19.82	19.87	19.87
Ether extract	3.35	3.17	3.00	3.42	3.25	3.12
Crude fiber	3.00	3.46	3.90	2.99	3.40	3.88
Ash	7.47	7.60	7.38	7.15	7.58	7.49
NFE	67.16	63.69	63.69	66.62	65.90	65.64

§: Each kg premix contains: Vitamin A: 4,000,000 IU, Vitamin D3: 800,000 IU, Vitamin E: 4 g, Vitamin K: 400 mg, Vitamin B1: 400 mg, Vitamin B2: 1.6 g, Vitamin B6: 600 mg, Vitamin B12: 4 g, Pantothenic acid: 4 g, Niacin: 8 g, Folic acid: 400 mg, Biotin: 20 mg, Choline: 200 g, Fe: 12 g, Mn: 16 g, Zn: 189 mg, Cu: 1.2 g, Se: 40 mg, Co: 40 mg and I: 120 mg

droppings voided were quantitatively determined. Daily droppings voided for each three cockerels per treatment were pooled, dried, ground and stored until analysis. Daily samples of droppings per treatment were considered as a replication when these data were subjected to statistical analysis. Fractions of fecal and urinary nitrogen in the droppings were chemically separated. The percentage of urinary organic matter was calculated by multiplying the percentage of urinary nitrogen by 2.62, according to Abou-Raya and Galal[6]. The experimental diets and dried droppings were analyzed for dry matter, crude protein, ether extract, crude fiber, ash by using the official methods, described by AOAC[7], accordingly, nitrogen-free extract was calculated. The digestibility of dry matter, organic matter, crude protein, crude fiber, ether extract and nitrogen-free extract and the retention rates of N and ash were estimated.

At 14 weeks of age, 6 birds of each dietary treatment (whose body weight approached the average weight of its respective treatment) were chosen for the evaluation of the effect of dietary treatments on carcass traits. Prior to slaughter the birds were fasted for 18 h. The selected birds were individually weighed and immediately killed by cutting their jugular veins with a sharp knife according to the Islamic method of sacrifice. After complete bleeding, their carcasses were scalded, feather-plucked and then eviscerated. Procedures of evisceration and excising the abdominal fat were performed on a hot carcass basis. The weight of abdominal fat (AF, the adipose tissues surrounding the gizzard and bursa of fabricius and those adjacent to the cloaca) was determined. The individual weights of carcass yield and edible organs (giblets, i.e., heart, liver without gall bladder and skinned empty gizzard) were also recorded. Total edible parts were estimated as carcass yield plus giblets. All carcass traits measurements were expressed as percent of live body weight at slaughter.

At the end of experiment, blood samples were collected from the jugular veins of birds during slaughtering into heparinized tubes. Blood plasma was separated by centrifugation at 4000 rpm for 10 min. Plasma concentrations of total protein, albumin, glucose, cholesterol and triglycerides were determined using commercial kits, according to the methods described by the researchers cited, respectively[8-12]. Blood plasma globulin level was estimated as plasma total protein minus that of albumin, neglecting the fibrinogen content of blood plasma.

A completely randomized design, in a factorial arrangement of treatments (3×2), three dietary ME levels (3100, 3000 and 2900 kcal kg^{-1}) and two dietary CP levels (20 and 18%), was used. The statistical processing of data was made by using two-way analysis of variance by means of the Statistical Analysis System SAS[13]. The significant main effects of dietary ME and CP levels were separated at $p<0.05$ by Duncan's new multiple range test[14].

RESULTS AND DISCUSSION

Growth performance of Mamourah cockerels: It is interesting to note that no deaths or morbidity of Mamourah cockerels were occurred throughout this study. Therefore, data on mortality rate were not tabulated here.

Effect of dietary protein level: Growth performance criteria of Mamourah cockerels as influenced by dietary protein and energy levels from 6-14 weeks of age are presented in Table 2. These results show that birds fed the diets containing 20% protein during the whole experimental period exhibited significantly higher ($p \leq 0.01$) final live body weight but the protein efficiency ratio was negatively affected compared with those fed the 18% protein diets, regardless of dietary energy level. Similarly, total feed intake and total body weight gain of Mamourah cockerels significantly increased ($p \leq 0.05$) by rising the dietary CP level from 18-20% but feed conversion ratio and efficiency of energy utilization were not affected. On the other hand, birds fed the diets containing 18% protein displayed significantly better ($p \leq 0.05$) economic efficiency of feeding than those fed the 20% protein diets. The superior growth rate of birds fed the diets containing 20% protein to those fed the 18%-protein diets can be attributed mainly to the higher feed intake of the former than the latter, since the efficiency of energy utilization of both were approximately the same (Table 2). The lack of effect of dietary protein level on feed conversion ratio is primarily attributable to the fact that both feed intake and body weight gain responded in the same direction. Again as dietary protein increased, the amount of protein eaten per unit of weight gain increased, while the amount of ME consumed per unit of gain was unchanged. This means that neither the efficiency of energy utilization nor protein efficiency ratio had a role in the improved growth performance for birds fed the high dietary protein level (20% CP).

The increased final live body weight and body weight gain of Mamourah cockerels due to increasing dietary protein level from 18-20%, observed in the present study is in harmony with those of Miah *et al.*[5], who evaluated the growth performance of Bangladeshi desi chicks as affected by feeding diets differing in protein levels (11.42, 15.33, 17.20 and 19.10%) from 12-22 weeks of age. They found that body weight and weight gain of birds fed the intermediate-protein diet (17.20% CP) were significantly higher than those of other dietary treatments. The present results harmonize also with those of Malomo *et al.*[15], who found that feed intake and weight gain of broilers during the fattening period (0-6 weeks old) were significantly depressed as the dietary crude protein decreased from 22-16%. Our results agree also with the findings of Golian *et al.*[16], who reported that body weight of broiler chicks significantly increased as dietary protein level increased during the whole experimental period (5-35 days of age).

The improved protein efficiency ratio for birds fed the diets containing 18% protein compared with those fed the

Table 2: Effect of dietary protein and energy levels on growth performance of Mamourah cockerels from 6-14 weeks of age

Main effects	Final LBW (g)	Total BWG (g)	Total FI (g)	FCR (g feed:g gain)	PER (g CP eaten:g gain)	EEU (kcal ME eaten:g gain)	EEF (%)
CP level (A) (%)							
20 (A1)	1656[a]	963[a]	3732[a]	3.883	0.778[b]	11.67	39.48[b]
18 (A2)	1577[b]	901[b]	3478[b]	3.875	0.699[a]	11.66	46.16[a]
SEM	18.37	16.81	64.83	0.057	0.011	0.17	2.11
Significance	**	*	*	NS	**	NS	*
ME level (B) (kcal kg^{-1})							
3100 (B1)	1546[b]	869[b]	3604	4.148[b]	0.789[b]	12.87[b]	32.11[b]
3000 (B2)	1664[a]	972[a]	3574	3.684[a]	0.702[a]	11.07[a]	49.58[a]
2900 (B3)	1640[a]	955[a]	3637	3.806[a]	0.725[a]	11.05[a]	46.78[a]
SEM	22.50	20.58	79.42	0.070	0.014	0.21	2.58
Significance	**	**	NS	**	**	**	**
AB interactions							
A1B1	1597	903	3705	4.102	0.822	12.74	30.44
A1B2	1680	988	3626	3.673	0.737	11.02	46.82
A1B3	1690	998	3866	3.874	0.775	11.24	41.19
A2B1	1494	836	3504	4.193	0.756	13.00	33.78
A2B2	1649	957	3523	3.694	0.668	11.12	52.34
A2B3	1589	912	3409	3.738	0.674	10.85	52.37
SEM	31.82	29.2	112.3	0.099	0.019	0.30	3.65
Significance	**	NS	NS	NS	NS	NS	*

LBW: Live body weight, BWG: Body weight gain, FI: Feed intake, FCR: Feed conversion ratio, PER: Protein efficiency ratio, EEU: Efficiency of energy utilization and EEF: Economic efficiency of feeding, NS: Not significant, *,**Significant at $p \leq 0.05$ and $p \leq 0.01$, respectively. Sale price kg^{-1} live weight: 18 LE, [a,b]For each of the main effects, means in the same column bearing different superscripts differ significantly at $p \leq 0.05$, SEM: Standard error of the means

20% protein diets, observed in this study is in agreement with the findings of Magala *et al.*[17], who showed that cockerels fed the low-protein diet (18%) exhibited superior protein efficiency ratio to that of birds fed on the high-protein diet (20%). In addition, Liu *et al.*[4] evaluated the growth performance of Lueyang black-boned chickens fed diets with different protein concentrations 12, 14, 16, 18 and 20% from 7-12 weeks of age and reported that birds fed the diets containing 18-16% CP exhibited greater growth rate and better feed conversion ratio than those of birds fed the other dietary treatments but feed intake was not influenced by dietary protein level.

However, Magala *et al.*[17] observed that dietary protein level had no effect on growth performance of Ugandan cockerels from 8-16 weeks of age. Similarly, Darsi *et al.*[18] found that performance and appetite of male broiler chicks were not affected by dietary protein level 18, 19.5 and 21% from 10-28 days of age. In addition, Golian *et al.*[16] reported that feed intake of broiler chicks was not affected by dietary protein level during the period from 5-35 days of age. In an early study, Rabie *et al.*[19] observed no significant differences in growth performance of broilers fed diets with different protein levels 18, 20 and 22% during the period from 18-53 days of age.

Effect of dietary energy level: Decreasing dietary ME level for Mamourah cockerels from 3100-2900 kcal kg^{-1} did not affect their total FI but positively affected ($p\leq 0.01$) final live body weight, total body weight gain, feed conversion ratio, protein efficiency ratio, efficiency of energy utilization and economic efficiency of feeding during the whole experimental period, with no significant differences in these criteria among birds fed on diets with intermediate and low energy contents, irrespective of dietary protein level. Inasmuch as feed intake of birds was not influenced by dietary energy level, the improved growth performance for birds fed the low and intermediate-energy diets (2900 and 3000 kcal ME kg^{-1}) compared with those fed the high-energy diets (3100 kcal ME kg^{-1}) cannot be attributed to hyperphagia but rather to a more efficient utilization of dietary energy and protein as evidenced by the superior means of efficiency of energy utilization and protein efficiency ratio and thus, a better efficiency of feed utilization (Table 2). A possible role of energy to protein ratio of the experimental diets in modulating growth cannot be ruled out. The observation that birds fed on the intermediate-energy diets displayed significantly higher ($p\leq 0.05$) ether extract digestibility as compared to those fed the high-energy diets (Table 3) might also had a role in this respect.

There were no significant interactions ($p>0.05$) between dietary protein and energy levels on all criteria of growth performance except for final live body weight and economic efficiency of feeding, the CP by ME interactions were significant. The highest live body weight was achieved by birds fed the diets containing 20% CP and 2900 kcal ME kg^{-1}, followed by those fed on the diets having 20% CP and

Table 3: Nutrient metabolizability (%) of 13 weeks old Mamourah cockerels as affected by dietary protein and energy levels

Main effects	DM	OM	CP	EE	CF	NFE	NR	AR
CP level (A) (%)								
20 (A1)	76.26^{b}	75.26^{b}	94.62^{b}	67.54^{b}	20.36	71.14	68.86	55.15
18 (A2)	81.22^{a}	81.27^{a}	95.34^{a}	74.32^{a}	20.32	76.61	72.48	54.68
SEM	1.21	1.38	0.18	0.46	0.09	1.99	1.33	0.52
Significance	*	*	**	**	NS	NS	NS	NS
ME level (B) (kcal kg^{-1})								
3100 (B1)	78.72	78.58	94.73	69.68^{b}	20.37	73.07	68.03	54.06
3000 (B2)	80.56	79.76	95.10	72.25^{a}	20.47	75.05	68.98	55.60
2900 (B3)	76.95	76.45	95.12	70.87^{ab}	20.18	73.49	68.46	55.10
SEM	1.48	1.69	0.23	0.57	0.11	2.45	1.56	0.64
Significance	NS	NS	NS	*	NS	NS	NS	NS
AB interactions								
A1B1	75.60	75.03	94.33	66.20	20.37	70.94	67.30	53.33
A1B2	77.84	76.26	95.03	69.83	20.57	72.26	73.73	63.20
A1B3	75.34	74.47	94.50	66.60	20.13	70.48	65.53	56.70
A2B1	81.83	82.12	95.13	73.17	20.37	75.21	68.77	54.80
A2B2	83.27	83.26	95.17	74.67	20.37	83.23	77.27	63.53
A2B3	78.55	78.43	95.73	75.13	20.23	76.52	71.40	53.50
SEM	2.09	2.39	0.32	0.80	0.16	3.46	2.21	0.90
Significance	NS	NS	NS	NS	NS	NS	NS	NS

DM: Dry matter, OM: Organic matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, NFE: Nitrogen-free extract, NR: N retention and AR: Ash retention, SEM: Standard errors of the means. ^{a,b}For each of the main effects, means in the same column bearing different superscripts differ significantly at $p\leq 0.05$, NS: Not significant, *,**Significant at $p\leq 0.05$ and at $p\leq 0.01$, respectiviely

3000 kcal ME kg^{-1} and then those fed on the diets with 18% CP and 3000 kcal ME kg^{-1}, in a descending order respectively. Also, birds fed the diets containing 18% CP and 3000 kcal ME kg^{-1} or 18% CP and 2900 kcal ME kg^{-1} displayed the best means of economic efficiency of feeding.

The improved growth performance for birds fed the low and intermediate-ME diets (2900 and 3000 kcal kg^{-1}) compared with those fed the high-energy diets (3100 kcal kg^{-1}), observed herein is in agreement with the finding of Rabie *et al.*[20], who found that decreasing dietary ME level in both starter and grower periods from 3100-2700 kcal kg^{-1} positively affected the efficiency of energy utilization in broiler chicks but feed intake and body weight gain were not affected. They also observed no significant effect on feed conversion ratio and protein efficiency ratio of birds of decreasing dietary energy level from 3100-2900 kcal ME kg^{-1} but when dietary energy level reached 2700 kcal ME kg^{-1} both variables were significantly depressed.

The present results, however, disagree with those of Saldana *et al.*[21], who evaluated the response of growing pullets to feeding diets with different levels of energy from hatching to seventeen weeks of age. They found that daily feed intake linearly increased and feed conversion ratio improved in response to increasing energy content of the diet. Similarly, Golian *et al.*[16] indicated that increasing dietary energy level (from 2900-3200 kcal ME kg^{-1}) caused significant increases in feed intake and body weight and improved feed conversion of broiler chicks. In addition, Tang *et al.*[22] reported that broilers fed on the medium- and high-energy diets (13.38 and 13.79 MJ ME kg^{-1}) were significantly heavier than those fed on the low-energy diets (12.96 MJ ME kg^{-1}). In an early report, Rabie and Szilagyi[23] observed that decreasing dietary energy level (13.5-12.2 MJ ME kg^{-1}) caused a significant increase in feed intake and negatively affected final live body weight, body weight gain and feed conversion ratio of broiler chicks from 18-53 days old. On the other hand, Magala *et al.*[17] found that dietary energy level (2800, 2900 and 3000 kcal ME kg^{-1}) had no effect on growth performance of Ugandan cockerels from 8-16 weeks of age.

Nutrient metabolizability of Mamourah cockerels

Effect of dietary protein level: The effects of feeding diets differing in crude protein and energy levels on nutrient metabolizability of 13 weeks old Mamourah cockerels were given in Table 3. Apart from dietary energy level, birds fed the diets containing 18% protein exhibited significantly higher ($p\leq 0.01$) digestibility of crude protein and ether extract than those fed the 20%-protein diets. Similarly, dry matter and organic matter digestibility were positively affected ($p\leq 0.05$) by decreasing dietary protein level from 20-18%. Dietary protein level did not significantly affect ($p>0.05$) the digestibility coefficients of crude fiber, nitrogen-free extract or ash and nitrogen retention.

It was surprising for us to note that birds fed the 18% CP-diets had higher digestibility coefficients of ether extract, crude protein, dry matter and organic matter as compared to those fed the 20% CP-diets (Table 3), which did not mirror the better growth performance of the former than the latter (Table 2). Currently, there is no definite explanation for this observation based on the results obtained in this study. Besides the effect of dietary protein level, the nutrient digestibility of poultry diet can be influenced by various factors such as feed ingredients, dietary energy level, source and level of dietary fat, type of dietary carbohydrates, feed form (mash vs., pellets), avian factors (genotype, gender, age, gut health status and role of intestinal microflora), plane of nutrition (*ad libitum* vs., feed restriction), stressful conditions (e.g., heat stress, crowding, lack of water, fright and diseases) and any other factors that may directly or indirectly affect the digestion, absorption and/or availability of nutrients.

In disagreement with the present results, Hussein *et al.*[24] observed no significant differences in nutrient digestibility and percentages of ash and nitrogen retention of Sinai cockerels fed diets with different crude protein levels (14-18% CP). Similar results were obtained by Ghazalah *et al.*[25], who reported that dietary protein levels had no significant effect on digestibility coefficients of organic matter, crude protein, ether extract, crude fiber or nitrogen-free extract in broiler chicks.

Effect of dietary energy level: In Table 3, dietary energy level did not significantly ($p>0.05$) affect nutrient digestibility, examined herein, with the exception of a slight increase ($p\leq 0.05$) in ether extract digestibility for birds fed the diets containing intermediate-ME level (3000 kcal kg^{-1}) compared with those fed the low and high-ME diets (2900 and 3100 kcal kg^{-1}). In general, a lack of effect of dietary energy level on nutrient digestibility of 13 weeks old Mamourah cockerels, observed in this study, might be an indication that these birds could digest and absorb the nutrients present in the diets with different energy contents at the same rate. The interactions between dietary protein and energy levels were not significant for all nutrient metabolizability parameters measured in this study. The lack of effect of dietary protein by energy levels interactions on nutrient digestibility and utilization may indicate that both factors were not interrelated.

In partial agreement with the present results, Rabie *et al.*[20] demonstrated that digestibility coefficients of dry matter, organic matter, crude protein and nitrogen-free extract and ash retention were not affected by decreasing dietary ME level from 3100-2900 kcal kg^{-1} in broiler chicks but when dietary energy level reached 2700 kcal ME kg^{-1} these parameters were significantly depressed. On the other hand, Hussein *et al.*[24] reported that increasing dietary energy level from 2600-2750 kcal kg^{-1} positively affected the digestibility of organic matter, crude protein, ether extract and nitrogen-free extract but dietary energy level had no significant effect on digestibility of dry matter and crude fiber and percent nitrogen retention of Sinai cockerels. In addition, Ghazalah and Alsaady[26] evaluated the nutrient digestibility of broiler chicks as affected by feeding diets containing two levels of energy (3100 vs., 2900 kcal kg^{-1} in starter and 3200 vs., 3000 kcal kg^{-1} in grower diets) along with different levels of phytase. They found that dietary treatments had no significant effect on the digestibility of organic matter, crude protein and nitrogen-free extract. They also observed significant differences in ether extract and crude fiber digestibility due to the interaction between dietary energy and phytase addition, with no clear-cut trend.

Carcass characteristics of Mamourah cockerels

Effect of dietary protein level: Carcass characteristics of 14 weeks old Mamourah cockerels as affected by dietary protein and energy levels are illustrated in Table 4. These results clearly show that dietary protein level had no significant effect ($p>0.05$) on carcass traits of Mamourah cockerels, except the relative weight of gizzard which was significantly higher ($p\leq0.05$) for birds fed the 18% CP-diets than those fed the 20% CP-diets, irrespective of dietary energy level.

In good harmony with our results, Magala *et al.*[17] observed no significant differences in carcass yield and slaughter characteristics of 16 weeks old Ugandan cockerels due to dietary protein level (18 vs. 20%). Similar results were obtained by Girish and Payne[27] demonstrated that dietary protein level did not affect ready to cook yield and breast yield but abdominal fat increased in broiler chickens fed the low protein diets relative to those fed the high protein diets.

On the other hand, Kamran *et al.*[28] fed broiler chicks on diets having different CP levels 20, 21, 22 and 23% with energy to protein ratios of 139.0, 146.5, 152.4 and 160.0 from 1-42 days old and found that birds fed the lowest dietary protein level achieved significantly higher eviscerated carcass yield than other dietary treatments but breast meat yield, abdominal fat and composition of breast meat were not affected by dietary protein level. Moreover, in an early study performed by Rabie *et al.*[19] increasing dietary protein level from 18-22% in grower and finisher of broilers produced significant increases in breast yield, breast meat yield and thigh meat yield but absolute and relative weights of abdominal fat were significantly decreased.

In general, the contradictions in the scientific literature on the responsiveness of carcass characteristics of growing poultry to dietary protein are primarily related to other factors such as dietary energy level, type and level of dietary fat, energy to protein ratio, the ratio of lysine and total sulfur amino acids to energy, dietary amino acid profile, physical form of the feed, environmental temperature, duration of study, experimental protocol, bird stocking density and avian genotype, age and gender.

Effect of dietary energy level: In Table 4, dietary energy level did not significantly ($p>0.05$) affect the relative weights of gizzard and heart of 14 weeks old Mamourah cockerels. The obtained results also indicate that decreasing dietary energy level from 3100-3000 kcal ME kg^{-1} had no significant ($p>0.05$) effect on the percentages of carcass yield, total edible parts or liver of cockerels but when dietary ME level reached 2900 kcal kg^{-1} these carcass traits were negatively affected ($p\leq0.05$). Abdominal fat percentage was significantly lower in birds fed the low-energy diets than those fed the high-energy diets but no significant differences were observed in abdominal fat of birds fed low vs. intermediate or intermediate vs. high-energy diets. The dietary protein by energy interactions were not significant for all carcass traits measured in this study. This observation may indicate that each dietary factor acted independently from the other.

The present results agree with those of Magala *et al.*[17], who found no effect of dietary energy level on carcass yield or slaughter characteristics of 16 weeks old Ugandan cockerels. Similar results were obtained by Rabie *et al.*[20], who reported that carcass traits of broiler chicks were not affected by dietary energy level. Additionally, Corduk *et al.*[29] demonstrated that carcass yield and proportions of carcass sections were not affected by dietary ME level 12.55-13.39 and 12.79-13.80 MJ kg^{-1} in starter and grower diets, respectively. Moreover, Tang *et al.*[22] showed that dietary ME level 12.96, 13.38 and 13.79 MJ kg^{-1} did not significantly affect carcass weight or breast muscle weight of broilers but dressing percentage significantly increased as dietary ME level increased from 12.96-13.79 MJ kg^{-1}.

On the other hand, Girish and Payne[27] evaluated the response of broiler chickens to feeding diets of three ME levels (high, medium and low) and found that carcass traits including ready to cook yield and abdominal fat were

Table 4: Carcass characteristics of 14 weeks old Mamourah cockerels as affected by dietary protein and energy levels

Main effects	LBW (g)	CY (%)	GI (%)	LI (%)	HE (%)	TEP (%)	AF (%)
CP level (A) (%)							
20 (A1)	1741	71.52	1.66^{b}	1.69	0.54	75.60	0.10
18 (A2)	1658	70.41	1.94^{a}	1.71	0.53	74.37	0.18
SEM	39.15	0.50	0.08	0.04	0.01	0.46	0.04
Significance	NS	NS	*	NS	NS	NS	NS
ME level (B) (kcal kg^{-1})							
3100 (B1)	1676	72.15^{a}	1.98	1.69^{ab}	0.533	76.33^{a}	0.243^{a}
3000 (B2)	1756	70.79^{ab}	1.68	1.61^{b}	0.542	74.62^{ab}	0.112^{ab}
2900 (B3)	1666	69.73^{b}	1.74	1.80^{a}	0.517	73.79^{b}	0.072^{b}
SEM	47.95	0.61	0.09	0.045	0.018	0.57	0.046
Significance	NS	*	NS	*	NS	*	*
AB interactions							
A1B1	1669	71.42	1.79	1.66	0.568	76.03	0.117
A1B2	1769	72.23	1.62	1.66	0.518	76.02	0.114
A1B3	1785	70.90	1.58	1.76	0.519	74.75	0.070
A2B1	1683	70.36	2.16	1.71	0.498	74.10	0.370
A2B2	1743	72.08	1.75	1.57	0.566	75.96	0.110
A2B3	1547	68.79	1.91	1.84	0.514	73.06	0.073
SEM	67.81	0.87	0.134	0.063	0.025	0.80	0.065
Significance	NS	NS	NS	NS	NS	NS	NS

LBW: Live body weight at slaughter, CY: Carcass yield, GI: Gizzard, LI: Liver, HE: Heart, TEP: Total edible parts and AF: Abdominal fat, SEM: Standard errors of the means, ^{a,b}For each of the main effects, means in the same column bearing different superscripts differ significantly at $p\leq 0.05$, NS: Not significant, *Significant at $p\leq 0.05$

Table 5: Blood plasma parameters of 14 weeks old Mamourah cockerels as affected by dietary protein and energy levels

	Total protein	Albumin	Globulin	Glucose	Triglycerides	Cholesterol
Main effects	(g dL^{-1})			(mg dL^{-1})		
CP level (A) (%)						
20 (A1)	4.61	3.11	1.50	132^{b}	156	125
18 (A2)	4.63	3.05	1.58	149^{a}	134	129
SEM	0.13	0.23	0.24	4.19	9.27	6.75
Significance	NS	NS	NS	*	NS	NS
ME level (B) (kcal kg^{-1})						
3100 (B1)	4.54	2.87	1.67	141	169	149^{a}
3000 (B2)	4.76	3.21	1.55	140	131	116^{b}
2900 (B3)	4.56	3.16	1.41	141	136	117^{b}
SEM	0.15	0.28	0.29	5.14	11.3	8.27
Significance	NS	NS	NS	NS	NS	*
AB interactions						
A1B1	4.23	2.61	1.62	114	180	133
A1B2	4.82	3.41	1.41	138	137	119
A1B3	4.77	3.31	1.47	143	150	124
A2B1	4.85	3.13	1.71	167	157	164
A2B2	4.69	3.01	1.68	142	124	113
A2B3	4.35	3.01	1.34	139	122	110
SEM	0.22	0.39	0.42	7.26	16.0	11.7
Significance	NS	NS	NS	**	NS	NS

^{a,b}For each of the main effects, means in the same column bearing different superscripts differ significantly at $p\leq 0.05$, NS: Not significant, *,**Significant at $p\leq 0.05$ and $p\leq 0.01$ respectively, SEM: Standard error of the means

significantly reduced as dietary ME was reduced but breast weight was not affected. Similarly, Rabie and Szilagyi[23] pointed out that decreasing dietary ME level from 13.5-12.2 MJ kg^{-1} led to significant decreases in absolute weights of eviscerated carcass, liver, breast and thigh yields, meat yields of breast and thigh, total edible parts and abdominal fat of broiler chicks.

Blood parameters of Mamourah cockerels

Effect of dietary protein level: Blood parameters of 14 weeks old Mamourah cockerels as influenced by dietary protein and energy levels are presented in Table 5. These results indicate that dietary crude protein level had no significant effect ($p>0.05$) on plasma concentrations of total protein, albumin, globulin, triglycerides or total cholesterol of Mamourah cockerels but birds fed the 18% CP-diets had significantly higher ($p \leq 0.05$) plasma glucose level than those fed the 20% CP-diets, regardless of dietary energy level.

The absence of a significant effect of dietary protein level on most blood parameters, measured in this study, harmonizes with the findings of Liu *et al.*[4], who found that blood serum levels of total protein, globulin, urea nitrogen, insulin and thyroxin of 84 days old Lueyang black-boned chickens were not affected by dietary protein level 12, 14, 16, 18 and 20% but serum albumin level significantly reduced due to decreasing dietary protein level from 20-14 or 12%. The present results agree also with those obtained by Abdel-Gawad *et al.*[30], who found that blood constituents of broiler chicks were not affected by dietary protein level. Additionally, Hussein *et al.*[24] reported that blood constituents of 49 weeks old Sinai laying hens were not influenced by dietary protein level.

However, Darsi *et al.*[18] found that lowering dietary protein level from 21-18% for broiler chicks caused significant increases in plasma concentrations of the main electrolytes (Na^+, K^+, Cl^-) while plasma uric acid concentration was reduced in parallel with crude protein reduction but levels of Ca^{++} and HCO_3^- ions were not affected by dietary protein level.

Effect of dietary energy level: As illustrated in Table 5, dietary energy level had no significant effect ($p>0.05$) on plasma levels of total protein, albumin, globulin, glucose or triglycerides of Mamourah cockerels but level of total cholesterol significantly decreased ($p \leq 0.05$) when dietary ME level was reduced from 3100 to 3000 or 2900 kcal kg^{-1}, with no significant differences between total cholesterol concentrations of birds fed the low- and intermediate-energy diets. The interactions between dietary protein and energy levels were not significant for all blood plasma parameters tested here, except for plasma glucose concentration in which the dietary CP by ME was significant ($p \leq 0.01$). Birds fed the diets containing 18% CP and 3100 kcal ME kg^{-1} exhibited the highest plasma glucose concentration while those fed on the diets having 20% CP and 3100 kcal ME kg^{-1} displayed the lowest plasma glucose level.

Our results harmonize with the findings of Rabie *et al.*[20], who reported that blood parameters of broiler chicks were not affected by dietary energy level. The present results are also in accordance with those of Elzubeir *et al.*[31], who indicated that dietary energy level 2850 vs., 3050 kcal kg^{-1} did not significantly affect plasma concentrations of total protein, albumin, globulin, sodium, potassium, calcium and inorganic phosphorus in broiler chicks. In line also with the current results, Corduk *et al.*[29] demonstrated that blood parameters of broiler chickens were not affected by dietary ME level 12.55-13.39 and 12.79-13.80 MJ kg^{-1} in starter and grower diets, respectively but activity of aspartate aminotransferase was higher in blood serum of birds fed on the high-energy diet than those fed the low-energy diet. However, Abou-Zeid *et al.*[32] found that increasing dietary ME level for broiler chickens from 2800-3200 kcal kg^{-1} caused significant increases in blood plasma levels of total lipids, triglycerides and cholesterol.

CONCLUSION

Taking the economic aspect , growth and carcass traits of cockerels into account, it can be concluded that optimal dietary levels of crude protein and energy are suggested to be 20% CP and 3000 kcal ME kg^{-1} diet from 6-14 weeks of age.

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