Effect of Dietary with Different Energy and Protein Levels on Laying Quails Performance

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ABSTRAK

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Performa burung puyuh merupakan fungsi dari beberapa faktor produksi, salah satunya adalah pakan. Akan tetapi, kandungan energi termetabolis dan protein kasar yang optimal untuk performa burung puyuh petelur hingga saat ini masih kontradiktif. Tujuan dari penelitian ini adalah untuk mengevaluasi pengaruh pemberian pakan dengan aras energi termetabolis dan protein kasar yang berbeda terhadap performa puyuh petelur. Sebanyak 540 puyuh petelur berumur delapan minggu dialokasikan secara acak pada sembilan perlakuan pakan. Setiap perlakuan terdiri dari empat ulangan dengan 15 ekor puyuh petelur per ulangan. Perlakuan pakan terdiri dari tiga aras energi termetabolis (2.700, 2.800, dan 2.900 kkal/kg) dan tiga aras protein kasar (17, 19, dan 21%) dalam rancangan percobaan faktorial. Setelah satu minggu periode adaptasi, perlakuan pakan dilakukan selama lima minggu (umur 9-13 minggu). Terdapat adanya interaksi antara energi termetabolis dan protein kasar pada konsumsi pakan (P<0,05). Konsumsi pakan menunjukkan penurunan seiring dengan peningkatan aras energi termetabolis ketika aras protein kasar 17 dan 19%. Akan tetapi, konsumsi pakan cenderung meningkat ketika energi termetabolis tinggi dikombinasikan dengan protein kasar tinggi (2.900 kkal/kg dan 21%). Interaksi antara energi termetabolis dan protein kasar tidak terlihat pada variabel lain (produksi telur, berat telur, massa telur, dan rasio konversi pakan) (P>0,05). Pemberian pakan dengan aras energi metabolis yang berbeda berpengaruh nyata terhadap rasio konversi pakan (P<0,05), tetapi tidak berpengaruh nyata terhadap produksi telur, berat telur, dan massa telur puyuh petelur (P>0,05). Protein kasar sebagai faktor tunggal berpengaruh nyata terhadap produksi telur, berat telur, massa telur, dan rasio konversi pakan puyuh petelur (P<0,05). Analisis regresi linier menunjukkan bahwa konsumsi energi termetabolis secara linier meningkatkan produksi telur, berat telur, massa telur, dan rasio konversi pakan. Selain itu, konsumsi protein kasar juga secara linier meningkatkan produksi telur, berat telur, massa telur, dan rasio konversi pakan. Dapat disimpulkan bahwa untuk memberikan performa puyuh petelur yang optimal diperlukan pakan yang mengandung energi termetabolis 2900 kkal/kg dan protein kasar 21%.

Kata Kunci: Puyuh Petelur, Energi Termetabolis, Protein Kasar, Rasio Konversi Pakan, Produksi Telur

ABSTRACT

Edi DN, Andri F. 2023. Effect of dietary with different energy and protein levels on laying quails performance. JITV 28(1): 69-75. DOI: http://dx.doi.org/10/14334/jitv.v28.i1.3061.

The performance of quail is a function of several production factors, one of which is feed. However, the optimum metabolizable energy and crude protein for the performance of laying quails currently needs to be revised. This study aimed to evaluate the effects of feeding diets with different metabolizable energy and crude protein levels on the performances of laying quails. Five hundred forty (540) laying quails aged eight weeks were randomly allocated into nine dietary treatments. Each treatment consisted of four replicates with 15 laying quails per replicate. Dietary treatments comprised three metabolizable energy levels (2700, 2800, and 2900 kcal/kg) and three crude protein levels (17, 19, and 21%) in a factorial research methodology arrangement. After one week of the adaptation period, the feeding trial was conducted for five weeks (9-13 weeks old). Interaction between metabolizable energy and crude protein levels was recorded on feed intake (P<0.05). Feed intake was reduced along with the increase in the metabolizable energy when crude protein levels were 17 and 19%. However, the feed intake tended to be improved when high metabolizable energy was combined with high crude protein contents (2900 kcal/kg and 21%, respectively). No interaction was recorded on the other variables (egg production, egg weight, egg mass, and feed conversion ratio) (P>0.05). Feeding diets with different metabolizable energy levels had a significant effect on feed conversion ratio (P<0.05) but without any significant impact on egg production, egg weight, and egg mass of laying quails (P>0.05). Crude protein as a single factor significantly affects egg production, weight, mass, and feed conversion ratio of laying quails (P<0.05). Linear regression analysis indicated that metabolizable energy intake linearly improved egg production, weight, mass, and feed conversion ratio. Moreover, crude protein intake linearly improved egg production, weight, mass, and feed conversion ratio. Therefore, feeding diets containing 2900 kcal/kg metabolizable energy and 21% crude protein are required to provide optimum performance of laying quails.

Key Words: Laying Quail, Metabolizable Energy, Crude Protein, Feed Conversion Ratio, Egg Production

INTRODUCTION

Quail is one of the potential livestock in Indonesia. They have several advantages, such as fast growth, high egg production, lesser space and feed requirements, and cheaper capital investment (Agboola et al. 2016). For that reason, quail is suited for both industrial and small-scale farming to produce eggs and meat. According to DGLAH (2021), the quail population in 2017 was 14.6 million birds, while in 2021, the population increased to about 15.2 million birds. Furthermore, in terms of productivity, the quail egg production in 2017 was 25.0 thousand tons, while in 2021, was increased to about 25.3 thousand tons. These data prove that quail farming is essential to fulfilling animal product demand in Indonesia.

The performance of quail is a function of several production factors, one of which is feed. In Indonesia, protein sources are still imported, such as soybean meal, corn gluten meal, distillers' grain, solubles, and meat bone meal (Rakhmawati et al. 2022). The primary source of dietary energy for quail comes from corn. Edi (2021) stated that 70% of the energy requirement for poultry comes from corn, and the rest comes from protein and other nutrient sources. Prices of maize and imported feedstuffs tend to fluctuate and have an upward trend so that they will be correlated with the feed price.

Commercial quail feed has a higher nutrient content than the Indonesian National Standard SNI 01-3907-2006 for laying quail feed. The crude protein content of commercial quail is around 19-22%, while the standard in SNI is at least 17%, and the metabolizable energy is 2700 kcal/kg. Protein is one of the essential nutrients in poultry, and the availability of energy supports chicken activities and production goals (Saraswati et al. 2017; Andri et al. 2020). In addition, protein content functions for growth and production (Silodae & Polakitan 2018). Excess and lack of protein will have a negative impact biologically and economically.

One of the determinations of feed ingredients is more focused on the cost per unit spent to get the cost per unit product (meat, eggs) (Samadi 2012), meaning the comparison of production with costs incurred per unit of production. Therefore, efforts to increase feed efficiency can be made, including by making feed formulations with the right nutrient balance as needed. Macro-nutrients that can be used as indicators of nutrient balance in poultry are crude protein and metabolizable energy. However, to date, the optimum nutrient content for the performance of laying quails still needs to be revised. For that reason, the effects of feeding diets with different metabolizable energy and crude protein levels on the performances of laying quails were evaluated in this study.

MATERIALS AND METHODS

Birds and diets

A total of 540 laying quails aged eight weeks were involved in this study. The laying quails were acclimatized for one week before experimental treatments. At this period, the initial egg mass of laying quails was recorded at 7.29±0.72 g (coefficient of variation was 9.88%). The laying quails were randomly assigned to nine dietary treatments. Each treatment consists of four replicates with 15 laying quails per replicate. Dietary treatments consisted of three dietary ME (metabolizable energy) levels (2700, 2800, and 2900 kcal/kg) and three CP (crude protein) levels (17, 19, and 21%) in a factorial arrangement. The ingredients and nutrient composition of the dietary treatments are shown in Table 1. Diets were offered in mash form, with the amount of 30 g/bird/day. Drinking water was provided ad libitum throughout the experimental period. The feeding trial was conducted for five weeks.

Laying performance

Feed intake (g/bird/day) was calculated by a formula = offered feed - refused feed (Habsari et al. 2018). Egg production (%) was calculated by a formula = (number of egg/number of laying quails) x 100% (Sartika & Iskandar, 2019). A digital balance determines egg weight (g) (Edi et al. 2018). Egg mass (g/bird/day) was calculated by a formula = egg production x egg weight (Dijkslag et al. 2021). Finally, the feed conversion ratio was calculated by a formula = feed intake/egg mass (Leke et al. 2022).

Statistical analyses

Data were presented as means followed by the standard error of means. Data were analyzed using univariate variance analysis, with ME and CP levels regarded as fixed factors. When significant differences were found ($P<0.05$), Duncan's tests were performed to separate means. Statistical analyses were performed by using IBM SPSS Statistics Version 22.

RESULTS AND DISCUSSION

As can be seen in Table 2, interaction ($P < 0.05$) between metabolizable energy and crude protein levels was recorded on feed intake. Feed intake was reduced along with the increase in the metabolizable energy when crude protein levels were 17 and 19%. However, the feed intake tended to be improved when high metabolizable energy was combined with high crude protein contents (2900 kcal/kg and 21%, respectively)..

Table 1. Ingredient and nutrient composition of the experimental diets

Item	2700 kcal/kg ME			2800 kcal/kg ME			2900 kcal/kg ME		
	17% CP	19% CP	21% CP	17% CP	19% CP	21% CP	17% CP	19% CP	21% CP
Ingredient (%)									
Corn	49.26	44.68	42.03	47.77	48.00	42.87	55.79	51.37	48.21
Rice bran	18.00	16.29	13.13	17.41	11.81	10.52	8.19	6.73	3.71
Soybean meal	16.43	22.44	28.00	16.47	21.84	27.52	17.27	22.41	28.00
Meat bone meal	7.61	7.73	8.32	7.90	8.93	9.28	8.53	9.30	9.90
Crude palm oil	0.20	0.47	0.31	2.00	1.24	1.65	1.77	2.00	2.00
Limestone	3.73	3.70	3.61	3.70	3.60	3.60	3.70	3.60	3.60
Grit	3.73	3.70	3.61	3.70	3.60	3.60	3.70	3.60	3.60
Sodium	0.08	0.07	0.07	0.07	0.07	0.06	0.09	0.07	0.07
Toxinil	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Salt	0.11	0.11	0.11	0.11	0.10	0.10	0.11	0.10	0.10
Choline	0.04	0.02	0.02	0.04	0.02	0.02	0.04	0.03	0.02
L-Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
DL-Methionine	0.13	0.11	0.10	0.14	0.11	0.10	0.14	0.11	0.10
Premix	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Nutritional content based on calculations (%)									
ME (kcal/kg)	2700	2700	2700	2800	2800	2800	2900	2900	2900
CP	17.00	19.00	21.00	17.00	19.00	21.00	17.00	19.00	21.00
Calcium	3.60	3.60	3.60	3.60	3.63	3.67	3.65	3.66	3.72
Phosphorus	0.90	0.90	0.90	0.90	0.88	0.90	0.80	0.83	0.83
Lysine	0.89	1.03	1.15	0.89	1.02	1.15	0.89	1.02	1.15
Methionine	0.40	0.40	0.42	0.40	0.40	0.41	0.40	0.40	0.41

ME= metabolizable energy, CP= crude protein

No interaction (P>0.05) was recorded on the other variables (egg production, egg weight, egg mass, and feed conversion ratio). As a single factor, different metabolizable energy levels had a significant effect (P<0.05) on the feed conversion ratio of laying quails. Diets containing 2900 kcal/kg metabolizable energy had better results (P<0.05) on feed conversion ratio than those fed diets containing 2,700 kcal/kg metabolizable energy. However, it was observed that different metabolizable energy levels did not significantly affect (P>0.05) egg production, weight, and mass of laying quails

In line with the current findings, de Freitas et al. (2005) also found that the increase in energy level caused a linear reduction in feed intake. It was also reported that diets with varying metabolizable energy levels also had a significant effect on the feed intake of quails, in which the diet with high metabolizable energy was associated with reduced feed intake (Jahanian & Edriss 2015). In a study by Ratriyanto et al. (2017), high metabolizable energy also reduced the feed intake of laying quails. The reduction of feed intake due to the higher metabolizable energy content in the feed is probably related to the fact that the feeding activity of birds was aimed at fulfilling the energy requirement. Therefore, when the energy requirement is fulfilled, the birds will stop feeding activity so that the feed intake is adjusted according to the energy content in the feed (Fonseca et al. 2021). The reduction of feed intake due to the increment of dietary energy is also reported in other poultry, such as laying hens (Kang et al. 2018; Granghelli et al. 2019) and ducks (Xuang et al. 2018; Awad et al. 2022).

In this study, egg production, weight, and mass did not differ among varying metabolizable energy levels. This finding confirmed the previous study by Agboola

Table 2. Effects of feeding diets with different metabolizable energy and crude protein levels on performances of laying Japanese quails

Treatments	FI (g/b/d)	EP (%)	EW (g)	EM (g/b/d)	FCR
ME (kcal/kg)					
2700	25.32[b]	77.08	10.63	8.20	3.17[b]
2800	24.37[a]	79.36	10.85	8.23	3.03[ab]
2900	24.37[a]	79.39	10.50	8.36	2.99[a]
CP (%)					
17	23.49[c]	72.33[c]	10.20[c]	7.18[c]	3.33[e]
19	24.65[d]	78.17[d]	10.85[d]	8.28[d]	3.03[d]
21	25.93[e]	85.32[e]	10.94[e]	9.33[e]	2.82[c]
ME x CP					
2700 x 17	23.83[gh]	70.97	10.21	7.20	3.38
2800 x 17	23.49[fg]	76.08	10.24	7.23	3.30
2900 x 17	23.14[f]	69.95	10.15	7.09	3.33
2700 x 19	26.14[j]	77.05	10.70	8.25	3.23
2800 x 19	24.09[h]	77.15	11.35	8.15	3.00
2900 x 19	23.72[gh]	80.33	10.51	8.45	2.85
2700 x 21	26.00[j]	83.23	10.98	9.15	2.90
2800 x 21	25.53[i]	84.84	10.97	9.31	2.79
2900 x 21	26.25[j]	87.90	10.86	9.54	2.78
Pooled SEM	0.21	1.32	0.11	0.16	0.05
P-value					
ME	<0.001	0.575	0.328	0.620	0.036
CP	<0.001	<0.001	0.006	<0.001	<0.001
ME x CP	<0.001	0.544	0.629	0.726	0.424

ME= metabolizable energy, CP= crude protein, FI= feed intake, EP= egg production, EW= egg weight, EM= egg mass, FCR= feed conversion ratio. [a,b] different superscripts within a column indicate significant differences ($P < 0.05$); [c,d,e] different superscripts within a column indicate significant differences (P<0.05); [f, g, h, i, j] different superscripts within a column indicate significant differences (P<0.05)

et al. (2016), who also found that diets with varying metabolizable energy had no significant effect on hen day production and egg weight of laying quails. Similarly, Hijab & Albaddy (2022) also found that diets with varying metabolizable energy did not significantly alter laying quails' hen day production and egg weight. In another study, Ratriyanto et al. (2018) also found that the diet's high and low metabolizable energy contents provide equal egg mass in laying quails.

This study found that the high metabolizable energy provides a better feed conversion ratio of laying quails than the low metabolizable energy. In line with this study, Ratriyanto et al. (2018) also observed that feeding high metabolizable energy diets significantly A study by Fonseca et al. (2021) also reported that improved feed efficiency compared to feeding low metabolizable energy diets.

feeding diets with high energy content resulted in a better feed conversion ratio than feeding diets with low energy content. Therefore, the better feed conversion ratios reflect the lower feed intake due to the high metabolizable energy content in the diets.

Table 2 shows that the crude protein as a single factor significantly affects (P<0.05) egg production, egg weight, egg mass, and feed conversion ratio of laying quails. The increase in crude protein levels from 17, 19, to 21% gradually improved (P<0.05) egg production, weight, and mass but reduced f eed conversion ratio.

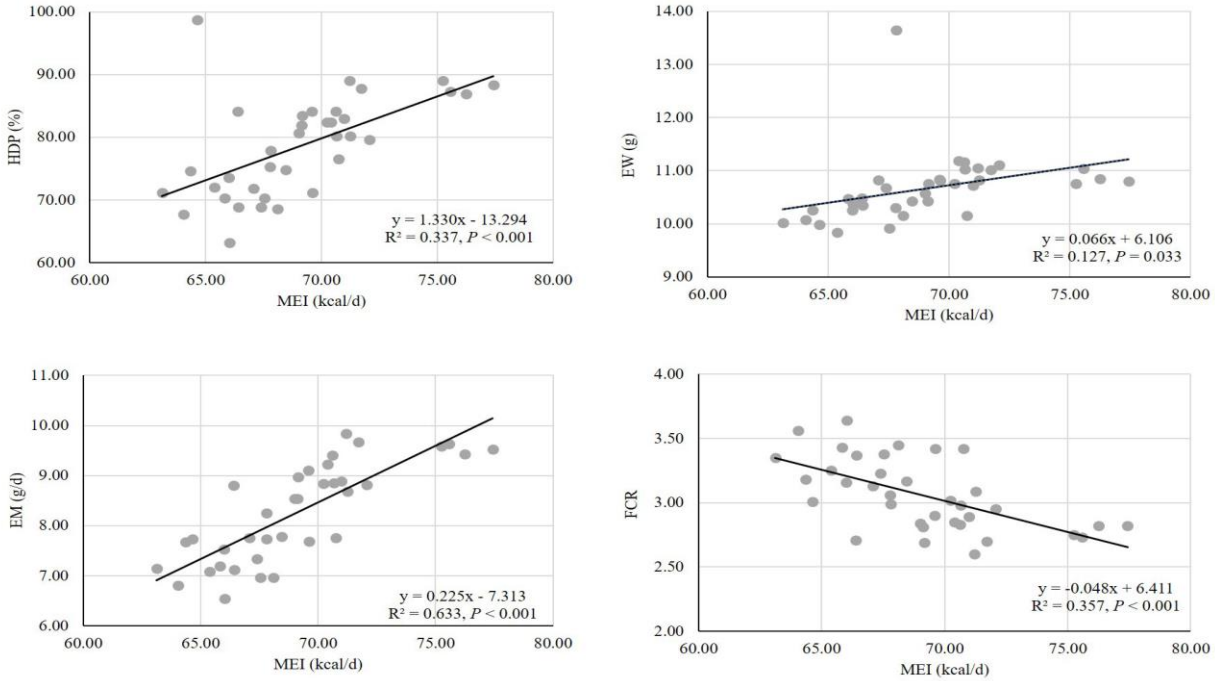

Figure 1. Linear regression of metabolizable energy intake (MEI) on hen day production (HDP), egg weight (EW), egg mass (EM), and feed conversion ratio (FCR)

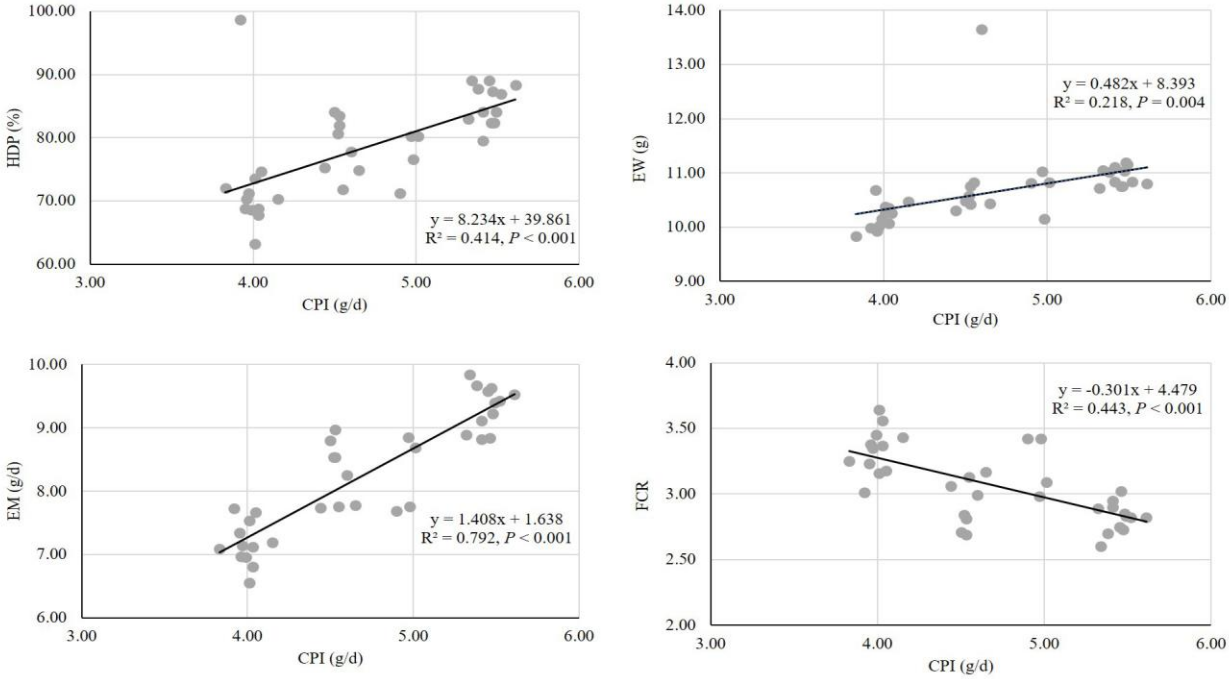

Figure 2. Linear regression of crude protein intake (CPI) on hen day production (HDP), egg weight (EW), egg mass (EM), and feed conversion ratio (FCR)

In line with this finding, El-Hindawy et al. (2021) also reported that the feeding diets with high crude protein contents resulted in higher egg production, egg weight, egg mass, and feed conversion ratio of laying quails. Jesuyon et al. (2021) also found that increasing crude protein levels in the diets increased the egg weight of laying quails. In another study, Salih et al. (2021) also noted that the higher crude protein contents in the diets resulted in higher egg production, egg mass, and feed conversion ratio. The protein supply from the diets is essential for egg formation synthesis (Macelline et al. 2021; Mnisi et al. 2022); the higher crude protein contents could provide better performance of laying quails.

Regression analyses between metabolizable energy and crude protein intakes on egg production, egg weight, egg mass, and feed conversion ratio of laying quails were also undertaken. The results showed that metabolizable energy intake linearly improved egg production, weight, mass, and feed conversion ratio (Figure 1). Similarly, crude protein intake linearly improved egg production, weight, mass, and feed conversion ratio (Figure 2). Previously, Bouvarel et al. (2010) also showed that a higher energy intake could improve laying performance. In addition, Gunawardana et al. (2008) also observed that increased crude protein intakes could improve laying performance in another study. This finding indicated that metabolizable energy and crude protein were critically important in supporting the production performance of laying quails.

In this study, a diet containing 2900 kcal/kg metabolizable energy and 21% crude protein provides the optimum performance of laying quails. However, the high energy content in the feed could reduce feed intake (Fonseca et al. 2021), and consequently, the reduction of other nutrient intakes will follow it. Therefore, high crude protein should be followed by high-energy diets to fulfill the protein requirement for optimum performance. In addition, feeding high-energy and protein diets could support estrogen synthesis, promoting egg formation and thus improving the production performance of laying quails (Lotfi et al. 2018).

CONCLUSION

According to the results of the current study, feeding diets containing 2900 kcal/kg metabolizable energy and 21% crude protein are required to provide optimum performance of laying quails.

REFERENCES

Agboola AF, Omidiwura BRO, Ologbosere DY, Iyayi EA. 2016. Determination of crude protein and metabolizable energy of Japanese quail (*Coturnix coturnix japonica*) during the laying period. J World Poult. Res. 6:131-138.

Andri F, Dono ND, Sasongko H, Zuprizal Z. 2020. The effects of dietary seaweed inclusion on growth performance of broiler chickens: a systematic review and meta-analysis. F1000Res. 9:1087. DOI: 10.12688/f1000research.25726.1.

Awad AL, Ghonim AI, Mostafa KEE, Shazly SAN, Ragab MA. 2022. Influence of dietary energy and protein throughout growth phase on subsequently egg production and hatching features of Sudani ducks. Egypt Poult Sci J. 42:121-136. DOI:10.21608/EPSJ.2022.229628.

Bouvarel I, Nys Y, Panheleux M, Lescoat P. 2010. Comment l'alimentation des poules influence la qualité des oeufs?. INRA Prod Anim. 23:167-182.

de Freitas AC, Fuentes MdFF, Freitas ER, Sucupira FS, Oliveira BCMD. 2005. Dietary crude protein and metabolizable energy levels on laying quails performance. R Bras Zootec. 34:838-846. DOI:10.1590/S1516-35982005000300015.

[DGLAH] Directorate General of Livestock and Animal Health. 2021. Livestock and animal health statistics 2021. Jakarta (Indones): Directorate General of Livestock and Animal Health.

Dijkslag MA, Kwakkel RP, Martin-Chaves E, Alfonso-Carrillo C, Walvoort C, Navarro-Villa A. 2021. The effects of dietary calcium and phosphorus level, and feed form during rearing on growth performance, bone traits and egg production in brown egg-type pullets from 0 to 32 weeks of age. Poult. Sci. 100:101130. DOI:10.1016/j.psj.2021.101130.

Edi DN. 2021. Bahan pakan alternatif sumber energi untuk substitusi jagung pada unggas (ulasan). J Peternak Indones . 23:43-61.

Edi DN, Habsari IK, Andri F. 2018. Effects of supplementing Mojosari ducks diet with fish oil or fish oil in combination with tomato powder on hatching egg quality during storage. Livest Res Rural Dev. 30:29.

El-Hindawy MM, Alagawany M, Mohamed LA, Soomro J, Ayasan T. 2021. Influence of dietary protein levels and some cold pressed oil supplementations on productive and reproductive performance and egg quality of laying Japanese quail. J Hell Vet Med Soc. 72:3185-3194. DOI:10.12681/jhvms.28513.

Fonseca TdS, Ton APS, Corassa A, Sbardella M, Rodrigues CP, de Andrade EA, do Amaral AG, Domiciano IR, Grieser, DdO. 2021. Metabolizable energy and digestible lysine for Japanese quails reared in a hot climate. Livest Sci. 245:104427. DOI:10.1016/j.livsci.2021.104427.

Gunawardana P, Roland Sr DA, Bryant MM. 2008. Effect of energy and protein on performance, egg components, egg solids, egg quality, and profits in molted Hy-Line W-36 hens. J Appl Poult Res. 17:432-439. DOI:10.3382/japr.2007-00085.

Granghelli CA, Burbarelli MFC, Lelis KD, Pelissari PH, Utimi NBP, Leite BGS, Roque FA, Zorzetto PS, Balieiro JCC, Araújo CS. 2019. Effects of dietary metabolizable energy levels and beak trimming on the performance, egg quality, and economic viability of layers. Poult. Sci. 98:5831-5839. DOI:10.3382/ps/pez145.

Habsari IK, Edi DN, Andri F. 2018. Economic evaluation of omega-3 fatty acid enriched duck egg production by feeding diet supplemented with Lemuru fish oil. Livest Res Rural Dev. 30:44.

Hijab ON, Albaddy MA. 2022. Effect of using different energy and protein contain in diet on some production performance characters of local brown quail breed. TJAS. 22: 105-111. DOI: 10.25130/tjas.22.1.10.

Huang X, Li C, Xiong H, Jiang G, Zhang X, Wang X, Hu Y. 2018. Effects of dietary metabolizable energy level on

laying performance, egg quality and serum biochemical indices of cage-rearing laying ducks. Chin. J Anim Nutr. 30:3882-3888.

Jahanian R, Edriss MA. 2015. Metabolizable energy and crude protein requirements of two quail species (*Coturnix japonica* and *Coturnix ypsilophorus*). J Anim Plant Sci. 25:603-611.

Jesuyon OMA, Aganga AA, Orunmuyi M, Falade GT. 2021. Effect of dietary protein level on egg production and egg-quality characteristics of Japanese quail (*Coturnix coturnix japonica*) in the tropical environment. Anim Prod Sci. 62:1430-1438.

Kang HK, Park SB, Jeon JJ, Kim HS, Park KT, Kim SH, Hong EC, Kim CH. 2018. Effect of increasing levels of apparent metabolizable energy on laying hens in barn system. AJAS. 31:1766-1772. DOI:10.5713%2Fajas.17.0846.

Leke JR, Wantasen E, Laihad J, Pudjihastuti E, Podung A, Siahaan R. 2022. Egg production and blood cholesterol of layers fed after adding fragrant pandan leaf flour (*Pandanus amarylifolius* Roxb.). J Ilmu-Ilmu Peternak. 32:167-173. DOI:10.21776/ub.jiip.2022.032.02.02.

Lotfi E, Karimi N, Kavan, BP, Sharifi MR. 2018. Influence of different dietary levels of energy and protein on reproductive and post hatch growth performance in Japanese quails. Iran J Appl Anim Sci. 8:137-145.

Macelline SP, Toghyani M, Chrystal PV, Selle PH, Liu SY. 2021. Amino acid requirements for laying hens: A comprehensive review. Poult Sci. 100:101036. DOI:10.1016/j.psj.2021.101036.

Mnisi CM, Oyeagu CE, Ruzvidzo O. 2022. Mopane worm (*Gonimbrasia belina westwood*) meal as a potential protein source for sustainable quail production: A review. Sustainability. 14:5511. DOI:10.3390/su14095511.

Rakhmawati R, Sofiana A, Indariyanti N, Bokau RJM. 2022. Decreasing crude fiber in Indigofera leaves flour hydrolyzed with cellulase enzyme as a feed protein source. IOP Conf Ser Earth Environ Sci. 1012:012060. DOI:10.1088/1755-1315/1012/1/012060.

Ratriyanto A, Indreswari R, Nuhriawangsa AMP, Arifin AA. 2017. Dietary metabolizable energy and methionine affect the performance of quails. Isnansetyo, A., Nuringtyas, T, editors. Proceeding of the 1st International Conference on Tropical Agriculture. Spinger, Charm. p. 329-335.

Ratriyanto A, Indreswari R, Nuhriawangsa AMP, Purwanti E. 2018. Feed efficiency of diets with different energy and protein concentrations supplemented with methionine in laying quails. IOP Conf Ser Earth Environ Sci. 142: 012001. DOI:10.1088/1755-1315/142/1/012001.

Salih JH, Mohammed DA, Hussen SH. 2021. Impact of protein source and its levels on egg production and egg quality of Japanese quail (*Coturnix coturnix japonica*). Sci J Univ Zakho. 9:138-143. DOI:10.25271/sjuoz.2021.9.3.829.

Samadi S. 2012. Konsep ideal protein (asam amino) fokus pada ternak ayam pedaging (review artikel). J Agripet. 12:42-28.

Saraswati S, Atmomarsono U, Kismiati S. 2017. Pengaruh sumber protein berbeda terhadap laju alir pakan, kecernaan protein dan retensi nitrogen ayam lokal persilangan. J Sain Peternak Indones. 12:372-378. DOI:10.31186/jspi.id.12.4.372-378.

Sartika T, Iskandar S. 2019. The productivity of 4th generation KUB-2 chicken. JITV. 24:151-157. DOI:10.14334/jitv.v24i4.2033.

Silondae H, Polakitan D. 2018. Pengaruh imbangan energi dan protein serta kepadatan kandang terhadap penampilan ayam pedaging. J Peternak Indones. 20:175-180. DOI:10.25077/jpi.20.3.175-180.2018.