

Estimation of Energy and Protein Requirements of Arabic Hens during Rearing Period by Free Choice Feeding

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ABSTRACT

The present experiment was conducted to estimate the metabolizable energy (ME) and crude protein (CP) requirements of female Arabic chickens under a semi-scavenging system from starter to first egg-laying age. Two hundred and forty-five day-old chicks were allotted into 12 sheltered pens with 20 chicks each. They were offered either control or choice diet and replicated six times. The control group was offered a control diet based on the Hy-line Brown Nutrient Requirements Standard, whereas the choice group was offered a control diet (starter period: 2910 kcal of ME/kg and 19.7% of CP; grower period: 2854 kcal of ME/kg and 17.5% of CP; developer period: 2754 kcal of ME/kg and 16.0% of CP; pre-laying period: 2776 kcal of ME/kg and 16.5% of CP; and laying period: 2814 kcal of ME/kg and 18.4% of CP) together with four other diets (high energy-high protein [3101 kcal of ME/kg and 23.0% of CP], high energy-low protein [3133 kcal of ME/kg and 14.3% of CP, low energy-high protein [2638 kcal of ME/kg and 23.4% of CP], and low energy-low protein [2677 kcal of ME/kg and 14.6% of CP]). Data were analyzed using Proc Mixed of SAS. Results showed that feed intake was significantly lower in choice dietary treatments in all periods, except in the starter period. ME and CP intakes were similar ($p>0.05$) in all periods. However, ME and CP concentrations in the diet consumed were higher ($p<0.05$) in choice dietary treatment in all periods, except CP concentration in the starter period. BWG started to be higher ($p<0.05$) in choice dietary treatment during the developer and pre-laying period. The onset of laying was two days early in choice-fed birds. It can be concluded that free choice feeding on a diet varying in energy and protein had a beneficial effect on the growth rate of female Arabic hens by consuming more a high energy-high protein and a high energy-low protein diet. ME and CP requirements of Arabic hens for starter period were 3026 kcal of ME/kg and 18.8%, for grower period were 3081 kcal of ME/kg and 18.4%, for developer period were 3091 kcal of ME/kg and 18.5%, and for pre-laying period were 3072 kcal of ME/kg and 18.8% to faster the onset of laying.

Keywords: self-selection; Arabic chicken; energy intake; protein intake; tropic

INTRODUCTION

A specific breed of native chicken that has been recognized having a high egg production is Arabic chicken (Hartawan & Dharmayanti, 2016). Therefore, Arabic hens could be realized to increase the contribution to national egg production in the future. Director General of Livestock and Animal Health (2019) reported that the egg production of local village chickens decreased 3.9% from 2017 to 2018 and increased 3.7% from 2018 to 2019. The contribution of the production of egg by local village chicken to the national egg production increased only 0.08% from 2018 to 2019. The poor egg contribution during the last year indicates that the productive performance of local chickens is still low, although the rearing system has been changed to semi and intensive system. One of the main constraints to increase egg production in these chickens might be the nutrient requirements are not suitable for them.

Limited information is available in the literature related to local chicken's metabolizable energy (ME) and crude protein (CP) requirements. Kristina Dewi *et al.* (2015) reported that the growth rate and feed conversion ratio (FCR) of native chicken in Bali during the starter phase (0-8 weeks) increased with an increase in dietary energy (3100 kcal ME/kg) and CP (22%). Raphulu and van Rensburg (2018) reported that crude protein (CP) in the diet about 17% with 2627 kcal AME/kg for starter period (0-6 weeks) and 15% with 2866 kcal AME/kg for grower period (7-17 weeks) are needed to optimize the growth rate and FCR for unsex local chicken in South Africa. Perween *et al.* (2016) reported that the backyard breed, namely Vanaraja developed by the Project of Directorate of Poultry (PDP), Hyderabad that was very well acclimatized to village climate in India have a better body weight gain and FCR with 17% and 19% CP combined with 3000 kcal ME/kg. These studies suggested that the nutrient requirements of local village chickens are still not conclusive.

Self-selection feeding is another strategy to get the appropriate ME and CP requirements for birds in the tropics. Self-selection feeding permits the birds to choose the nutrient requirements from a set of nutrients suitable for their growth and physiological development conditions. Cruz *et al.* (2005) and Syafwan *et al.* (2012) reported that broiler was able to meet the nutrient requirements by offering various ingredients with different contents of protein and energy at the high temperature indicated by a similar BW gain as a control diet. In laying hens, only hens fed with the most concentrated diets were able to meet the recommended daily protein intake at high temperatures when offering diets varying in energy and nutrient density to overcome the nutritional stresses associated with the onset of laying and with periods of high temperature although egg mass output remained low with the highest ME and protein intakes (Daghir, 2008). However, it is not known what kind of diet the Arabic chicken would select from various diets varying in protein and energy contents to compose their nutrient requirements that suitable with their physiological development conditions. This selection may result in a faster growth rate and onset of laying compared with a control diet.

The objectives of this study were (1) to determine the nutrient composition of diets consumed by Arabic female chicks when they were offered various choices of diet varying in energy and protein contents; (2) to determine what are the protein and energy requirements for Arabic female chicks during the growing period; (3) and to determine the time of onset of laying in Arabic chicks when they were given a choice fed diets.

MATERIALS AND METHODS

Animal Care, Birds, and Housing

All experiments were approved by the Ethical Clearance Committee of Animal Science Faculty, University of Jambi, with number 001/UN21.7/ECC/2021. A total of 240 five-day-old female Silver Arabic hens were used in this research. This chicken is a specific breed of native chicken for layer purposes (Hartawan & Dharmayanti, 2016). The experimental chicks were allotted to 12 sheltered pens with 20 chicks each. The pens were covered with netted nylon. Two meters of the pen were inside the barn and 3 meters of the pen were outside the barn. The width and height of pen were similar inside and outside the barn (1.75 x 2 m). The pen's floor inside the barn was covered with sand as a litter and the pen's floor outside the barn was soil. The house was an open-sided barn and the hens could go in and out of the pen and enter the yard freely.

Each diet was placed in a separate feed trough. The positions of the feeding trough were changed every day randomly to avoid the habituation of hens. Bell-shaped drinkers were used for drinking water. Feeds and drinking ware were offered *ad libitum*.

Temperature (T) and relative humidity (RH) were recorded in the morning (07:00 h), the day (12:00 h), and the afternoon (17:00 h) by thermo-hygrometer. After two weeks of age, half of the pen high inside the barn was

covered with black plastic and the chicks were warmed with an electric bulb.

Experimental Design and Treatments

A completely randomized design with 2 treatments and 6 replicates (pens) of 20 chicks were used in this experiment. The no-choice hens offered a control ration containing ME, CP, and other nutrients for 4 phases (starter [0-6 weeks of age], grower [7-12 weeks of age], developer [13-15 weeks of age], pre-laying [16-17 weeks of age], and laying [18 weeks of age]) as were recommended by The Hy-line Brown Commercial Management Guide (HyLine, 2011). This recommendation was chosen because the bodyweight of the Arabic chick was 10% lower than that of the targeted mean BW of Hy-line Brown chick. To be save, the pre-laying control feed was stopped at the 17th week, although the hens did not lay eggs yet and continued with laying standard feed from the 18th week of age until they laid the eggs.

The choice groups were given a control diet (starter period: 2910 kcal of ME/kg and 19.7% of CP; grower period: 2854 kcal of ME/kg and 17.5% of CP; developer period: 2754 kcal of ME/kg and 16.0% of CP; pre-laying period: 2776 kcal of ME/kg and 16.5% of CP; and laying period: 2814 kcal of ME/kg and 18.4% of CP) and four other diets (high energy-high protein, **HEHP** [3101 kcal of ME/kg and 23.0% of CP], high energy-low protein, **HELP** [3133 kcal of ME/kg and 14.3% of CP], low energy-high protein, **LEHP** [2638 kcal of ME/kg and 23.4% of CP], and low energy-low protein, **LELP** diet [2677 kcal of ME/kg and 14.6% of CP]). All the diets were offered in a mash form. The nutrients contents of the diets are presented in Table 1. These four diets differed from the control diet in the energy and protein contents, while the other nutrients were almost identical.

Feed intake (FI) per pen was recorded by weighing the feed offered and feed residues on a weekly basis. ME and CP intakes were calculated from the intake of each of the five diets times the content of ME and CP in each diet, then divided by 1000 (g/kg) and were used to calculate the ME and CP utilizations. The concentrations of ME and CP in the diet intake were calculated from the ME and CP intakes divided by FI times 1000 (g/kg) (Syafwan *et al.*, 2012). BW gain was determined by weighing the bird weekly. The weights of birds that died or had to be culled were accounted for in their mean weekly BW gains. Protein (g/g BW gain) and energy utilization (ME/g BW gain) per pen were calculated from protein and energy intakes divided by BW gain, respectively (Syafwan *et al.*, 2012).

Statistical Analysis

Data were analyzed according to the method described by Syafwan *et al.* (2012) by using PROC MIXED in SAS. Since the data were taken repeatedly on the same animals, they could not be considered as separate units of observation (Littell *et al.*, 1998; Walter *et al.*, 2018). In the analysis, weeks of age or age phase were used as the time factor, and pen was considered an additional random effect.

Table 1. The ingredients (g/kg) composition and calculated nutrients content of dietary treatments

Ingredients	Control feed					Self-selection feed			
	Starter (0-6 week)	Grower (7-12 week)	Developer (13-15 week)	Pre-laying (16-17 week)	Laying (≥ 18 week)	HEHP ³	HELP ⁴	LEHP ⁵	LLEP ⁶
Rice bran	95.0	140.0	329.5	199.2	160.0	0.0	174.0	243.0	366.0
Corn	498.5	540.0	350.0	450.0	320.0	433.0	550.0	287.0	360.0
Soybean meal	290.0	234.6	230.0	220.0	251.5	355.0	130.0	405.0	200.0
Fish meal	51.0	39.0	20.0	40.0	82.0	90.0	50.0	40.0	0.0
Salt	3.3	3.0	3.5	2.8	3.0	2.0	2.0	2.0	3.0
Top Mix ¹	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Dicalcium phosphate	6.5	8.0	12.0	6.0	2.0	0.0	3.0	3.0	12.0
Ca-carbonate	15.0	20.0	30.0	52.0	95.0	15.0	20.0	15.0	50.0
DL-Methionine	0.7	0.4	0.0	0.0	1.5	0.0	2.0	0.0	2.0
L-lysine HCL	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	2.0
Palm oil	35.0	10.0	20.0	25.0	80.0	100.0	60.0	0.0	0.0
Total	1000	1000	1000	1000	1000	1000	1000	1000	1000
Nutrient composition (calculated)									
Dry matter (%)	88.6	90.8	92.1	91.3	85.2	92.4	82.6	86.0	92.5
CP (%)	19.7	17.5	16.0	16.5	18.4	23.4	23.0	14.3	14.6
ME (kcal ME/kg) ²	2910	2854	2754	2776	2814	2638	3101	3133	2677
EE (%)	4.05	4.94	8.77	4.66	4.78	7.00	1.88	4.96	9.01
CF (%)	4.30	4.54	5.01	4.69	4.11	4.53	3.90	4.65	4.77
Lysine (%)	1.25	1.06	1.02	1.07	1.28	1.53	1.56	1.24	1.03
Methionine (%)	0.47	0.40	0.35	0.38	0.56	0.45	0.48	0.52	0.47
Met+Cys (%)	0.81	0.71	0.65	0.68	0.88	0.86	0.87	0.78	0.76
Ca (%)	1.02	1.19	1.57	2.52	4.24	0.95	1.06	1.11	2.31
NPP (%)	0.80	0.85	1.04	0.85	0.79	0.93	0.62	0.76	1.10
Na (%)	0.45	0.44	0.45	0.48	0.46	0.39	0.45	0.35	0.41

Note: ¹= Composition of 1 kg Top Mix: vitamin A (retinyl acetate) 12,000 IU; vitamin D3 (cholecalciferol) 2,000 IU; vitamin E (dl- α -tocopherol) 8.0 mg; vitamin K 2.0 mg; vitamin B1 (thiamin) 2.0 mg; vitamin B2 (riboflavin) 5.0 mg; vitamin B6 (pyridoxine-HCl) 0.5 mg; vitamin B12 (cyanocobalamin) 12 mg; vitamin C 25 mg; niacin 40 mg; vitamin B5 (d-pantothenic acid) 6.0 mg; choline chloride 10 mg; methionine 30 mg; lysine 30 mg; iron 20 mg; copper 4 mg; manganese 120 mg; zinc 100 mg; cobalt 0.2 mg; iodine 0.2 mg; zinc bacitracin 21 mg, and santoquin (antioxidant) 10 mg. ²= Metabolisable energy was calculated by determining (combustion) gross energy of the entire diet multiplied with a ME/GE-conversion factor (0.725); ³= HEHP (high energy-high protein diet (3101 kcal of ME/kg and 23.0 g of CP/kg); ⁴= HELP (high energy-low protein diet (3133 kcal of ME/kg and 14.3 g of CP/kg); ⁵= LEHP (low energy-high protein diet (2638 kcal of ME/kg and 23.4 g of CP/kg); ⁶= LLEP (low energy-low protein diet (2677 kcal of ME/kg and 14.6 g of CP/kg).

A probability level less than 5% was considered to be statistically significant. Means were compared by pairwise comparison using the Least Significant Difference when the main effects or their interactions were significant. Means of significant effects were separated using the PDIFF option with PDMIX800 SAS macro at the $p < 0.05$ level (Syafwan *et al.*, 2012; Naseem and King, 2020). The Kenward-Roger method was used for computing the denominator df for the tests of main effects. The best covariance structure was based on the corrected Akaike Information Criteria (AICC).

For every period, the best covariance structures were as follows: Starter period: Simple covariance structure fit the data best for CP utilization. The first order ante-dependence covariance structure [ANTE(1)] fit the data best for FI and energy intake. The heterogeneous autoregressive covariance structure [ARH(1)] fit the data best for CP intake, concentration of CP, as well as ME and ME utilization. Autoregressive covariance structure [AR(1)] fit the data best for BWG. Grower period: Simple covariance structure fit the data best for FI, CP, and ME intake. ANTE(1) fits the data best for BWG, the concentration of CP, and ME. ARH(1) fits the data best for CP utilization and ME utilization. Developer

period: Simple covariance structure fit the data best for the concentration of ME. ANTE(1) fits the data best for BWG and ME utilization. ARH(1) fits the data best for FI, CP, ME intake, CP concentration, and CP utilization. Pre-laying period: Simple covariance structure fit the data best for BWG. ARH(1) fits the data best for the rest of the parameters.

RESULTS

Environmental Condition

During the experimental period, the average temperature and humidity from 1 to 22 weeks of treatment that were measured at 07.00 h, 12.00 h, and 17.00 h were $24.2 \pm 0.8^\circ\text{C}$ and $78.7 \pm 3.8\%$, $30.4 \pm 2.2^\circ\text{C}$ and $54.1 \pm 7.7\%$, as well as $28.7 \pm 2.2^\circ\text{C}$ and $60.8 \pm 8.6\%$, respectively.

Hens Performance

The mortality of birds during the experimental period was 3.8%. All performance data in the tables were corrected for mortality on a weekly basis.

Starter period. Table 2a presents the probability values of all parameters and Table 3 presents the differences in weekly performance of the hens with different dietary treatments.

There was no significant effect of treatments on feed intake (FI) of the chicks (Table 2a). The treatments did not affect protein and energy intakes (Table 2a). Feed intake, as well as protein and energy intakes were affected by the weeks of age (Table 2a and 3) and increased over time (Figure 1). There were interaction effects between dietary treatments and weeks of age on feed, protein, and energy intakes (Table 2a). Interaction between dietary treatments and weeks of age showed that the differences were significantly higher in 3 weeks of age for feed and energy intakes, but protein intakes were significantly higher during the last two weeks of the starter period for both dietary treatments (Figure 2).

BWG was not affected by the feeding method, but BWG was affected by the weeks of age during the starter period (Table 2a and 3). BWG increased by the increased age of chicks (Figure 1). However, there was no interac-

tion effect between dietary treatments and weeks of age during the starter period on BWG (Table 2a).

CP and ME concentrations were affected by the dietary treatment (Table 2a). CP and ME concentrations were significantly higher in the choice-fed hens than control-fed chicks (Table 3). CP and ME concentrations were affected by the weeks of age during the starter period (Table 2a). CP concentration declined sharply after the 3rd week of age until the 6th week (Figure 1). ME concentration increased from the 1st week of age until the 6th week (Figure 1). There were interaction effects between dietary treatments and weeks of age on CP and ME concentrations (Table 2a). Interaction between the dietary treatments and weeks of age during the starter showed that CP concentration in choice-fed chicks was significantly lower from weeks 4 onward in the trial. However, ME concentration was much higher in choice-fed hens from the beginning of the trial (Figure 2).

CP and ME utilizations were not influenced by the dietary treatments (Table 2a). However, CP utilization was higher in choice-fed chicks compared with control-

Table 2. Probability values of main effects and interaction between dietary treatment¹ and week for different traits

Phase	Variables	Treatment	Week	Treatment*Week
A. Starter period	Feed intake (g/hen/week)	0.774	<0.001	0.023
	Protein intake (g of CP/hen /week)	0.15	<0.001	<0.001
	Energy intake (kcal of ME/kg/hen/week)	0.449	<0.001	<0.001
	BWG (g/hen/week)	0.976	<0.001	0.121
	Protein concentration (g/kg)	<0.001	<0.001	<0.001
	Energy concentration (kcal ME/kg)	<0.001	<0.001	<0.001
	CP utilization (g of CP/g BWG)	0.122	<0.001	<0.001
	Energy utilization (kcal of ME/g BWG)	0.999	<0.001	0.01
B. Grower period	Feed intake (g/hen/week)	<0.001	<0.001	0.187
	Protein intake (g of CP/hen /week)	0.511	<0.001	0.173
	Energy intake (kcal of ME/kg/hen/week)	0.653	<0.001	0.144
	BWG (g/hen/week)	0.657	0.01	0.148
	Protein concentration (g/kg)	<0.001	0.043	0.043
	Energy concentration (kcal ME/kg)	<0.001	0.01	0.01
	CP utilization (g of CP/g BWG)	0.27	0.012	0.281
	Energy utilization (kcal of ME/g BWG)	0.455	0.015	0.425
C. Developer period	Feed intake (g/hen/week)	<0.001	0.002	0.006
	Protein intake (g of CP/hen /week)	0.46	0.002	0.059
	Energy intake (kcal of ME/kg/hen/week)	0.096	0.002	0.007
	BWG (g/hen/week)	0.035	0.006	0.701
	Protein concentration (g/kg)	<0.001	0.18	0.18
	Energy concentration (kcal ME/kg)	<0.001	0.42	0.42
	CP utilization (g of CP/g BWG)	0.156	0.002	0.24
	Energy utilization (kcal of ME/g BWG)	0.103	<0.001	0.197
D. Pre-laying period	Feed intake (g/hen/week)	0.017	<0.001	0.017
	Protein intake (g of CP/hen /week)	0.642	<0.001	0.001
	Energy intake (kcal of ME/kg/hen/week)	0.25	<0.001	<0.001
	BWG (g/hen/week)	0.023	<0.001	0.069
	Protein concentration (g/kg)	<0.001	<0.001	<0.001
	Energy concentration (kcal ME/kg)	<0.001	<0.001	<0.001
	CP utilization (g of CP/g BWG)	0.108	<0.001	0.096
	Energy utilization (kcal of ME/g BWG)	0.258	<0.001	0.134

Note: ¹= Control diet (a. starter diet: 0-6 w= 2910 kcal of ME/kg and 19.7 g of CP/kg; b. grower diet: 7-12 w= 2854 kcal of ME/kg and 17.5 g of CP/kg; c. developer diet: 13-15 w= 2777 kcal of ME/kg and 16.1 g of CP/kg; d. pre-laying diet: 16-17 w= 2797 kcal of ME/kg and 16.5 g of CP/kg; and e. laying diet: ≥ 18 w= 2814 kcal of ME/kg and 18.4 g of CP/kg). Self-selection feed (a= the control feed, b= HEHP (high energy- high protein diet (3101 kcal of ME/kg and 23.0 g of CP/kg); c= HELP (high energy-low protein diet (3133 kcal of ME/kg and 14.3 g of CP/kg); d= LEHP (low energy-high protein diet (2638 kcal of ME/kg and 23.4 g of CP/kg); e= LELP (low energy-low protein diet (2677 kcal of ME/kg and 14.6 g of CP/kg).

Table 3. Least square means of performance variables in local female chickens from 1 to 6 week of age as affected by dietary treatment¹

Variables	Week						Average
	1	2	3	4	5	6	
Feed intake (g/bird/week)							
Control	69.3	112.8	144.3 ^a	159.4	238	293.7	169.6
Self-Selection	69.0	110.7	164.0 ^b	173.7	219.4	274.2	168.5
SEM	2.28	3.31	5.92	8.12	6.85	7.33	2.60
Protein intake (g of CP/bird/week)							
Control	13.7	22.3	28.5	31.4	46.9 ^a	57.9 ^a	33.4 ^a
Self-Selection	13.4	22.4	32.4	31.6	38.5 ^b	49.1 ^b	31.2 ^b
SEM	0.41	0.78	1.54	1.55	1.34	1.78	0.66
Energy intake (kcal of ME/kg/bird/week)							
Control	201.7	328.4	419.9	463.9	692.5	854.8	493.6
Self-Selection	203.8	332.4	497.2 ^a	525.8	674.2	841.6	512.5
SEM	6.71	9.70	16.53 ^b	24.79	20.05	22.13	7.73
BWG (g/bird/week)							
Control	36.2	48.6	56.6	62.3	80.4	68.6 ^a	58.8
Self-Selection	35.6	45.4	51.6	58.9	73.3	87.6 ^b	58.7
SEM	5.15	5.15	5.15	5.15	5.15	5.15	1.34
Protein concentration (g of CP/kg)							
Control	197.2	197.2	197.2	197.2 ^a	197.2 ^a	197.2 ^a	197.2 ^a
Self-Selection	194.7	202.4	196.8	182.0 ^b	175.7 ^b	178.9 ^b	188.4 ^b
SEM	0.83	2.89	2.19	2.73	2.04	2.78	1.46
Energy concentration (kcal of ME/kg)							
Control	2910.4 ^a	2910.4 ^a	2910.4 ^a	2910.4 ^a	2910.4 ^a	2910.4 ^a	2910.4 ^a
Self-Selection	2951.8 ^b	3003.5 ^b	3033.5 ^b	3026.2 ^b	3072.9 ^b	3069.3 ^b	3026.2 ^b
SEM	5.63	2.84	10.92	6.17	2.70	3.49	2.41
Utilization of CP (g of CP/g BWG)							
Control	0.38	0.46	0.51 ^a	0.51	0.66	0.93	0.57
Self-Selection	0.38	0.49	0.63 ^b	0.54	0.53	0.57	0.52
SEM	0.06	0.06	0.06	0.06	0.06	0.06	0.02
Utilization of energy (kcal of ME/g BWG)							
Control	5.65	6.76 ^a	7.47 ^a	7.50 ^a	9.78	13.68 ^a	8.47
Self-Selection	5.76	7.35 ^b	9.65 ^b	9.07 ^b	9.21	9.79 ^b	8.47
SEM	0.209	0.186	0.344	0.381	1.426	1.179	0.287

Note: ¹= Control diet (a. starter diet: 1-6 w= 2910 kcal of ME/kg and 19.7 g of CP/kg; b. grower diet: 7-12 w= 2854 kcal of ME/kg and 17.5 g of CP/kg; c. developer diet: 13-15 w= 2777 kcal of ME/kg and 16.1 g of CP/kg; d. pre-laying diet: 16-17 w= 2797 kcal of ME/kg and 16.5 g of CP/kg; and e. laying diet: \geq 18 w= 2814 kcal of ME/kg and 18.4 g of CP/kg). Self-selection feed= (1) the control feed; (2) HEHP (high energy-high protein diet (3101 kcal of ME/kg and 23.0 g of CP/kg); (3) HELP (high energy-low protein diet (3133 kcal of ME/kg and 14.3 g of CP/kg); (4) LEHP (low energy-high protein diet (2638 kcal of ME/kg and 23.4 g of CP/kg); (5) LELP (low energy-low protein diet (2677 kcal of ME/kg and 14.6 g of CP/kg).

fed hens at the 3rd week of age, and ME utilization was higher in choice-fed chicks at the 3rd and the 4th weeks of ages and lower at the 6th week of age (Table 3). CP and ME utilizations were influenced by week (Table 2a). CP and ME utilization increased from the 1st week of age until the 6th week of age (Figure 1). There were also interactions between the dietary treatments and the weeks of age on CP and ME utilization (Table 2a). CP and ME utilizations showed that the differences were significantly higher in the last week of age during the starter period (Figure 2).

Grower period. Table 2b presents the probability values of all parameters and Table 4 presents the differences in performance of the pullets every week of age at different dietary treatments. There was an effect of treatments on FI (Table 2b). FI was lower in the choice-fed pullets (Table 4). The feeding method did not affect protein and energy intake (Table 2b). Feed intake and protein and

energy intakes were affected by weeks of age during the grower period (Table 2b and 4). They were increased at the 9th week of age and remained stable until the end of the grower period (Figure 3). There was no interaction between the dietary treatments and the week of age on feed, protein, and energy intake (Table 2b) during the grower period.

BWG was not affected by treatments ($p>0.05$, Table 2b), but BWG was affected by the weeks of age ($p=0.01$, Table 2b). BWG increased at the 9th week of age, remained stable until the 11th week of age, and declined significantly at the 12th week of age (Figure 4). However, there was no interaction between the dietary treatments and the weeks of age on BWG (Table 2b).

CP and ME concentrations were affected by the dietary treatment (Table 2b). CP and ME concentrations were significantly higher in the choice-fed hens than the control-fed pullets (Table 4). CP and ME concentrations were affected by the weeks of age (Table 2b). CP con-

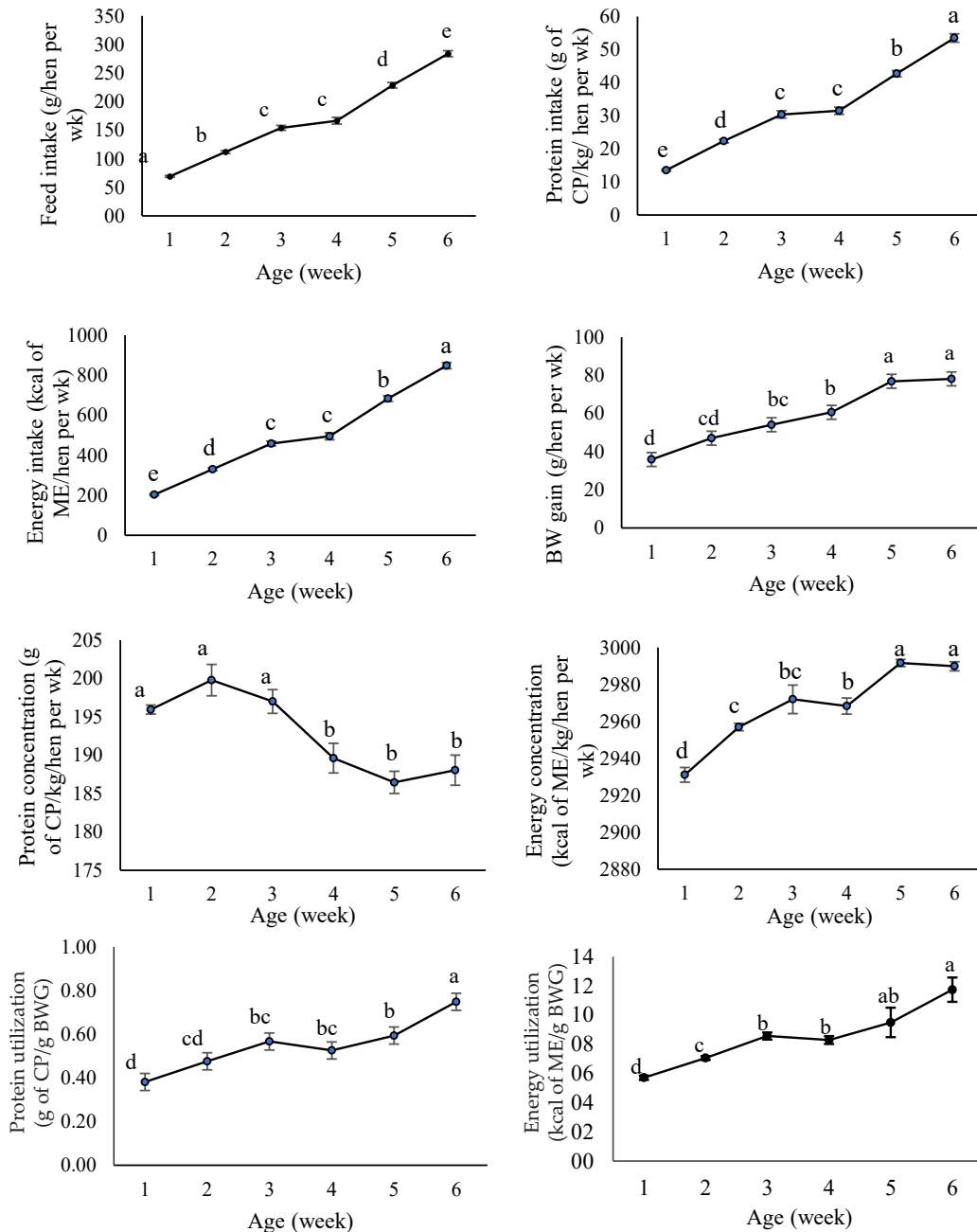


Figure 1. Least square means for traits that show a significant week effect in starter period. Means without a common letter (a-d) differ significantly ($p < 0.05$)

centration increased at the 8th week of age and remained stable after the 9th week of age onward (Figure 3). ME concentration increased significantly at the 10th week of age and was not significantly increased until the 12th week (Figure 4). There were interaction effects between the dietary treatments and the weeks of age on the CP and ME concentrations (Table 2b). Interaction between the dietary treatments and the week of age showed that CP concentration in the choice-fed pullets was significantly higher from the 8th until the 11th week of age. However, ME concentration was much higher in the choice-fed hens from the beginning of the grower period trial (Figure 4).

CP and ME utilizations were not influenced by the dietary treatments (Table 2b). CP and ME utilizations

were influenced by the week of age (Table 2b). The lowest CP and ME utilizations were found at the 7th week of age and the highest CP and ME utilization were found at the 12th week of age (Figure 3). There were no interactions between the dietary treatments and the weeks of age on CP and ME utilization (Table 2b).

Developer period. Table 2c presents the probability values of all parameters and Table 5 presents the differences in performance of the pullets every week of age at different dietary treatments. There was an effect of treatment on FI (Table 2c). FI was lower in the choice-fed pullets (Table 5). The feeding method did not affect protein and energy intakes (Table 2c). Feed intake as well as protein and energy intakes were affected by the week of

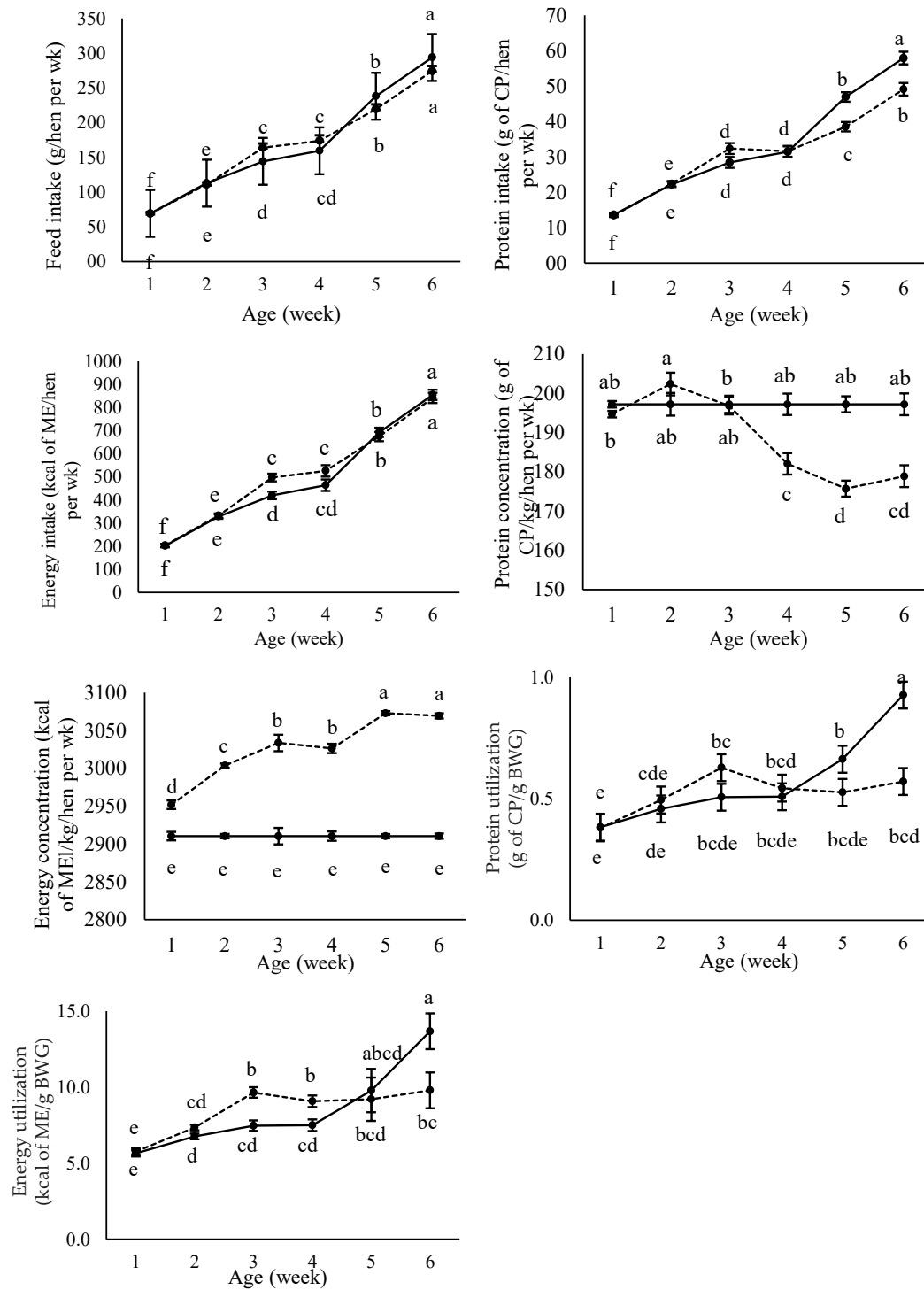


Figure 2. Least square means for traits that show a significant dietary treatments and week interaction in starter period. Means within and between lines without a common letter (a-e) differ significantly ($p < 0.05$). Control diet (a. starter diet: 0-6 w= 2910 kcal of ME/kg and 19.7 g of CP/kg; b. grower diet: 7-12 w= 2854 kcal of ME/kg and 17.5 g of CP/kg; c. developer diet: 13-15 w= 2777 kcal of ME/kg and 16.1 g of CP/kg; d. pre-laying diet: 16-17 w= 2797 kcal of ME/kg and 16.5 g of CP/kg; and e. laying diet: ≥ 18 w= 2814 kcal of ME/kg and 18.4 g of CP/kg). Choice diet = (1) the control diet, (2) HEHP (high energy- high protein diet (3101 kcal of ME/kg and 23.0 g of CP/kg), (3) HELP (high energy-low protein diet (3133 kcal of ME/kg and 14.3 g of CP/kg), (4) LEHP (low energy-high protein diet (2638 kcal of ME/kg and 23.4 g of CP/kg), or (5) LELP (low energy-low protein diet (2677 kcal of ME/kg and 14.6 g of CP/kg). Control (—•—); Self-selection (---•---).

age (Table 2c and 7) and were increased at the 15th week of age (Figure 5). There was an interaction between the dietary treatments and week of age on feed and energy intakes (Table 2c). Interaction between the dietary treat-

ments and the week of age showed that the differences were significantly higher in week 15 of age for feed and energy intakes (Figure 6).

Table 4. Least squares mean of performance variables in local female chickens from 7 to 12 week of age as affected by dietary treatment¹

Variables	Week						Average
	7	8	9	10	11	12	
Feed intake (g/bird/week)							
Control	337.1	331.2 ^a	390.9	389.2	429.1 ^a	411.5	381.5 ^a
Self-Selection	312.8	289.5 ^b	371.8	398.4	363.4 ^b	406.7	357.1 ^b
SEM	15.09	15.09	15.09	15.09	15.09	15.09	6.16
Protein intake (g of CP/bird/week)							
Control	58.8	57.8	68.2	67.9	74.9	71.8	66.6
Self-Selection	55.6	54.2	67.7	74.6	67.9	73.3	65.6
SEM	2.65	2.65	2.65	2.65	2.65	2.65	1.08
Energy intake (kcal of ME/kg/bird/week)							
Control	961.9	945.1	1115.4	1110.7	1224.3	1174.2	1088.6
Self-Selection	959.6	889.9	1143.1	1229.5	1121.5	1258.3	1100.3
SEM	44.98	44.98	44.98	44.98	44.98	44.98	18.36
BWG (g/bird/week)							
Control	89.5	76.9	99.7	84.2	88.6 ^a	65.2 ^a	84.0
Self-Selection	75.0	81.1	91.3	108.4	76.9 ^b	79.1 ^b	85.3
SEM	7.25	10.31	13.56	13.66	3.09	4.05	2.01
Protein concentration (g of CP/kg)							
Control	174.5	174.5 ^a	174.5 ^a	174.5 ^a	174.5 ^a	174.5	174.5 ^a
Self-Selection	178.1	187.9 ^b	182.6 ^b	187.3 ^b	187.4 ^b	180.0	183.9 ^b
SEM	1.93	1.21	1.47	1.48	2.90	2.50	1.04
Energy concentration (kcal of ME/kg)							
Control	2853.5 ^a	2853.5 ^a	2853.5 ^a	2853.5 ^a	2853.5 ^a	2853.5 ^a	2853.5 ^a
Self-Selection	3067.5 ^b	3073.0 ^b	3078.3 ^b	3086.1 ^b	3085.1 ^b	3094.2 ^b	3080.7 ^b
SEM	3.38	2.98	8.56	2.68	2.66	2.8	1.96
Utilization of CP (g of CP/g BWG)							
Control	0.66	0.87	0.80	1.07	0.85	1.12 ^a	0.89
Self-Selection	0.83	0.72	0.82	0.72	0.89	0.93 ^b	0.82
SEM	0.09	0.16	0.15	0.23	0.04	0.05	0.05
Utilization of energy (kcal of ME/g BWG)							
Control	10.78	14.22	13.01	17.44	13.86	18.29	14.60
Self-Selection	14.27	11.82	13.90	11.90	14.74	16.09	13.79
SEM	1.663	2.639	2.501	3.820	0.715	0.91	0.755

Note: ¹= Control diet (a. starter diet: 1-6 w= 2910 kcal of ME/kg and 19.7 g of CP/kg; b. grower diet: 7-12 w= 2854 kcal of ME/kg and 17.5 g of CP/kg; c. developer diet: 13-15 w= 2777 kcal of ME/kg and 16.1 g of CP/kg; d. pre-laying diet: 16-17 w= 2797 kcal of ME/kg and 16.5 g of CP/kg; and e. laying diet: \geq 18 w= 2814 kcal of ME/kg and 18.4 g of CP/kg). Self-selection feed= (1) the control feed; (2) HEHP (high energy-high protein diet (3101 kcal of ME/kg and 23.0 g of CP/kg); (3) HELP (high energy-low protein diet (3133 kcal of ME/kg and 14.3 g of CP/kg); (4) LEHP (low energy-high protein diet (2638 kcal of ME/kg and 23.4 g of CP/kg); (5) LELP (low energy-low protein diet (2677 kcal of ME/kg and 14.6 g of CP/kg).

BWG was affected by the feeding method ($p=0.035$, Table 2c), and BWG was higher in the choice-fed pullets ($p<0.035$; Table 5). BWG was affected by the week of age ($p=0.006$, Table 2c). BWG increased at the 14th week of age and decreased at the 15th week (Figure 6). However, there was no interaction between the dietary treatments and the week of age on BWG (Table 2c).

CP and ME concentrations were affected by the dietary treatments (Table 2c). CP and ME concentrations were significantly higher in the choice-fed pullets than the control-fed pullets (Table 5). There was no significant effect of a week of age, and there was no interaction effect between the dietary treatment and the week of age on CP and ME concentrations (Table 2c).

CP and ME utilizations were not influenced by the dietary treatments (Table 2c and 7). CP and ME utilizations were influenced by the week of age (Table 2c). CP and ME utilizations declined at the 14th week of age and

increased at the 15th week of age (Figure 6). There was no interaction between dietary treatments and the week of age on CP and ME utilization (Table 2c and 5).

Pre-laying period. Table 2d presents the probability values of all parameters, and Table 6 shows the differences in performance of the pullets every week of age at different dietary treatments.

There was an effect of treatment on FI ($p=0.017$; Table 2d). FI was lower in the choice-fed pullets (Table 6). The feeding method did not affect protein and energy intakes (Table 2d). Feed intake, as well as protein and energy intakes were affected by the weeks of age (Table 2d and 6) and were increased at the 18th week of age onward (Figure 7). There was an interaction between the dietary treatment and the week of ages on feed, protein, and energy intakes (Table 2d). Interaction between the dietary treatment and the week of age showed that the

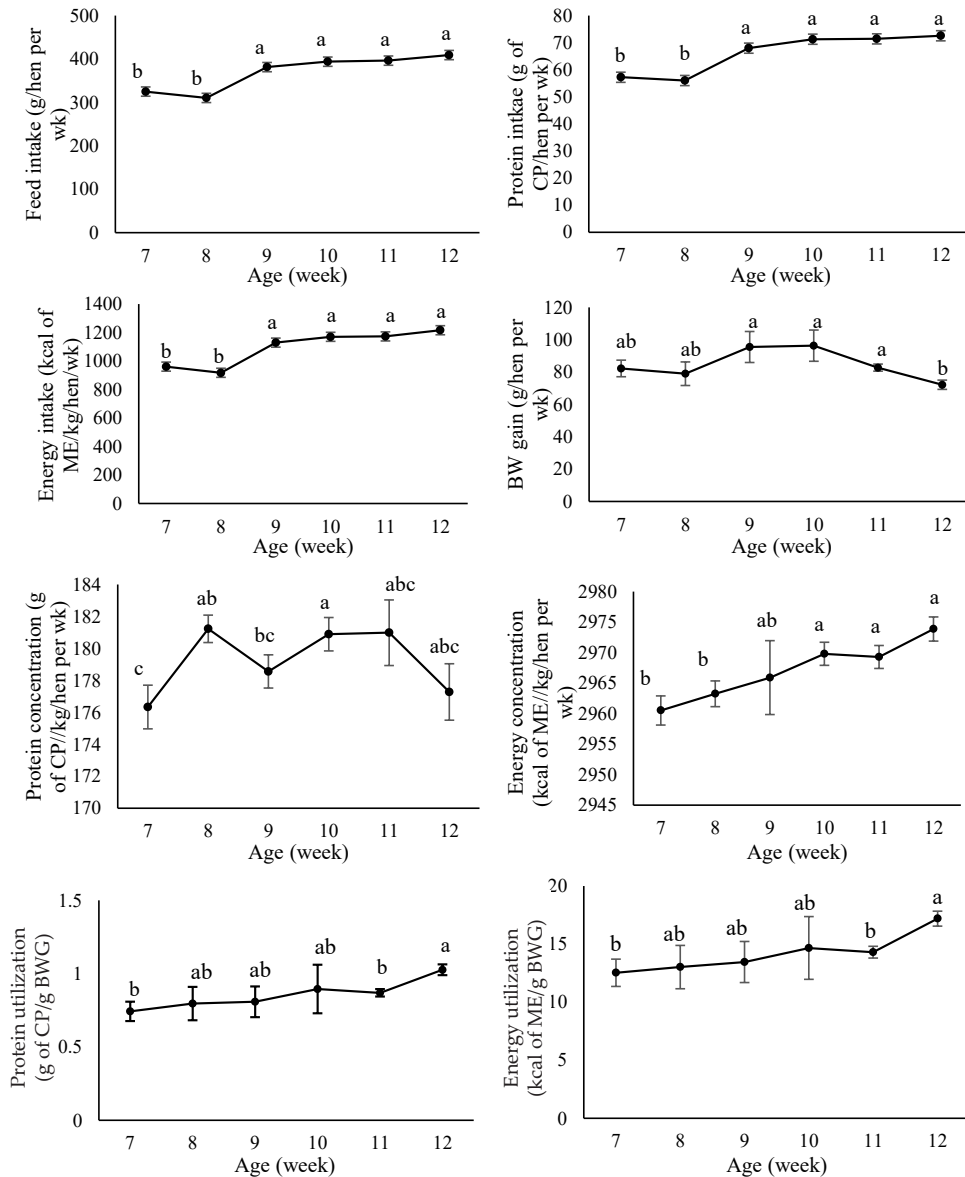


Figure 3. Least square means for traits that show a significant week effect in grower period. Means without a common letter (a-c) differ significantly ($p < 0.05$).

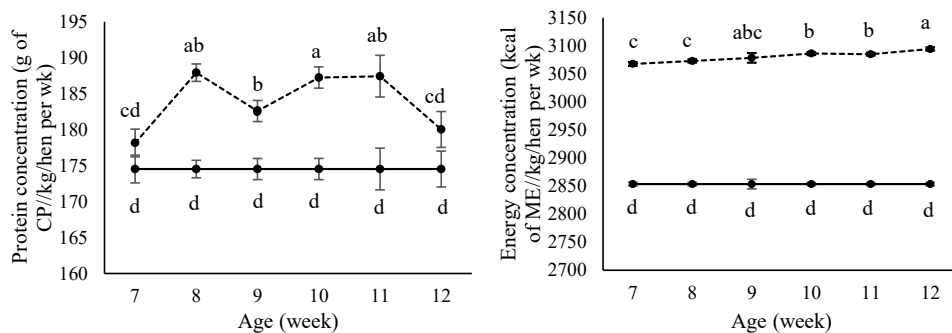


Figure 4. Least square means for traits that show a significant dietary treatments and week interaction in grower period. Means within and between lines without a common letter (a-d) differ significantly ($p < 0.05$). Control diet (a. starter diet: 0-6 w= 2910 kcal of ME/kg and 19.7 g of CP/kg; b. grower diet: 7-12 w= 2854 kcal of ME/kg and 17.5 g of CP/kg; c. developer diet: 13-15 w= 2777 kcal of ME/kg and 16.1 g of CP/kg; d. pre-laying diet: 16-17 w= 2797 kcal of ME/kg and 16.5 g of CP/kg; and e. laying diet: ≥ 18 w= 2814 kcal of ME/kg and 18.4 g of CP/kg). Choice diet = (1) the control diet, (2) HEHP (high energy- high protein diet (3101 kcal of ME/kg and 23.0 g of CP/kg), (3) HELP (high energy-low protein diet (3133 kcal of ME/kg and 14.3 g of CP/kg), (4) LEHP (low energy-high protein diet (2638 kcal of ME/kg and 23.4 g of CP/kg), or (5) LELP (low energy-low protein diet (2677 kcal of ME/kg and 14.6 g of CP/kg). Control (—●—); Self-selection (---●---).

Table 5. Least squares mean of performance variables in local female chickens from 13 to 15 week of age as affected by dietary treatment¹

Variables	Week			Average
	13	14	15	
Feed intake (g/bird/week)				
Control	468.4 ^a	428.3	552.3 ^a	483.0 ^a
Self-Selection	406.5 ^b	408.2	415.2 ^b	410.0 ^b
SEM	10.46	23.29	12.68	9.89
Protein intake (g of CP/bird/week)				
Control	75.5	69	89.0 ^a	77.8
Self-Selection	74.3	74.7	78.6 ^b	75.9
SEM	2.02	4.49	2.31	1.8
Energy intake (kcal of ME/kg/bird/week)				
Control	1300.6	1189.4	1533.8 ^a	1341.3
Self-Selection	1258.3	1260.5	1282.4 ^b	1267.1
SEM	29.7	68.61	35.54	28.74
BWG (g/bird/week)				
Control	60.9	75.2	38.6	58.2 ^a
Self-Selection	64.8	77.1	50.2	64.0 ^b
SEM	2.55	6.11	5.47	1.74
Protein concentration (g/kg)				
Control	161.1 ^a	161.1 ^a	161.1 ^a	161.1 ^a
Self-Selection	182.8 ^b	182.5 ^b	189.2 ^b	184.8 ^b
SEM	2.76	3.03	1.29	1.05
Energy concentration (kcal of ME/kg)				
Control	2776.9 ^a	2776.9 ^a	2776.9 ^a	2776.9 ^a
Self-Selection	3095.7 ^b	3088.8 ^b	3088.6 ^b	3091.0 ^b
SEM	3.01	3.01	3.01	1.74
Utilization of CP (g of CP/g BWG)				
Control	1.24	0.94	2.9	1.69
Self-Selection	1.16	0.99	1.63	1.26
SEM	0.06	0.07	0.59	0.2
Utilization of energy (kcal of ME/g BWG)				
Control	21.41	16.17	49.97	29.18
Self-Selection	19.7	16.61	26.57	20.96
SEM	1.024	0.987	10.022	3.249

Note: ¹= Control diet (a. starter diet: 1-6 w= 2910 kcal of ME/kg and 19.7 g of CP/kg; b. grower diet: 7-12 w= 2854 kcal of ME/kg and 17.5 g of CP/kg; c. developer diet: 13-15 w= 2777 kcal of ME/kg and 16.1 g of CP/kg; d. pre-laying diet: 16-17 w= 2797 kcal of ME/kg and 16.5 g of CP/kg; and e. laying diet: ≥ 18 w= 2814 kcal of ME/kg and 18.4 g of CP/kg). Self-selection feed= (1) the control feed; (2) HEHP (high energy-high protein diet (3101 kcal of ME/kg and 23.0 g of CP/kg); (3) HELP (high energy-low protein diet (3133 kcal of ME/kg and 14.3 g of CP/kg); (4) LEHP (low energy-high protein diet (2638 kcal of ME/kg and 23.4 g of CP/kg); (5) LELP (low energy-low protein diet (2677 kcal of ME/kg and 14.6 g of CP/kg).

differences were significantly higher in the last week of age (Figure 8).

BWG was significantly affected by the dietary treatments ($p=0.023$, Table 2d) and BWG was higher in the choice-fed pullets (Table 6). BWG was affected by the week of age ($p<0.001$, Table 2d). BWG decreased from the 16th to the 18th week of age and increased again until the 20th. After that, BWG decreased significantly until the 22nd week of age (Figure 7). There was an interaction effect between the dietary treatment and the week of age on BWG (Table 2d).

CP and ME concentrations were affected by the dietary treatments (Table 2d). CP and ME concentrations were significantly higher in the choice-fed pullets than the control-fed pullets (Table 6). CP and ME concentrations were affected by the week of age (Table 2d). CP concentration increased at the 18th week of age and remained stable until the 22nd week (Figure 7). ME concentration increased significantly after the 17th week of age onward (Figure 7). There were interaction effects between the dietary treatments and the week of age on CP and ME concentrations (Table 2d). Interaction between the dietary treatments and week of age showed that CP concentration in the choice-fed pullets was significantly higher than the 16th until the 21st. However, ME concentration was much higher in the choice-fed pullets from the beginning of the pre-laying period trial (Figure 4).

CP and ME utilizations were not influenced by the dietary treatments (Table 2d and 6). CP and ME utilizations were affected by the week of age (Table 2d). CP and ME utilization increased from the 16th to the 18th weeks of age and decreased until the 20th. After that, they increased until the 22nd week of age with the same level as at the 18th week (Figure 7). There was no interaction between the dietary treatments and the week of age on CP and ME utilization (Table 2d and 6).

The correlations between energy and CP levels with BWG are presented in Table 7. ME level of control dietary treatment has a negative correlation with BWG during a starter (-0.231) and a grower (-0.777) periods and a positive correlation during developer (0.922) and pre-laying (0.658) periods. On the other hand, all the ME level of the choice dietary treatment has a positive correlation with BWG during all ages (0.083 to 0.909). CP level of control dietary treatment has a negative correlation with BWG during the starter period (0.624) and a positive correlation during the grower (0.362), developer (0.922), and pre-laying (0.658) periods. While CP level of the choice dietary treatment has a negative correlation with BWG during the starter (-0.819) and developer (-0.908) periods and a positive correlation during the grower (0.396) and pre-laying (0.325) periods.

DISCUSSION

The cyclical temperature and relative humidity in the barn during the experiment depended on the environmental climate conditions. When the temperature in the barn rises, the relative humidity falls and vice versa. Dropping in relative humidity at the time of high temperature could help the bird release the heat load by evaporation to the environment, especially during the hot period that generally happens between 12:00 to 17:00 h. We observed that the birds were changing their behavior and panting when the temperature raised above 28°C, and it depicted that the temperature was above the normal range for them. Therefore, the environmental temperature conditions indicate that the birds experience heat stress during the time of hot period of the day because changing the behavior and panting are indicators of heat stress (Sugiharto *et al.*, 2017; Wang *et al.*, 2018) and the birds spent more time for panting and drinking and less time for walking and

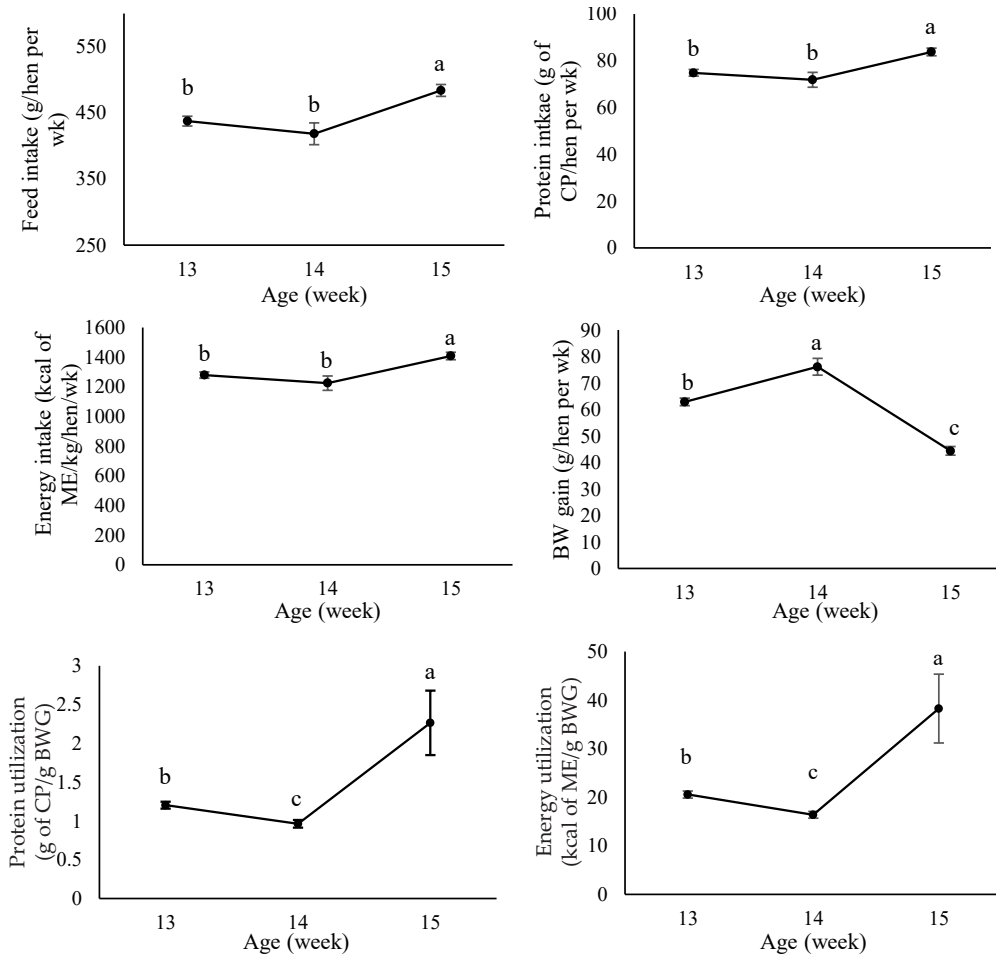


Figure 5. Least square means for traits that show a significant week effect in developer period. Means without a common letter (a-c) differ significantly ($p < 0.05$).

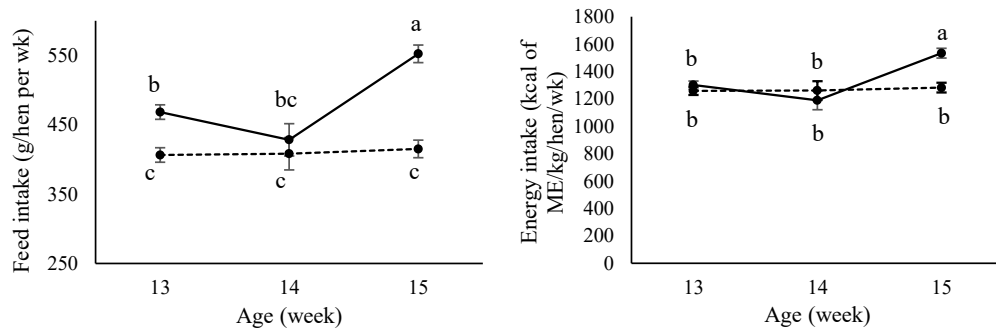


Figure 6. Least square means for traits that show a significant dietary treatments and week interaction in developer period. Means within and between lines without a common letter (a-c) differ significantly ($p < 0.05$). Control diet (a. starter diet: 0-6 w= 2910 kcal of ME/kg and 19.7 g of CP/kg; b. grower diet: 7-12 w= 2854 kcal of ME/kg and 17.5 g of CP/kg; c. developer diet: 13-15 w= 2777 kcal of ME/kg and 16.1 g of CP/kg; d. pre-laying diet: 16-17 w= 2797 kcal of ME/kg and 16.5 g of CP/kg; and e. laying diet: ≥ 18 w= 2814 kcal of ME/kg and 18.4 g of CP/kg). Choice diet= (1) the control diet, (2) HEHP (high energy- high protein diet (3101 kcal of ME/kg and 23.0 g of CP/kg), (3) HELP (high energy-low protein diet (3133 kcal of ME/kg and 14.3 g of CP/kg), (4) LEHP (low energy-high protein diet (2638 kcal of ME/kg and 23.4 g of CP/kg), or (5) LELP (low energy-low protein diet (2677 kcal of ME/kg and 14.6 g of CP/kg). Control (—●—); Self-selection (---●---).

feeding (He *et al.*, 2018). High ambient temperature has a negative effect on body weight and feed intake of laying hens (He *et al.*, 2018) and broilers (Syafwan *et al.*, 2011, 2012; Wang *et al.*, 2018).

The choice-fed hens in the present study consumed a much lower amount of feed than the control-fed hens during the grower until pre-laying periods, and overall they consumed feed 7% lower than the control-fed hens. The lower feed intake in the choice-fed hens was related

Table 6. Least squares mean of performance variables in local female chickens from 16 to 22 week of age as affected by dietary treatment¹

Variables	Week							
	16	17	18	19	20	21	22	Average
Feed intake (g/bird/week)								
Control	504.6 ^a	414.5	514.9 ^a	537.4	587.0 ^a	558.5	580.6 ^a	528.2 ^a
Self-Selection	417.4 ^b	364.8	414.2 ^b	539.7	520.6 ^b	563.7	656.3 ^b	496.6 ^b
SEM	10.88	18.63	23.27	46.97	9.67	18.95	18.71	8.58
Protein intake (g of CP/hen/week)								
Control	83.2	68.3	94.7 ^a	98.8	107.9 ^a	102.7	106.7 ^a	94.6
Self-Selection	77.5	68.7	78.0 ^b	103.4	97.2 ^b	107.5	122.9 ^b	93.6
SEM	2.06	2.93	4.31	8.97	1.63	3.40	3.32	1.52
Energy intake (kcal of ME/kg/bird/week)								
Control	1411.2 ^a	1159.2	1449.1 ^a	1512.2	1652	1571.7	1527.9 ^a	1484.1
Self-Selection	1290.5 ^b	1102.9	1267.9 ^b	1663.1	1602.2	1734.4	2034.4 ^b	1527.9
SEM	33.71	52.31	65.99	147.31	29.65	56.26	26.16	26.15
BWG (g/bird/week)								
Control	37.7 ^a	33.2	33.6	66.5	74.4	57.7 ^a	57.6	51.34 ^a
Self-Selection	52.2 ^b	31.9	37.1	74.5	82.5	79.0 ^b	46.1	57.59 ^b
SEM	5.05	5.05	5.05	5.05	5.05	5.05	5.05	1.90
Protein concentration (g of CP/kg)								
Control	164.9 ^a	164.9 ^a	183.9	183.9 ^a	183.9 ^a	183.9 ^a	183.9	178.4 ^a
Self-Selection	185.6 ^b	188.8 ^b	188.3	191.6 ^b	186.9 ^b	190.9 ^b	187.4	188.5 ^b
SEM	1.12	2.37	1.78	1.28	0.95	1.05	1.21	0.55
Energy concentration (kcal of ME/kg)								
Control	2796.8 ^a	2796.8 ^a	2814.1 ^a	2814.1 ^a	2814.1 ^a	2814.1 ^a	2814.1 ^a	2809.1 ^a
Self-Selection	3091.5 ^b	3023.6 ^b	3061.4 ^b	3078.7 ^b	3077.8 ^b	3077.4 ^b	3098.7 ^b	3072.7 ^b
SEM	4.19	5.59	3.92	4.61	4.26	3.49	4.06	2.31
Utilization of CP (g of CP/g BWG)								
Control	2.36 ^a	2.24	2.96	1.53	1.46 ^a	1.85 ^a	2.14	1.85
Self-Selection	1.56 ^b	2.35	2.19	1.41	1.19 ^b	1.38 ^b	2.84	1.96
SEM	0.19	0.33	0.3	0.14	0.05	0.14	0.10	0.10
Utilization of energy (kcal of ME/g BWG)								
Control	40.04 ^a	37.92	45.31	23.43	22.33	28.32	32.75	30.20
Self-Selection	26.06 ^b	37.90	35.72	22.80	19.66	22.28	46.97	33.05
SEM	3.271	5.501	4.765	2.381	0.869	2.197	4.947	1.62

Note: ¹= Control diet (a. starter diet: 1-6 w= 2910 kcal of ME/kg and 19.7 g of CP/kg; b. grower diet: 7-12 w= 2854 kcal of ME/kg and 17.5 g of CP/kg; c. developer diet: 13-15 w= 2777 kcal of ME/kg and 16.1 g of CP/kg; d. pre-laying diet: 16-17 w= 2797 kcal of ME/kg and 16.5 g of CP/kg; and e. laying diet: ≥ 18 w= 2814 kcal of ME/kg and 18.4 g of CP/kg). Self-selection feed= (1) the control feed; (2) HEHP (high energy-high protein diet (3101 kcal of ME/kg and 23.0 g of CP/kg); (3) HELP (high energy-low protein diet (3133 kcal of ME/kg and 14.3 g of CP/kg); (4) LEHP (low energy-high protein diet (2638 kcal of ME/kg and 23.4 g of CP/kg); (5) LELP (low energy-low protein diet (2677 kcal of ME/kg and 14.6 g of CP/kg).

Table 7. Correlation between energy (kcal of ME/kg) and protein (g/kg) with body weight gain (g).

Period	Control				Choice			
	Energy	BWG	Correlation	Sig.	Energy	BWG	Correlation	Sig.
Starter	2910	58.8	-0.231	0.659	3026	58.7	0.909	0.011
Grower	2854	84	-0.777	0.068	3081	85.3	0.257	0.622
Developer	2777	58.2	0.922	0.252	3091	64	0.083	0.946
Pre-laying	2809	51.5	0.658	0.108	3073	57.5	0.461	0.297
	CP	BWG	Correlation	Sig.	CP	BWG	Correlation	Sig.
Starter	197.2	58.8	-0.642	0.168	188.4	58.7	-0.819	0.046
Grower	174.5	84	0.362	0.481	183.8	85.3	0.396	0.436
Developer	161.1	58.2	0.922	0.252	184.8	64	-0.908	0.274
Pre-laying	178.44	51.5	0.658	0.108	188.5	57.5	0.325	0.476

Note: BWG= body weight gain; CP= crude protein.

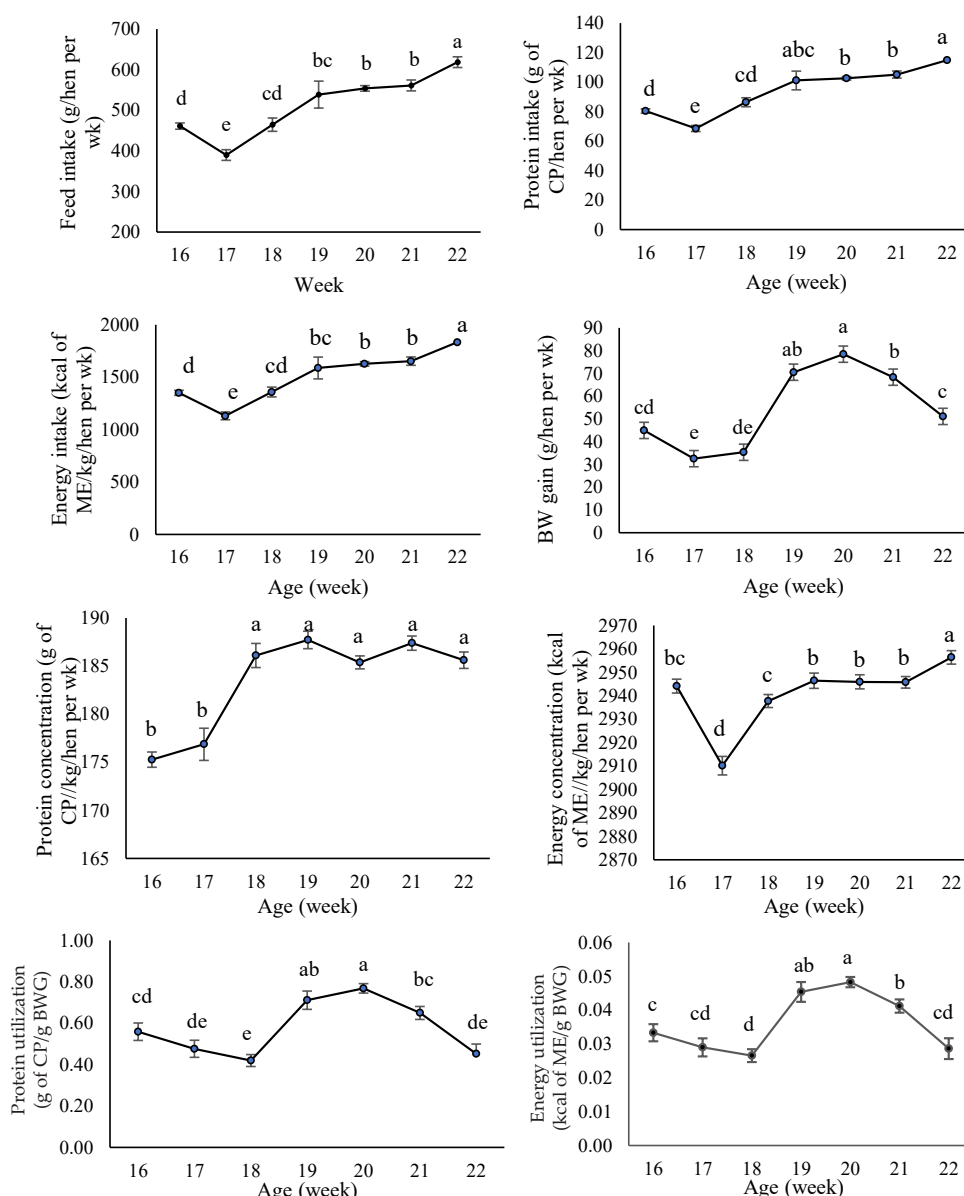


Figure 7. Least square means for traits that show a significant week effect in pre-laying period. Means without a common letter (a-e) differ significantly ($p < 0.05$).

to a higher concentration of CP and ME in the ingested feed in all periods (Table 3, 4, 5, and 6). This result agrees with another study in the broiler that feeds intake decreased with the increased protein and lipid concentrations in the broiler diet. Dietary protein and lipid concentration had a more pronounced impact on feed intake than starch, and feed intakes were reduced with the increased protein concentrations (Liu *et al.*, 2016; Khoddami *et al.*, 2018). The birds will reduce protein intake under a high-temperature condition to avoid the heat load (Syafwan *et al.*, 2011). Higher lipid concentration reduces feed intake causing ‘ileal brake’ triggered by the lipid. Gastrointestinal motility modulates and delays gastric emptying by decreasing the frequency of the gastric cycle, increasing duodenogastric refluxes, and elongating the migrating myoelectric complex when the intraluminal infusion with lipids (Khoddami *et al.*, 2018).

Although the hens on the choice-fed diets consumed much less feed, overall CP and ME intakes were similar to those offered the control diet in all periods. The preferences of the hens to diet to meet the CP and ME requirements during the whole period were higher from HEHP diet (41.59%), HELP diet (41.37%), and control diet (11.79%) and lower from LEHP diet (2.69%) and LELP diet (2.56%) (Figure 9). The shifted preference to a high-energy diet was also observed in broilers at high temperatures (Syafwan *et al.*, 2012). The higher preference for a high-energy diet and lower preference for a high-CP diet suggest that the hens have an ability to adjust the nutrients’ needs. Such an ability was observed by Fanatico *et al.* (2013), where the dietary low CP feedstuff-fed broiler chickens were able to gain some nutrients from the scavenging yard emulating the final body weights of the dietary 20% CP-fed chickens. Capability in adjusting energy intake by consuming

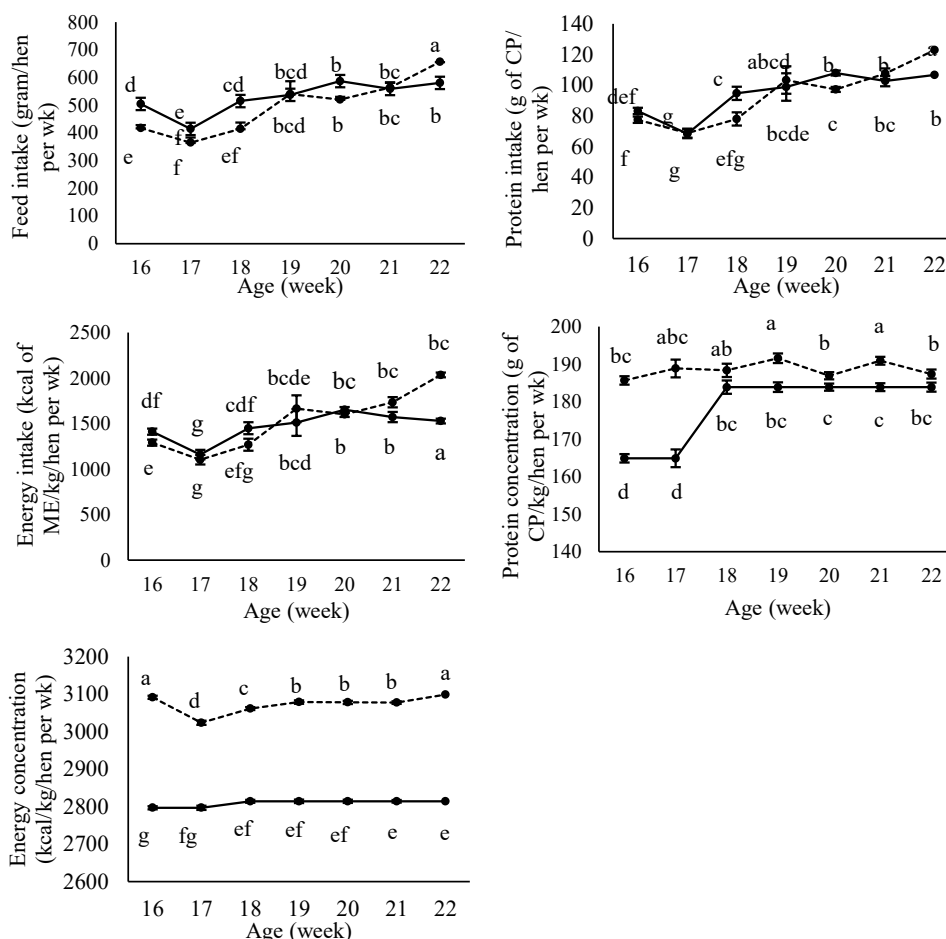


Figure 8. Least square means for traits that show a significant dietary treatments and week interaction in pre-laying period. Means within and between lines without a common letter (a-g) differ significantly ($p < 0.05$). Control diet (a. starter diet: 0-6 w= 2910 kcal of ME/kg and 19.7 g of CP/kg; b. grower diet: 7-12 w= 2854 kcal of ME/kg and 17.5 g of CP/kg; c. developer diet: 13-15 w= 2777 kcal of ME/kg and 16.1 g of CP/kg; d. pre-laying diet: 16-17 w= 2797 kcal of ME/kg and 16.5 g of CP/kg; and e. laying diet: ≥ 18 w= 2814 kcal of ME/kg and 18.4 g of CP/kg). Choice diet = (1) the control diet, (2) HEHP (high energy- high protein diet (3101 kcal of ME/kg and 23.0 g of CP/kg), (3) HELP (high energy-low protein diet (3133 kcal of ME/kg and 14.3 g of CP/kg), (4) LEHP (low energy-high protein diet (2638 kcal of ME/kg and 23.4 g of CP/kg), or (5) LELP (low energy-low protein diet (2677 kcal of ME/kg and 14.6 g of CP/kg). Control (—●—); Self-selection (---■---).

more of a high-energy diet has also been reported in broiler chickens when given free choice feeding (Syafwan *et al.*, 2012).

Bodyweight gain of female Arabic hens was higher when they consumed a high concentration of CP as was found in the choice-fed hens (Table 2b-d). The higher growth rate of chickens was also observed when they consumed a high-protein diet (Fanatico *et al.*, 2016). The effect of dietary protein on the growth rate of broiler chickens was affected by the concentration of lipid in the diet (Liu *et al.*, 2017). It seems that female Arabic hens in our study were tolerant in a high cyclic ambient temperature, although they consumed a higher concentration of CP than the standard concentration of CP in the control diet. Since the temperature in the barn followed the natural cyclic temperature, the hens could make some advantages of nutrients for growth by the time of the day less stressful. The bodyweight of broilers was lower when they were kept at a constant high temperature than when they were kept at a high cyclic

temperature and reduced meat quality (Quinteiro-Filho *et al.*, 2010; Zhang *et al.*, 2012).

Treatments had a very significant effect on CP and ME concentrations of the diet consumed by the hens (Table 2a-d). Those given a choice to feed could likely maintain its CP need (on average: 186.7 vs. 180.1 g/kg; $p < 0.001$). Regarding the dietary ME concentration, Tables 3, 4, 5, and 6 depicted that the ME in the diet consumed by the choice group of hens was higher than those by the control group of hens (on average: 3065 kcal of ME/kg vs. 2844 kcal/kg; $p < 0.001$). These data support the fact that hens were able to select diets containing nutrients of their needs. The higher CP and ME concentrations of the feed consumed by self-selection group than by the control group indicated hen's ability to compose available diets to fulfill the requirement of protein and energy. These results reveal that CP requirement for female Arabic hens is higher after the starter period, and ME requirement is higher from the starter period than in the control diet for Brown Laying hens.

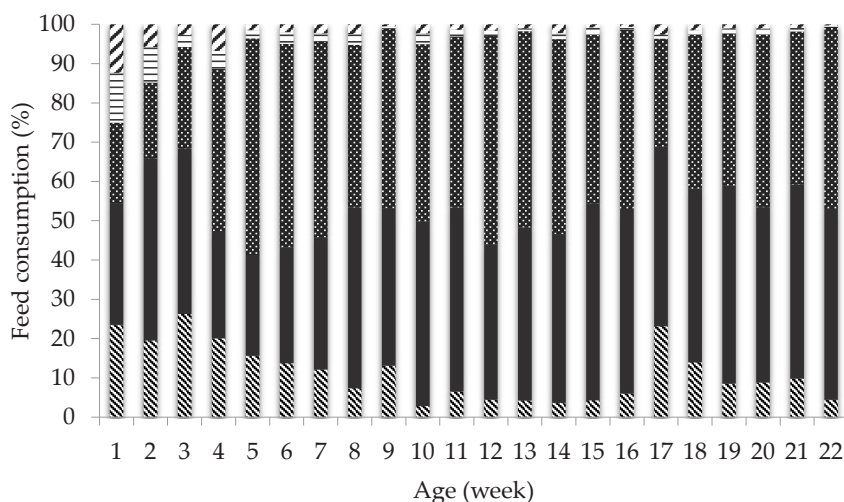


Figure 9. Consumption of a control diet, HEHP (high energy-high protein), HELP (high energy-low protein), LEHP (low energy-high protein) and LELP (low energy-low protein) as a portion of feed intake. Control diet (a. starter diet: 0-6 w= 2910 kcal of ME/kg and 19.7 g of CP/kg; b. grower diet; 7-12 w= 2854 kcal of ME/kg and 17.5 g of CP/kg; c. developer diet: 13-15 w= 2777 kcal of ME/kg and 16.1 g of CP/kg; d. pre-laying diet: 16-17 w= 2797 kcal of ME/kg and 16.5 g of CP/kg; and e. laying diet: \geq 18 w= 2814 kcal of ME/kg and 18.4 g of CP/kg). Choice diet = (1) the control diet, (2) HEHP (high energy- high protein diet (3101 kcal of ME/kg and 23.0 g of CP/kg), (3) HELP (high energy-low protein diet (3133 kcal of ME/kg and 14.3 g of CP/kg), (4) LEHP (low energy-high protein diet (2638 kcal of ME/kg and 23.4 g of CP/kg), or (5) LELP (low energy-low protein diet (2677 kcal of ME/kg and 14.6 g of CP/kg). Control HEHP HELP = LEHP LELP.

Assessment of efficiency of protein and energy utilization enables a better understanding of the effect of dietary treatments beyond insights that grow. The utilization of CP and ME in this study was similar between the choice-fed hens and the control-fed hens. Every week, the decline in protein and energy efficiency ratio was due to the decline in BW gain while the intake of protein and energy increased. The similarity in the utilization of CP and ME indicated that the effectivity in utilizing the CP and ME in the diet composed by the choice-fed birds was the same as the control diet. The higher the protein and energy efficiency ratio, the more efficient the hens in utilizing the protein and energy consumed. The higher protein in the diet could mean that the smaller protein ratio resulted in a significant effect on the value of protein efficiency ratio (Sari *et al.*, 2014).

The onset of laying of Arabic hens in this study (10% of egg production) occurred on the 6th day of 21 weeks of age in the choice-fed group and on the 1st day of 22 weeks of age in the control-fed group. Although three units of experiment in the control-fed group did not produce egg until the 1st day of 22 week of age, one unit of these three units was not laying an egg until the 6th day of 22 weeks of age. So, the choice-fed group was mature two days earlier than the control-fed group. Therefore, the pre-laying period of Arabic hen is not the same as the White Leghorn hen, which occurred at 18 weeks of age. The faster age at point of laying of hens offered a choice diet could be related to the higher CP and ME concentrations in the diet consumed. Based on BW gain of this study, the ME (kcal/kg) and CP (g/kg) requirements for Arabic laying hens during the rearing period are as the following: Starter (1 to 6 weeks): 3026 and 188.4; Grower (7 to 12 week): 3081 and 183.9;

Developer (13 to 15 week): 3091 and 184.8; and Pre-laying (16 to 22 week): 3073 and 188.5. Therefore, CP requirement (in terms of g/kg in the diet consumed) for starter period was lower ($p < 0.001$) and for other periods were higher ($p < 0.001$), while ME requirement (in term of kcal/kg in the diet consumed) was higher ($p < 0.001$) for all rearing periods than Hy-line management guide 2011.

ME level of control dietary treatment has a small and a strong negative correlation with BWG during a starter and grower period and a strong positive correlation during the developer and pre-laying period. On the other hand, ME level of choice dietary treatment has a strong positive correlation during a starter and a very small positive correlation during developer periods. A small and medium positive correlation has occurred during the grower and pre-laying periods. CP level of control dietary treatment has a strong negative correlation during a starter period and a medium to strong positive correlation from grower to pre-laying periods. In contrast, CP level of choice dietary treatment has a strong negative correlation during starter and developer periods and a medium positive correlation during the grower and pre-laying periods.

CONCLUSION

Free choice feeding on a diet varying in energy and protein had a beneficial effect on the growth rate of female Arabic hens by consuming a more high energy-high protein and high energy-low protein diet. ME and CP requirements of Arabic Arab hens for starter period were 3026 kcal of ME/kg and 18.8%, for grower period were 3081 kcal of ME/kg and 18.4%, for developer period were 3091 kcal of ME/kg and 18.5%, and for pre-

laying period were 3072 kcal of ME/kg and 18.8% to faster the onset of laying.

CONFLICT OF INTEREST

None of the authors of this work has financial or other relationships with people or organizations that could influence inappropriately or bias on the contents of this paper.

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