Impacts of varying dietary energy and crude protein levels on growth, carcase traits and digestibility coefficients of growing Japanese quail (Coturnix Coturnix Japonica) during the summer season

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ABSTRACT
An experiment that included crude protein (CP) levels and metabolisable energy (ME) energy (Kcal/kg diet) in meat-type Japanese quail chicks was conducted to evaluate their impacts on performance, carcase traits, digestibility coefficients and nutritional value during the growing period. A total of 540 one-week-old (16.0 ± 0.60 g) Japanese quail chicks were randomly divided into nine treatment groups in a factorial experimental design (3/C2 3), which included three levels of CP and ME (22, 24 and 26%) plus three levels of (2800, 2900, or 3000 Kcal ME/kg diet) during the summer season. The highest values of body weight at marketing age, daily weight gain and best feed conversion during all experimental periods were observed for chicks given 24% CP with a 3000 Kcal ME/Kg diet. A significant (P < 0.01) interaction effect was observed due to energy and protein levels on the digestion coefficients of CP, ether extract (EE), nitrogen-free extract (NFE) and organic matter (OM). Results of digestion coefficients generally coincided with those of growth performance. The interaction effect between dietary energy and protein levels on total digested nutrients (TDN) and ME was significant (P < 0.01). Chicks fed the 3000 Kcal ME/Kg with a 24% CP diet had the highest values of TDN and ME. The interaction between energy and protein levels showed insignificant effects on all carcase traits studied. In conclusion, a dietary energy level of 3000 Kcal ME/Kg with 24% CP is recommended to feed growing Japanese quail from 1–6 weeks of age under summer season conditions.

Introduction
Quail production throughout the world is increasing both for meat and egg consumption. While they are still considered largely luxury foods, improvements in the genetic quality of the birds have led to better productivity and a more satisfactory economic outlook for their widest pared demand. Advances in genetics, management, nutrition, health, and facilities have increased the productivity and development of poultry production, allowing for lower production costs and improved final product quality. Advancements necessitate the ongoing monitoring of the nutrient requirements of the birds in breeding and variations in climatic and other environmental circumstances (Dairo et al. 2010; Abdul Hafeez et al. 2021; Qureshi et al. 2021). For a long time, environmental thermal comfort was regarded as a secondary concern for animal behaviour and performance (Vercese et al. 2012).

Regarding the nutrient requirements of the birds, the two key elements that can affect the productivity limits in poultry are energy and protein (Kamran et al. 2008; Alagawany et al. 2019; Ashour et al. 2020; El-Hindawy et al. 2021). These nutrients are the main factors that affect chicken diets cost. Diets with a lower percentage of dietary protein and energy content may
be less expensive, allowing for significant cost savings (Abdel-Hafeez et al. 2016; Arif et al. 2017; Alagawany et al. 2018, 2022; Hussein et al. 2019, 2020). The most expensive component in broiler diets is a dietary CP. As a result, tremendous efforts were made to lower the cost of feeding by employing the best quantities of CP and ME. Supplementing low-protein diets with necessary and/or non-essential amino acids were explored (Moosavi et al. 2012; Abdel-Hafeez et al. 2016). In the case of thermal heat stress, feed intake dropped drastically, resulting in lower protein and ME intake; as a result, a loss in all productive and growth performance parameters (Abdelnour et al. 2018; Rehman et al. 2018; Mahrose et al. 2019). Kaur et al. (2008) studied the effects of dietary quantities of essential amino acids at varying energy levels on growing quails’ growth and immunity parameters. They found that 25.83% CP with 2700 Kcal/kg of dietary ME are the optimum levels for optimum growth and feed conversion ratio throughout the first five weeks of age. Many researchers also recommended that the best CP level for quails during the growing period ranges from 24 to 27% (NRC 1994; Mosaad and Iben 2009). The current study hypothesised that reducing CP and ME levels might not affect the growth performance of growing Japanese quails which will positively reflect on production economics. Therefore, the main goals of this study were to assess the impacts of various dietary CP and ME levels on the growth performance, digestibility coefficients and carcase characteristics of growing Japanese quail (1–6 weeks of age) during the summer season.

Materials and methods

Birds, experimental design and diets

A total of 540 unsexed one-week-old Japanese quail chicks weighted 16.0 ± 0.60 g were randomly assigned to a 3 × 3 factorial arrangement. Nine treatment groups (each with 60 chicks) were subdivided into six replicates (10 chicks each). Each replicate was housed in a cage of size 90 L × 40 W × 40 H cm. Experimental groups were arranged as follows; three levels of CP (22, 24 and 26%) and three levels of energy (2800, 2900 and 3000 Kcal ME/kg). The diets were prepared as a mash and calculated for growing quail requirements using NRC (1994), as shown in Table 1.

The indoor ambient temperature and relative humidity were recorded daily at noon. The daily lowest and maximum ambient temperatures ranged from 32 to 37 °C, with a relative humidity of 58–68 percent. Temperature and humidity index (THI) values were calculated from observed measurements as described below by Ajakaiye et al. (2010) and Kang et al. (2020) as follows:

\[
\text{THI} = 1.8 \times \text{DBT} - (1 - \text{RH}) \times (\text{DBT} - 14.3) + 32
\]

where: THI = Temperature-humidity index; DBT = Dry-bulb temperature (°C); RH = Air relative humidity.

The temperature-humidity index (THI) ranged from 79.73 to 81.75. Under the supervision of a veterinarian, vaccination and medical programs were carried out according to the quail age. Chicks were housed in brooders with raised wire floors. All chicks were kept under the same management and sanitary circumstances. The provided lighting regimen was 23 h of light and 1 h of darkness. Quails were fed ad-libitum. The experimental diets (in mash form) and freshwater were available throughout the experimental period (1–6 weeks of age), depending on their treatment.

Data collection

Quails were weighed individually to the nearest gram using a digital scale (0.5 gm) at weeks 1, 3 and 6; feed consumption and feed conversion ratio (FCR) (feed intake/weight gain) were measured and calculated for replicates daily within groups, then measured for periods 1–3, 3–6 and 1–6 weeks. The mortality and liveability percentages were recorded daily. At the end of the experiment, five birds/treatments were selected randomly to assess carcase parameters. Quails were then fastened for 12 h, weighed and slaughtered for complete bleeding using a sharp knife. Slaughtered quails, then feather plucked and eviscerated manually. The carcase, dressing, and giblets (liver, gizzard and heart) percentages of quails were calculated as a proportion of their pre-slaughter live body weights.

Excreta collection and drying

Six birds were individually housed in metal cages for each treatment. To ensure that the birds maintained their weight, they were weighed before and after collection. A drawer was provided in each cage for the collecting of excreta. A layer of aluminium foil was placed over the drawer to make excreta collecting easier. Fixed containers provided ad libitum access to the experimental diets and water. Underneath the feeding trough was a little drawer with a plastic sheet to allow for quick collecting of any stray food. The birds were starved for 24 h before being subjected to a three-day experiment. After the collection period began, feed intake was recorded, and manure collection began 24 h later. During excreta collection, it was sprayed
with acid to avoid bacterial fermentation on the excreta. After that, excreta were separated from feathers and any stray feed. The droppings were collected and weighed daily. Each replicate’s and sampling’s excreta were homogenised, and a subsample of 100 g was oven dried for 48 h at 70°C. After leaving for a few hours, the dried excreta from the previous three days were ground, combined, and placed in screw-top glass jars for chemical analysis to achieve equilibrium with the atmosphere. Finally, the excreta samples were ground and stored in screw-top glass jars until they were analysed.

**Analytical methods**

The proximate analysis of experimental diets and total nitrogen dried excreta was carried out according to the Association of Official Analytical Chemists (AOAC 2006), using triplicate samples for each nutrient. The Jakobsen et al. (1960) trichloroacetic acid procedure was adopted to estimate faecal nitrogen. Urinary nitrogen was determined by difference (excreta N - faecal N). Urinary organic matter was calculated. Urinary organic matter = urinary N x 2.62. The percentage of urinary organic matter in the faeces was added to the sum of its other components (% faecal CP + % EE + % CF + % Ash) to calculate the fraction of NFE by differences (Sheikhhasan et al. 2020).

\[
\text{NFE}\% = 100 - (\% \text{CP} + \% \text{EE} + \% \text{CF} + \% \text{urinary OM} + \% \text{Ash})
\]

The dry matter consumed and excreta and their percentage analysis were used to calculate the digestion coefficient of different nutrients.

**Calculation of nutritional value**

Nutritive values were calculated and expressed as TDN and ME. The TDN was calculated using factors 1, 2.25 and 1 for CP, EE and crude carbohydrates (CF and NFE), respectively, and ME was calculated as 4.2 per gram TDN, as suggested by Titus (1961).

**Statistical analysis**

Analysis of variance for data was accomplished using the SAS General Linear Models Procedure (SPSS 2008) on a 3 x 3 factorial design basis according to Snedecor and Cochran (1982) by adopting the following model:

\[
Y_{ijk} = \mu + E_i + P_j + EP_{ij} + e_{ijk}
\]

where: \(Y_{ijk}\) = an observation, \(\mu\) = the overall mean, \(E_i\) = effect of energy level (i = 1–3), \(P_j\) = effect of protein level (j = 1–3), \(EP_{ij}\) = the interaction between energy level and protein level and \(e_{ijk}\) = random error. Duncan’s New Multiple Range Test tested differences among means within the same factor (Duncan 1955).

**Results**

**Growth performance**

**Effect of dietary energy level and protein level and their interaction:**

Results in Table 2 showed that the different dietary energy levels had no significant influence on all growth performance traits studied during the

| Protein level, % | Energy level, Kcal ME/kg | CP% | ME (Kcal /Kg) | Lysine | Ca% | P% | Methionine + Cystine % |
|------------------|--------------------------|-----|---------------|--------|-----|----|------------------------|
| 22               | 2800                     | 22.04 | 2804          | 1.60   | 0.87 | 0.42 | 0.98                  |
| 24               | 2900                     | 21.90 | 2913          | 1.60   | 0.87 | 0.40 | 0.98                  |
| 26               | 3000                     | 22.08 | 3011          | 1.60   | 0.87 | 0.44 | 0.98                  |

**Table 1. Composition (%) and analysis of growing quail diets.**

Protein level, % 22 24 26

Energy level, Kcal ME/kg 2800 2900 3000

Yellow corn 57.57 61.00 63.02 54.13 57.27 58.69 51.82 51.96 52.72

Wheat bran 5.00 0.00 0.00 4.00 0.00 0.00 3.00 0.00 0.00

Corn gluten 60% 4.00 5.00 7.00 5.50 6.00 10.00 7.00 8.00 11.00

Soy bean meal 44% 28.00 29.50 23.10 30.10 30.10 24.60 32.10 33.10 29.00

Fish meal 72% 2.00 1.00 3.00 3.00 3.00 3.00 3.00 3.00 3.00

Cotton seed oil 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

Salt 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30

Premix % 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30

Dicalcium phosphate 1.50 1.50 1.50 1.50 1.50 1.50 1.50 1.50 1.50

Limestone 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00

L-Lysine 0.13 0.18 0.26 0.04 0.03 0.16 0.00 0.00 0.00

D-L Methionine 0.21 0.22 0.16 0.13 0.12 0.07 0.04 0.04 0.00

Analysis: CP% 22.04 21.90 22.08 24.02 24.10 24.04 26.00 25.96 26.05

ME (Kcal /Kg) 2804 2913 3011 2827 2922 3008 2834 2930 3006

Lysine 0.16 1.60 1.60 1.60 1.60 1.60 1.60 1.60 1.60

Ca% 0.87 0.87 0.87 0.87 0.87 0.87 0.87 0.87 0.87

P% 0.42 0.40 0.44 0.45 0.44 0.47 0.46 0.46 0.48

Methionine + Cystine % 0.98 0.98 0.98 0.98 0.98 0.98 0.98 0.98 0.98

Grower Vit. Min. premix: Each 2.5 kg consists of Vit. A 12000.000 IU; Vit. D3, 2000.000 IU; Vit. E, 10 g; Vit k3, 2 g; Vit B1, 1000 mg; Vit B2, 4 g; Vit B6, 1.5 g; Vit B12, 10 mg; Pantothenic acid, 10 g; Niacin, 20 g; Folic acid, 1000 mg; Biotin, 50 mg; Choline chloride, 500 g; Fe, 30 g; Mn, 40 g; Cu, 3 g; Co, 200 mg; Si, 100 mg and Zn, 45 g. **NRC (1994).**

CP: crude protein; ME: metabolisable energy.
experimental periods. However, feed intake and conversion tended to improve with low dietary energy levels (2800 Kcal/Kg). Concerning the effect of the dietary CP level on the live body weight of quails, quail chicks that received 24% dietary CP showed higher ($P < 0.05$) live body weight at six weeks of age than those consumed 22 and 26% CP. Moreover, Table 2 showed that the different protein levels had no significant effect on daily body weight gain and feed conversion ratio during all the experimental periods.

Daily feed intake was significantly ($P < 0.01$) higher in chicks that received 22% CP than those fed 24 and 26% during 3–6 weeks. While daily feed intake was not significantly affected by dietary CP levels during 1–3 and 1–6 weeks of age. Our results suggested that increasing CP levels may decrease the feed intake of birds. A low protein diet may maintain optimal levels of essential amino acids and improve growth performance and feed efficiency.

Concerning dietary energy protein interaction, there were no significant interactions between the protein and energy levels in all parameters studied of growth performance during all the experimental periods (Table 2). The highest values of body weight at marketing age, daily weight gain and best feed conversion ratio during all experimental periods were observed for chicks given 24% CP with a 3000 Kcal ME/Kg diet.

### Digestibility coefficients and feeding values of the experimental diets

Table 3 showed that dietary energy levels exerted significant effects on the digestibility of CP ($P < 0.05$), EE ($P < 0.01$) and NFE ($P < 0.05$). The highest dietary energy level (3000 Kcal ME/Kg) was significantly better than the other dietary energy levels for CP, EE and NFE digestibilities. Increasing the CP level (22–26%) in quail diets resulted in significant effects on digestion coefficients of DM ($P < 0.01$), CF ($P < 0.01$), EE ($P < 0.01$), CF ($P < 0.05$) and NFE ($P < 0.01$). Increasing the dietary protein level almost increased the digestibility of EE, CF and OM, whereas it decreased DM and NFE digestibilities. It is worth noting that the chicks fed diet contained 24% CP digestibility more than the other dietary protein levels tested (Table 3). Results in Table 3 showed significant ($P < 0.01$) interaction due to energy and protein levels on digestion coefficients for CP, EE, NFE and OM. It is of great importance to note that results of digestion coefficients generally coincided with those of growth performance. There was no clear trend of the effects due to the different treatments. Generally, the interaction between the highest CP and ME levels provided the best digestibility coefficients of the nutrients above.

### Nutritional values

The nutritive values (TDN and ME) were significantly ($P < 0.01$) influenced by dietary energy levels, whereas these values were not significantly affected by dietary protein levels (Table 3). TDN and ME value significantly ($P < 0.01$) increased by increasing the dietary energy level (2800–3000 Kcal ME/Kg diet). At the same time, TDN and ME significantly decreased by increasing dietary protein levels (22–26%).

The interaction effect between dietary energy and protein levels on TDN and ME was significant.

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**Table 2. Growth performance (X ± SE) of Japanese quail chicks as influenced by energy and protein levels during the experimental period (1–6 weeks of age).**

| Traits                  | Energy level (Kcal ME /Kg) | Protein level (%) | P value |
|-------------------------|----------------------------|-------------------|---------|
|                         | 2800                       | 2900              | 3000    | 22    | 24    | 26    | P value |
| Body weight (g)         |                            |                   |         |       |       |       |       |
| 1 week                  | 16.2 ± 0.59                | 15.9 ± 0.60       | 16.2 ± 0.62 | 0.562 | 15.7 ± 0.57 | 16.6 ± 0.61 | 16.0 ± 0.62 | 0.414 |
| 3 weeks                 | 66.5 ± 1.77                | 65.5 ± 1.58       | 70.1 ± 1.82 | 0.215 | 67.5 ± 1.69 | 67.2 ± 1.80 | 67.4 ± 1.83 | 0.054 |
| 6 weeks                 | 157.5 ± 2.14               | 158.5 ± 2.17      | 159.1 ± 2.24 | 0.125 | 158.9 ± 2.08 | 161.8 ± 3.02 | 154.4 ± 2.12 | 0.033 |
| Daily body weight gain (g) |                           |                   |         |       |       |       |       |
| 1–3 weeks               | 3.4 ± 0.24                 | 3.3 ± 0.22        | 3.6 ± 0.49 | 0.086 | 3.3 ± 0.34 | 3.4 ± 0.27 | 3.4 ± 0.15 | 0.545 |
| 4–6 weeks               | 4.3 ± 0.31                 | 4.2 ± 0.12        | 4.4 ± 0.25 | 0.084 | 4.3 ± 0.30 | 4.5 ± 0.21 | 4.1 ± 1.45 | 0.511 |
| 1–6 weeks               | 3.9 ± 0.09                 | 4.0 ± 0.07        | 4.0 ± 0.17 | 0.128 | 4.0 ± 0.13 | 4.0 ± 0.11 | 3.8 ± 0.10 | 0.554 |
| Daily feed intake (g)   |                            |                   |         |       |       |       |       |
| 1–3 weeks               | 10.4 ± 0.82                | 11.0 ± 0.26       | 11.2 ± 1.42 | 0.241 | 10.9 ± 0.88 | 10.4 ± 0.84 | 11.3 ± 1.08 | 0.845 |
| 4–6 weeks               | 16.6 ± 0.94                | 16.5 ± 1.02       | 16.2 ± 0.73 | 0.651 | 17.0 ± 0.47 | 16.1 ± 0.50 | 16.2 ± 0.53 | 0.002 |
| 1–6 weeks               | 16.0 ± 1.38                | 15.7 ± 0.96       | 15.5 ± 0.58 | 0.214 | 16.0 ± 0.40 | 15.8 ± 1.08 | 15.0 ± 1.14 | 0.064 |
| Feed conversion (g)     |                            |                   |         |       |       |       |       |
| 1–3 weeks               | 2.99 ± 0.10                | 3.26 ± 0.21       | 3.25 ± 0.19 | 0.211 | 3.14 ± 0.20 | 3.17 ± 0.19 | 3.15 ± 0.11 | 0.536 |
| 4–6 weeks               | 3.81 ± 0.13                | 3.72 ± 0.24       | 3.95 ± 0.17 | 0.117 | 3.92 ± 0.13 | 3.64 ± 0.11 | 3.92 ± 0.10 | 0.544 |
| 1–6 weeks               | 4.03 ± 0.10                | 3.94 ± 0.09       | 4.16 ± 0.21 | 0.854 | 4.11 ± 0.11 | 4.08 ± 0.20 | 3.94 ± 0.11 | 0.961 |
| Mortality rate (%)      |                            |                   |         |       |       |       |       |
| 1–6 weeks               | 6.1 ± 2.79                 | 10.3 ± 1.90       | 7.7 ± 2.45 | 0.085 | 9.0 ± 2.35 | 7.7 ± 3.01 | 8.4 ± 2.09 | 0.556 |

Means in the same row within each classification bearing different letters are significantly ($P < 0.05$) different.
Table 3. Digestibility coefficients and nutritive values of growing Japanese quail diets as influenced by energy, protein levels and their interaction during the summer season.

| Energy level (Kcal ME/Kg) | Protein level (%) | Digestibility coefficients % | Nutritional values (as fed) |
|--------------------------|-------------------|------------------------------|-----------------------------|
|                          | DM                | CP              | EE              | CF              | NFE             | OM              | TDN %          | ME (Kcal/Kg)  |
| 2800                     | 67.20 ± 1.94      | 83.50 ± 0.29b   | 67.20 ± 2.39b   | 27.90 ± 1.10    | 77.80 ± 0.48b   | 66.05 ± 0.25c   | 2744.10 ± 10.65c | 2902.10 ± 8.71b |
| 2900                     | 66.90 ± 1.04      | 83.40 ± 0.40b   | 71.90 ± 1.80b   | 29.40 ± 1.41    | 77.80 ± 0.61b   | 69.10 ± 0.09b   | 71.84 ± 0.31a   | 3017.50 ± 12.01a |
| 3000                     | 68.40 ± 0.94      | 84.00 ± 0.09a   | 72.40 ± 2.03a   | 29.60 ± 0.81    | 79.50 ± 0.08a   | 71.84 ± 0.40a   | 68.63 ± 0.22    | 2882.40 ± 9.69   |
| P value                  | 0.543             | 0.021           | 0.245           | 0.245           | 0.030           | 0.684           | 0.001          | 0.321          |
| 22                       | 70.00 ± 2.10 a    | 83.20 ± 0.33b   | 63.40 ± 1.09b   | 26.60 ± 2.01b   | 80.20 ± 0.37a   | 67.30 ± 0.09b   | 69.25 ± 0.19    | 2908.70 ± 9.13   |
| 24                       | 68.01 ± 2.40b   | 84.90 ± 0.08a   | 68.90 ± 0.91a   | 27.40 ± 1.80ab  | 77.90 ± 0.20b   | 70.40 ± 0.51a   | 68.63 ± 0.22    | 2882.40 ± 9.69   |
| 26                       | 65.90 ± 1.72 c   | 83.30 ± 0.41b   | 69.90 ± 2.09a   | 29.90 ± 2.31a   | 77.00 ± 0.19b   | 71.50 ± 0.40a   | 0.512          | 0.321          |
| P value                  | 0.001             | 0.001           | 0.035           | 0.001           | 0.001           | 0.001           | 0.001          | 0.001          |
| 2800                     | 69.70 ± 3.36      | 82.50 ± 0.50a   | 60.80 ± 4.15b   | 25.80 ± 2.06    | 81.30 ± 0.84a   | 70.60 ± 0.88a   | 67.30 ± 0.44bc  | 2826.00 ± 18.45bc |
| 2900                     | 69.05 ± 2.91      | 83.60 ± 0.31b   | 65.10 ± 2.81b   | 24.80 ± 1.71    | 76.50 ± 0.91b   | 71.50 ± 0.77b   | 68.53 ± 0.31c   | 2739.90 ± 16.02c |
| 3000                     | 64.40 ± 1.99      | 82.40 ± 0.41b   | 66.70 ± 3.21b   | 28.30 ± 0.99    | 75.60 ± 1.02b   | 65.90 ± 1.13b   | 69.70 ± 0.44b   | 2927.60 ± 18.40b |
| P value                  | 0.519             | 0.001           | 0.001           | 0.001           | 0.001           | 0.001           | 0.001          | 0.001          |
| 22                       | 71.40 ± 3.26      | 84.60 ± 0.50a   | 68.10 ± 4.01ab  | 27.90 ± 2.11    | 81.50 ± 0.71a   | 73.20 ± 1.00b   | 68.53 ± 0.44b   | 2891.70 ± 20.80b |
| 24                       | 65.10 ± 3.00      | 84.00 ± 0.42a   | 70.60 ± 3.01ab  | 31.80 ± 1.81    | 77.50 ± 0.19b   | 67.90 ± 0.91a   | 68.75 ± 0.39b   | 2887.50 ± 22.41b |
| 26                       | 63.80 ± 2.50      | 81.70 ± 0.09b   | 74.70 ± 3.00a   | 33.40 ± 2.01    | 76.30 ± 0.81b   | 65.80 ± 0.70b   | 73.70 ± 1.01a   | 3019.90 ± 18.91ab |
| P value                  | 0.519             | 0.001           | 0.001           | 0.001           | 0.001           | 0.001           | 0.001          | 0.001          |

Means in the same column within each classification bearing different letters are significantly (P < 0.05) different.
DM: dry matter, CP: crude protein, EE: ether extract, CF: crude fibre, NFE: nitrogen-free extract, OM: organic matter, TDN: total digested nutrients.
(P < 0.01). Chicks were fed the 3000 Kcal ME/Kg with a 24% CP diet, and gave the highest TDN and ME values. In a converse trend, the combination between 2800 Kcal ME/Kg with 24 or 26% CP resulted in the lowest (P < 0.01) TDN and ME values compared to the other combinations.

**Carcasse traits**

Results in Table 4 showed that energy level had a significant (P < 0.05) effect on giblets and dressing percentages, while the effect was insignificant on carcase percentage. Dressing parentage decreased (P < 0.05) with the increased energy level in diet from 2800 to 3000 Kcal ME/Kg diet (Table 4), while chicks fed the diet contained 2900 Kcal ME/Kg diet recorded significantly (P < 0.05), the best giblets percentage as compared with the other energy levels (2800 and 3000 Kcal ME/Kg diet).

Data in Table 4 indicated that carcase and dressing percentages were not significantly affected by the diet protein level. At the same time, giblets percentages significantly decreased along with increased protein levels in the diet from 22 to 26%. The interaction among energy and protein levels showed insignificant effects on all carcase traits studied (Table 3).

**Discussions**

Our results showed no significant influence on all growth performance traits studied due to dietary energy levels. These results agreed with Gheisari et al. (2011), who found that the overall growth rate (0–6 weeks) of Japanese quail in the tropics favoured low-energy diets. Growing Japanese quail may perform better at lower dietary energy levels in the tropics because of the higher environmental temperature, which probably calls for lower energy needs to maintain basal metabolism (Gopi et al. 2015; Rehman et al. 2018). However, the results disagreed with those obtained by Elangovan et al. (2004), who reported that quails received a diet with 12.15 MJ ME/kg was significantly lower in feed intake and had best FCR (p < 0.01) than quails that were fed diets containing either 11.30 or 10.46 MJ ME kg − 1 diet. Furthermore, Jabbar (2014) found that quails receiving a diet containing a high level of energy (3100 Kcal/kg) resulted in increased feed intake, higher body weight gain, and better FCR than those receiving either a 2700 or 2900 Kcal/kg diet.

Our results suggested that elevating CP levels may decrease the feed intake of birds. Jiang et al. (2005) assured that broiler feed intake was depressed as essential amino acid concentration increased since the bird’s requirements were met much earlier. This study’s growth performance results agreed with those reported by Ashour et al. (2020). They found that Japanese quail in the tropics required a dietary protein level of 28% from 0 to 3 weeks of age and 20% from 4 to 6 weeks of age for optimal growth rate and feed efficiency. Similarly, Hussein et al. (2020) recommended protein levels ranging from 26 to 28% for the rapid growth of quails during their early stages. Birds that receive lower protein diets tend to consume more feed to compensate for the deficiency in amino acid content and requirements to maintain their body weight and functions (Rabie and El-Maaty 2015; Alagawany et al. 2018, 2022; Hussein et al. 2019).

In line with our results, Ashour et al. (2020) found that the effect of protein x energy on Japanese quail’s performance was significant. However, the interaction among energy and protein levels showed insignificant effects on all growth performance traits studied. These results agreed with Gheisari et al. (2011), who found that the overall growth rate (0–6 weeks) of Japanese quail in the tropics favoured low-energy diets. Growing Japanese quail may perform better at lower dietary energy levels in the tropics because of the higher environmental temperature, which probably calls for lower energy needs to maintain basal metabolism (Gopi et al. 2015; Rehman et al. 2018). However, the results disagreed with those obtained by Elangovan et al. (2004), who reported that quails received a diet with 12.15 MJ ME/kg was significantly lower in feed intake and had best FCR (P < 0.01) than quails that were fed diets containing either 11.30 or 10.46 MJ ME kg − 1 diet. Furthermore, Jabbar (2014) found that quails receiving a diet containing a high level of energy (3100 Kcal/kg) resulted in increased feed intake, higher body weight gain, and better FCR than those receiving either a 2700 or 2900 Kcal/kg diet.

Our results suggested that elevating CP levels may decrease the feed intake of birds. Jiang et al. (2005) assured that broiler feed intake was depressed as essential amino acid concentration increased since the bird’s requirements were met much earlier. This study’s growth performance results agreed with those reported by Ashour et al. (2020). They found that Japanese quail in the tropics required a dietary protein level of 28% from 0 to 3 weeks of age and 20% from 4 to 6 weeks of age for optimal growth rate and feed efficiency. Similarly, Hussein et al. (2020) recommended protein levels ranging from 26 to 28% for the rapid growth of quails during their early stages. Birds that receive lower protein diets tend to consume more feed to compensate for the deficiency in amino acid content and requirements to maintain their body weight and functions (Rabie and El-Maaty 2015; Alagawany et al. 2018, 2022; Hussein et al. 2019).

**Table 4.** Some carcase traits (g/100g Pre-slaughter weight) of growing Japanese quail as influenced by energy, protein levels and their interaction during the summer season.

| Energy level (Kcal /Kg) | Protein level (%) | Pre-slaughter weight(g) | Carcase (%) | Giblets (%) | Dressing (%) |
|------------------------|-------------------|-------------------------|-------------|-------------|--------------|
| 2800                   | 161.1 ± 2.42      | 77.7 ± 0.51             | 4.6 ± 0.31^b| 82.3 ± 2.12^a|
| 2900                   | 161.1 ± 3.16      | 75.8 ± 0.84             | 5.1 ± 0.80^a| 80.9 ± 3.10^b|
| 3000                   | 169.0 ± 1.28      | 75.6 ± 0.69             | 4.3 ± 0.54^b| 79.9 ± 0.99^b|
| P value                | 0.654             | 0.413                   | 0.021       | 0.038       |
| 22                     | 166.8 ± 4.41      | 76.0 ± 0.78             | 5.1 ± 0.29^a| 81.1 ± 2.31 |
| 24                     | 158.5 ± 2.62      | 76.8 ± 0.71             | 4.7 ± 0.45^ab| 81.5 ± 1.92 |
| 26                     | 166.0 ± 3.25      | 76.4 ± 0.60             | 4.3 ± 0.28^b| 80.7 ± 0.97 |
| P value                | 0.654             | 0.861                   | 0.041       | 0.095       |
| 2800                   | 159.6 ± 3.91      | 76.5 ± 0.63             | 4.9 ± 0.45  | 81.4 ± 0.69 |
| 24                     | 154.1 ± 3.21      | 78.0 ± 1.21             | 4.6 ± 0.37  | 82.6 ± 0.35 |
| 26                     | 169.1 ± 2.83      | 78.7 ± 0.93             | 4.3 ± 0.72  | 83.0 ± 0.91 |
| 2900                   | 168.3 ± 2.51      | 76.1 ± 1.15             | 5.9 ± 0.46  | 82.0 ± 0.51 |
| 24                     | 160.7 ± 4.11      | 75.6 ± 1.24             | 5.1 ± 0.53  | 80.7 ± 0.74 |
| 26                     | 154.2 ± 3.62      | 75.7 ± 0.84             | 4.4 ± 0.57  | 80.1 ± 0.88 |
| 3000                   | 172.6 ± 1.98      | 74.5 ± 0.95             | 4.6 ± 0.48  | 79.1 ± 1.04 |
| 22                     | 160.6 ± 2.91      | 77.0 ± 0.72             | 4.3 ± 0.61  | 81.3 ± 0.95 |
| 24                     | 173.9 ± 3.17      | 75.3 ± 0.97             | 4.2 ± 0.39  | 79.5 ± 0.79 |
| P value                | 0.856             | 0.431                   | 0.322       | 0.645       |

Means in the same column within each classification bearing different letters are significantly (P < 0.05) different.
body weight gain in the tropics was insignificant. Also, Van Nguyen and Bunchasak (2005) observed no significant interaction effects due to energy and protein levels in all growth performance parameters studied of Betong chickens. At the same time, Dowarah and Sethi (2014) reported that the interaction between protein/C2 energy significantly affected nutrient utilisation and growth parameters during both starter and finisher phases of Japanese quails. Different results may be attributed to factors affecting poultry production like temperature, ventilation, and genetic strain. These variables have the biggest effects on poultry performance. Each genetic strain under study is affected by the factors in different ways, which has a unique impact on intensive production. Onyimonyi and Okeke (2000) found that the diet with 24% CP and 2800 Kcal ME/Kg was recommended to satisfy minimum requirements. Data in Tables 2 and 5 did not show any significant effect on mortality rate due to dietary energy level; dietary protein level and their interaction same results were recorded by Van Nguyen and Bunchasak (2005) in Betong chickens fed different levels of energy and protein in their diets. Our results agree with Soliman et al. (1999) for digestibility trials. They indicated that the average digestion coefficient values for broiler diets of different energy levels (3200–3400 Kcal ME/Kg diet), protein levels (23–25%) and their interaction during the summer season of Egypt were nearly similar. Abd El-Galil (2007) found that the CP digestibility significantly (p < 0.05) decreased for squabs received diets with an increase in protein level and This may be due to the increases in the amount of uric acid dietary protein level. Moreover, Rabie and El-Maaty (2015) concluded that quail’s feed intake increased while their dietary CP level decreased indicating a faster rate of feed passage through their gastrointestinal tract, resulting in reduced nutritional digestibility. Our findings assured that dressing percentage decreased with the increased energy level in diet. These results disagree with Ashour et al. (2020), who found that dressing percentage in Japanese quail diets from 24 to 28% in starter diets and 18–22 in finisher diets was not influenced by dietary ME level (2800-3150 Kcal ME/Kg diet) under high environmental temperatures. Also, Oliveira et al. (2000) found that carcase yield of broiler chickens was not influenced by dietary ME level (2800-3150 Kcal ME/Kg diet) under high environmental temperatures. These results lead to the conclusion that dressing percentage is affected by factors other than dietary energy level. Our results showed that dressing percentage decreased with the increased energy level in diet. These results are in agreement with Ashour et al. (2020), who found that dressing percentage in Japanese quail diets from 24 to 28% in starter diets and 18–22 in finisher diets was not influenced by dietary ME level (2800-3150 Kcal ME/Kg diet) under high environmental temperatures. Also, Oliveira et al. (2000) found that carcase yield of broiler chickens was not influenced by dietary ME level (2800-3150 Kcal ME/Kg diet) under high environmental temperatures.

Table 5. Growth performance (X ± SE) of Japanese quail chicks was influenced by the interaction between energy and protein levels during the experimental periods (1–6 weeks of age).

| Energy level (Kcal ME/Kg) | Protein level (%) | 22 | 24 | 26 | 22 | 24 | 26 | 22 | 24 | 26 | P value |
|--------------------------|-------------------|----|----|----|----|----|----|----|----|----|---------|
| Body weight (g)          |                   |    |    |    |    |    |    |    |    |    |         |
| 1 week                   | 16.0 ± 0.42       | 16.2 ± 0.35 | 16.3 ± 0.35 | 15.4 ± 0.54 | 16.7 ± 0.08 | 15.6 ± 0.21 | 15.6 ± 0.27 | 16.8 ± 0.31 | 16.2 ± 0.68 | 0.235 |
| 3 weeks                  | 66.3 ± 3.08       | 64.9 ± 0.63 | 68.4 ± 1.40 | 67.7 ± 3.33 | 66.7 ± 0.44 | 62.1 ± 3.48 | 68.4 ± 3.77 | 69.9 ± 0.36 | 71.8 ± 3.29 | 0.145 |
| 6 weeks                  | 162.6 ± 3.66      | 159.8 ± 1.51 | 152.2 ± 2.01 | 161.2 ± 3.58 | 158.6 ± 0.94 | 155.7 ± 2.74 | 152.8 ± 3.51 | 167.2 ± 3.84 | 157.3 ± 4.22 | 0.351 |
| Daily body weight gain (g)|                   |    |    |    |    |    |    |    |    |    |         |
| 1–3 weeks                | 3.4 ± 0.37        | 3.3 ± 0.06 | 3.5 ± 0.08 | 3.5 ± 0.22 | 3.3 ± 0.29 | 3.1 ± 0.26 | 3.5 ± 0.23 | 3.5 ± 0.14 | 3.7 ± 0.25 | 0.553 |
| 3–6 weeks                | 4.6 ± 0.19        | 4.5 ± 0.13 | 3.9 ± 0.14 | 4.4 ± 0.07 | 4.2 ± 0.22 | 4.3 ± 0.27 | 4.6 ± 0.46 | 4.6 ± 0.16 | 4.1 ± 0.09 | 0.225 |
| 1–6 weeks                | 4.1 ± 0.08        | 4.0 ± 0.07 | 3.7 ± 0.13 | 4.0 ± 0.13 | 3.9 ± 0.08 | 3.8 ± 0.02 | 3.8 ± 0.20 | 4.2 ± 0.17 | 3.9 ± 0.15 | 0.314 |
| Daily feed intake (g)    |                   |    |    |    |    |    |    |    |    |    |         |
| 1–3 weeks                | 10.3 ± 0.07       | 10.0 ± 0.26 | 10.5 ± 0.70 | 11.2 ± 0.30 | 10.9 ± 0.13 | 11.0 ± 1.10 | 11.2 ± 0.51 | 10.4 ± 0.42 | 12.0 ± 0.53 | 0.541 |
| 3–6 weeks                | 17.1 ± 0.28       | 16.4 ± 0.16 | 16.0 ± 0.16 | 17.2 ± 0.46 | 16.0 ± 0.48 | 16.6 ± 0.21 | 16.7 ± 0.22 | 15.8 ± 0.37 | 16.2 ± 0.33 | 0.332 |
| 1–6 weeks                | 16.5 ± 0.31       | 15.8 ± 0.57 | 15.7 ± 0.46 | 15.9 ± 0.29 | 16.1 ± 0.36 | 15.3 ± 0.68 | 15.6 ± 0.11 | 15.7 ± 0.54 | 15.0 ± 0.45 | 0.456 |
| Feed conversion          |                   |    |    |    |    |    |    |    |    |    |         |
| 1–3 weeks                | 2.83 ± 0.17       | 2.93 ± 0.08 | 3.09 ± 0.03 | 3.38 ± 0.30 | 3.29 ± 0.17 | 3.10 ± 0.10 | 3.20 ± 0.20 | 3.30 ± 0.09 | 3.6 ± 0.13 | 0.548 |
| 3–6 weeks                | 3.66 ± 1.01       | 3.68 ± 0.81 | 4.11 ± 0.22 | 3.81 ± 0.41 | 3.75 ± 0.08 | 3.67 ± 0.15 | 4.31 ± 1.00 | 3.55 ± 0.29 | 4.0 ± 0.11 | 0.647 |
| 1–6 weeks                | 4.04 ± 0.17       | 3.85 ± 0.12 | 4.19 ± 1.01 | 3.99 ± 0.09 | 4.09 ± 0.15 | 3.75 ± 0.17 | 4.29 ± 0.09 | 4.31 ± 0.12 | 3.88 ± 0.11 | 0.641 |
| Mortality rate           |                   |    |    |    |    |    |    |    |    |    |         |
| 1–6 weeks                | 5.7 ± 4.84        | 3.8 ± 2.67 | 4.89 ± 3.91 | 9.6 ± 4.41 | 10.6 ± 3.62 | 9.7 ± 4.71 | 9.6 ± 2.98 | 7.8 ± 4.05 | 10.6 ± 4.80 | 0.364 |
indicated that interaction between energy level and protein level did not exert significant effects on the percentages of carcass plus neck, gizzard, liver and heart of broiler chicks in the tropics.

Conclusions
The results showed that the best body weight, weight gain and feed conversion ratio values were observed for chicks receiving 24% CP with a 3000 Kcal ME/Kg diet. Chicks fed 3000 Kcal ME/Kg × 24% CP diet gave the highest values of TDN and ME. Based on the obtained results, it is recommended to offer growing quails (1–6 weeks) diets containing a dietary energy level of 3000 Kcal ME/Kg interacted with 24% CP for best growth performance under tropical conditions.

Ethical approval
This work was done and approved by the Local Experimental Animal Care and Ethics Committee at the Department of Poultry (Quail Research Farm), Faculty of Agriculture, Zagazig University, Egypt.

Disclosure statement
The author reported no potential conflict of interest.

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Data availability statement
The data that support the findings of this study are available from the corresponding author, [Abd El-Hack, M.E.], upon reasonable request.

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