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Energy concentration and protein inclusion in diets for broilers: Effects on growth performance

Hisham A. Mandalawi*

Department of Animal Science, College of Agricultural Engineering Science, University of Sulaimani, Iraq

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ABSTRACT

We studied the effect of inclusion crude protein (CP) and energy concentration in the diet on growth performance, gastrointestinal tract (GIT) traits, and carcass weight in broilers from 0 to 42 d of age. The experimental design was completely randomized with six diets combined as a 2 x 3 factorial with two levels of CP (20 vs. 22%) and three levels of energy (2900, 3000, and 3100 kcal/kg). Each treatment was 4 replicate and the experimental unit was a pen with 20 birds. All diets were based on corn, soybean meal, wheat, and included sunflower oil. For the entire experiment, the inclusion of CP in the diet did not affect growth performance and the other variables studied. From 0 to 42 d of age, increase energy concentration up to 3100 kcal/kg in diet tended to reduce average daily feed intake (ADFI) ($P = 0.053$) and improve feed conversion ratio (FCR) ($P < 0.01$) than energy concentration at level of 2900 kcal/kg. However, average daily gain (ADG) was not affect. Most of the benefits of increase energy concentration on broiler growth was observed from 14 to 21 d and 28 to 35 d of age, a period in which energy concentration improved ADFI and FCR ($P < 0.01$), respectively. On d 42, increase energy levels in the diet did not affect GIT or carcass relative weight, except for the liver relative weight was heavier ($P < 0.05$) when intermedia energy concentration 3000 kcal/kg was included in the diet. It is concluded that energy concentration were well utilized by broilers, at level of inclusion.

INTRODUCTION

In a commercial poultry production, nutrition includes providing balanced food materials that meet the needs of chickens to grow, maintain and production. And for economic reasons, these foodstuffs should be at the lowest prices. Feed accounts for over 65% of poultry meat and over 60% of egg production costs. Supply of energy represents the major cost in feed formulation. Inclusion of energy in broilers diet affects feed intake and productive performance (Leeson et al., 1996; Infante-Rodríguez et al., 2016), pullets (Saldaña et al., 2015), and laying hens (Harms et al., 2000). Chickens fed to assure their energy essential and therefore, volitional feed intake reduced as the

* *Corresponding author: E-mail*: hisham.dawd@univsul.edu.iq

high energy inclusion of the diet (Pérez-Bonilla et al., 2012; Saldaña et al., 2015; Guzmàn et al., 2015). However, the adaptation of the gastrointestinal tract of the chickens to regulate feed intake with changes in energy content of the diet might not be complete. Protein is an essential constituent of all tissues of animal body protein having major effect on productive performance of the birds is the most expensive nutrient in poultry diets (Kamran et al, 2004; Abdallh et al., 2020). Increase level of crude protein in broilers diet may compensate for the reduced feed intake (Alleman and Leclerca, 1997; Temim et al., 1999). The carcass characteristics can be affected through the altered the level of inclusion of dietary protein or energy in broilers (Niu et al., 2009). We hypothesized that birds fed 3100 kcal/kg energy diets could reduce in feed intake (FI) and improved feed conversion ratio but also weak effect on the gastrointestinal tract (GIT) development than birds fed 2900 kcal/kg energy diets. The aim of this study was to evaluate the effects of different energy concentration and protein of the diet and their interactions on growth performance, GIT development, and carcass characteristics of broilers from 0 to 42 d of age.

MATERIAL AND METHODS

Husbandry

In total, 480 one-day-old Ross 308 chicks were obtained from a commercial hatchery and distributed at random into 24 pens. The floor was covered with wood shavings. Feed was provided in circular feeders. Room temperature was kept at 33°C during the first 3 d of life and then it was reduced gradually according to age until reaching 24°C at 42 d. Chicks received a 23 h/d light program for the first 7 d of life and then, 20 h of light until the end of the experiment. Broilers had free access to feed and water throughout the experiment.

Experimental Design and Diets

There were 6 diets organized as a 2 × 3 factorial with 2 inclusion of crude protein (20 vs. 22%) and 3 concentration of energy (2900, 3000, and 3100 kcal/kg). Each treatment was replicated 4 times, and the experimental unit was a pen with 20 birds. All diets were based on corn, soybean meal, wheat, and included sunflower oil. For the formation and mixing of the feeds, all diets were formulated according to Fundación Española Desarrollo Nutrición Animal (2010). Treatment diets were presented in mash form. As the level of protein increased, the amount of corn and sunflower oil decreased and that of soybean meal increased in the diet. The ingredient composition and the calculated analysis of the diets are presented in Table 1.

Table (1): Ingredient and chemical composition of the experimental diets (%, as-fed basis, unless otherwise stated) from 0 to 42 d of age

Crude protein (CP, %)	20			22		
Energy (AMEn, kcal/kg)	2900	3000	3100	2900	3000	3100
Ingredient						
Corn	29.00	34.00	36.34	28.00	32.24	34.84
Wheat	30.00	22.74	19.50	28.70	22.50	18.50
Soy bean meal (45,5% CP)	32.50	33.50	34.00	34.80	35.50	36.00
Sunflower oil	3.00	4.50	5.50	3.00	4.50	6.00
Calcium carbonate	0.84	0.80	0.70	0.84	0.80	0.70
Dicalcium phosphate	2.70	2.50	2.00	2.70	2.50	2.00
Sodium chloride	0.46	0.46	0.46	0.46	0.46	0.46
DL-Met (99%)	0.34	0.34	0.34	0.34	0.34	0.34
L-Lys-HCl (78.5%)	0.16	0.16	0.16	0.16	0.16	0.16
Vitamin and mineral premix[1]	1.00	1.00	1.00	1.00	1.00	1.00
Calculated analysis						
AMEn, kcal/kg	2,904	3,004	3,099	2,900	3,000	3,099
CP	20.1	20.0	20.0	22.0	21.9	21.9
DM	88.9	88.8	88.7	88.8	88.8	88.8
Total ash	6.34	6.13	5.63	6.44	6.23	5.72
Ether extract	5.20	6.78	7.82	5.19	6.75	8.29

1 Provided the following (per kilogram of diet): vitamin A (retinyl acetate), 1.000.000 IU; vitamin D3, 300.000 IU; vitamin E (all-rac-alpha tocopherol acetate), 5.000 mg; niacinamide, 1.500 mg; vitamin B1 (thiamine mononitrate) 500 mg; vitamin B2 (riboflavin), 400 mg; vitamin B6 (pyridoxine hydrochloride), 400 mg; vitamin B12 (cyanocobalamin), 1.000 mcg; vitamin C (ascorbic acid), 2.500 mg; calcium-D-pantothenate, 2.000 mg; folic

acid, 1.000 mcg; Dl-methionine, 3.500 mg; Lysine HCl, 10.000 mg; 3-phytase (EC 3.1.3.8), 5.000 U; iron (Fe E1), 10.000 mg; manganese (Mn E5), 10.000 mg; zinc (Zn E6), 15.000 mg; copper (Cu E4), 1000 mg

Growth Performance, Digestive Traits and Carcass Weight

Body weight and feed consumption were determined by pen at 7, 14, 21, 28, 35, and 42 d of age. Feed wastage was recorded daily for each pen, and the mortality rate was also calculated. From these controls, ADG, ADFI, and FCR were calculated by week and for the whole period.

At 42 d old, 2 birds per box for each replicate were selected, weighed individually, and slaughtered. The GIT, from the beginning of the proventriculus to the cloaca, including digesta content, liver, spleen, and pancreas, was removed aseptically and weighed according to Mandalawi et al. (2014). The weight of the all GIT, gizzard, heart and liver was expressed as a percentage of body weight (BW). Also, in same age, 2 birds per replicate were randomly selected to evaluate carcass quality and cut yields of chickens. The weight of the carcass and cut yields was expressed as a percentage of BW.

Statistical Analysis

Data on growth performance, development of gastrointestinal tract and carcass weight were analysed as a completely randomized design using the GLM procedure of SAS Institute (1990). For the 6 diets arranged as a 2 x 3 factorial, the main effects (Protein inclusion and energy concentration) and the interaction were studied. When the variables studies were significant, the Tukey test was used to show the different between treatment means. Differences among treatments were considered significant at $P < 0.05$.

$$y_{ijk} = \mu + P_i + E_j + (PE)_{ij} + e_{ijk}$$

RESULTS AND DISCUSSION

Growth Performance, Digestive Traits and Carcass Weight

No interactions between protein inclusion and level of energy in the diet were detected for any of the variables studied and therefore, only main effects are shown (Tables 2, 3 and 4). Protein inclusion did not affect broiler performance in any of the periods considered. However, the inclusion of protein with 22% in the diet tended to improve FCR (P = 0.053) from 1 to 7 d of age, consistent with data of Yunana et al. (2019), who reported that low protein diets were well utilized by broilers, at both levels of inclusion (19 vs. 22%) for the starter and finisher phase. Sens et al. (2021) reported also that the inclusion of different concentration of soybean meal in the diets had no effect on growth performance in broilers from 1 to 42 d of age, in agreement with the results of the current experiment. In contrast, Rosebrough and Mcmurtry (1993) and Chrystal et al. (2020) reported that the increased of CP levels (15 vs. 20%) in the diet effect on growth performance of broilers from 7 to 35 d of age.

Broilers performance affected in different ways by increase energy level of the diets. From 0 to 42 d of age, broilers fed high energy (3100 kcal/kg) diets had similar ADG, but tended to reduced ADFI (P = 0.053) and improved FCR (P < 0.01) than broilers fed low energy (2900 kcal/kg) diets. Most of the benefits of energy concentration on broiler growth was observed from 14 to 21 d and 28 to 35 d of age, a period in which energy concentration improved ADFI and FCR (P < 0.01). Broilers fed the high energy (3100 kcal/kg) diet tended to reduced ADFI by 7 and 5g, than broilers fed low energy (2900 kcal/kg) and intermedia energy (3000 kcal/kg) diet, respectively, a result that was expected because birds eat to satisfy their energy requirements (Saldaña et al., 2015; Mandalawi et al., 2017). In this respect, Infante-Rodrìguez et al. (2016) reported that the increase of energy level from 2960 to 3160 kcal/kg in diet had similar BWG, but improved FI and FCR in broilers from 1 to 42 d of age, in agreement with the results of the current study. Similarly, Jafarnejad and Sadegh (2011) observed that the inclusion of energy (3000 vs. 3200 kcal/kg) in the diet improved feed efficiency in chickens from 0 to 21 d of age, although in this study BW was not affected. In pullets, Saldaña et al. (2015) observed that the increase level of energy differing in 50 kcal AMEn/kg, (2850 vs. 3050 kcal/kg) in diet improved ADFI and FCR, but did not affect ADG from 0 to 17 wk of age. However, Niu et al. (2009) reported that the increase energy level (2900 vs. 3100 kcal/kg) in diet increased BWG and FI, in contrast with the results of the current research, although in this research FCR was improved.

The effects of CP inclusion and level of energy in the diet on GIT weight of the broilers are shown in Table 3. At 42 d of age, broilers fed CP inclusion (20 vs. 22%) did not affect relative weight of GIT, gizzard, liver, or heart. In this respect, Fosoul et al. (2016) reported that the inclusion CP (17 vs. 25%) in diet had not affect GIT weight and digestive organs weight in broilers at 28 and 42 d of age, in agreement with the results of the current experiment. The authors have not found any other published reported on the effects of CP inclusion on GIT weight and relative weight of digestive organs in poultry.

Table (2): Influence of the level of crude protein (CP, %) and energy (AMEn, kcal/kg) content in the diet on growth performance of broilers

	Main effect							
	CP (%)		AMEn (kcal/kg)				Probability[5]	
	20	22	2900	3000	3100	SEM[4]	CP	AMEn
ADG[1], g								
1 to 7 d	15.20	15.41	15.32	15.09	15.51	0.27	0.368	0.327
7 to 14 d	39.46	39.66	37.72	39.67	41.37	2.24	0.914	0.304
14 to 21 d	57.28	59.82	60.36	57.88	57.40	3.89	0.434	0.721
21 to 28 d	80.07	78.24	79.93	76.52	81.02	3.65	0.548	0.452
28 to 35 d	86.70	85.85	87.09	83.05	88.68	3.18	0.746	0.217
35 to 42 d	94.16	92.28	92.31	92.87	93.98	3.05	0.460	0.765
ADFI[2], g								
1 to 7 d	15.59	15.42	15.39	15.44	15.69	0.36	0.393	0.510
7 to 14 d	42.56	42.48	43.14	43.05	41.37	1.50	0.947	0.431
14 to 21 d	73.47	76.78	79.08[a]	75.86[ab]	70.44[b]	2.37	0.104	0.006
21 to 28 d	117.8	115.1	120.3	118.0	111.3	6.97	0.646	0.408
28 to 35 d	149.1	149.9	153.8	151.0	144.6	4.19	0.813	0.067
35 to 42 d	179.4	175.5	183.3	178.4	170.6	5.35	0.384	0.085
FCR[3], g/g								
1 to 7 d	1.028	1.001	1.005	1.026	1.013	0.01	0.053	0.285
7 to 14 d	1.092	1.079	1.149	1.098	1.010	0.05	0.792	0.079
14 to 21 d	1.299	1.291	1.322	1.321	1.243	0.06	0.878	0.401
21 to 28 d	1.479	1.474	1.513	1.543	1.375	0.08	0.938	0.111
28 to 35 d	1.723	1.757	1.768[a]	1.824[a]	1.628[b]	0.05	0.440	0.005
35 to 42 d	1.912	1.909	1.987	1.928	1.817	0.08	0.971	0.156
Cumulative (0 to 42 d)								
ADG, g	62.14	61.88	62.12	60.85	63.06	1.34	0.810	0.281
ADFI, g	96.31	95.85	99.14	96.95	92.14	2.72	0.837	0.053
FCR, g/g	1.551	1.550	1.597[a]	1.593[a]	1.466[b]	0.03	0.969	0.001

1 Average daily gain. 2Average daily feed intake. 3Feed conversion ratio.
4 Standard error of the mean (n= 4 replicates of 20 birds each).
5The interaction between crude protein level and energy content was not significant (P > 0.10).

The increase of energy concentration in diet did not affect relative weight of GIT, gizzard, or heart of broilers. However, the inclusion of energy intermedia (3000 kcal/kg) in diet had heavier relative weight of liver ($P < 0.05$) than low and high energy concentration (2900 vs. 3100 kcal/kg), respectively. Scott (2002) reported that high energy concentration (3200 kcal/kg) had lighter relative weight of liver than low energy concentration (3060 kcal/kg) in broilers at 34 d of age. The reason of this discrepancy is not known but might be related with composition of diet. In pullets, Saldaña et al. (2015) observed that an increase in the AMEn concentration of the diet from 2850 to 3050 kcal/kg had not affect on relative weight of GIT, gizzard, or liver at 5 wk of age. Moreover, Min et al. (2007) reported that liver relative weight was affected by dietary energy, where lower energy levels (2600 vs. 3075 kcal/kg) caused heavier liver relative weight in goslings at 28 d of age.

Carcass relative weight was not affected by the inclusion of CP (20 vs. 22%) in the diet of broilers at 42 d of age (Table 4). In this respect, Niu et al. (2009) reported also that the increase of

CP level (20 vs. 23%) in the diet had not affect the carcass relative weight in broilers at 21 d of age, consistent with the results of the current study. In goslings, Min et al. (2007) reported that increase dietary CP from 15 to 20% had not affect carcass weight at 28 d of age. Similarly, Liu et al. (2019) did not detect any significant effect on carcass weight when CP (16 vs. 17.5%) was included in the diet of pekin ducks at 40 d of age. The reason for not improve the carcass relative weight as the CP in the diet increased is not apparent, but the data are consistent with the data of ADG that reported for growth performance.

Table (3): Influence of the level of crude protein (CP, %) and energy (AMEn, kcal/kg) content in the diet on gastrointestinal tract (GIT) weight in broilers at 42 d of age

		Relative weight (% of BW)			
	BW (g)	GIT[3]	Gizzard	Liver	Heart
CP (%)					
20	2204	6.73	2.80	2.46	0.66
22	2060	7.45	3.04	2.40	0.69
AMEn (kcal/kg)					
2900	2100	7.46	2.81	2.44[ab]	0.67
3000	2096	7.51	2.99	2.61[a]	0.68
3100	2200	6.31	2.96	2.24[b]	0.68
SEM[1]		0.692	0.242	0.137	0.051
Probability[2]					
CP		0.221	0.247	0.589	0.411
AMEn		0.173	0.716	0.049	0.966

1Standard error of the mean (n= 4 replicates of 2 birds each).
2The interaction between crude protein level and energy content was not significant (P > 0.10).
3Weight of the full GIT (from end of the crop to cloaca) including digesta contents and liver, spleen, and pancreas.

At 42 d of age, broilers fed high energy concentration (2900 vs. 3100 kcal/kg) in diet had not affect carcass relative weight. Infante-Rodrìguez et al. (2016) reported also that dietary energy level (3040 vs. 3160 kcal/kg) did not influence processed carcass weight in broilers at 42 d of age. Moreover, Nunes et al. (2012) reported that the carcass relative weight of broilers at 42 d of age was not affect when high energy (3000 vs. 3300 kcal/kg) was included in the diet. In contrast, Kim et al. (2012) observed that the increase of energy concentration (2950 vs. 3250 kcal/kg) in the diet reduced carcass weight in broilers at 38 d of age.

Table (4): Influence of the level of crude protein (CP, %) and energy (AMEn, kcal/kg) content in the diet on carcass weight in broilers at 42 d of age

		Relative weight (% of BW)				
	BW (g)	Breast	Leg	Wing	Back	Ribcage
CP (%)						
20	2204	22.6	20.2	7.89	8.56	5.61
22	2060	22.7	20.1	7.91	8.95	5.02
AMEn (kcal/kg)						
2900	2100	21.9	20.1	7.98	8.50	5.25
3000	2096	23.7	20.4	8.01	8.77	5.55
3100	2200	22.5	19.9	7.70	8.99	5.14
SEM[1]		1.106	0.454	0.242	0.646	0.425
Probability[2]						
CP		0.894	0.879	0.927	0.469	0.107
AMEn		0.261	0.650	0.391	0.748	0.614

1Standard error of the mean (n= 4 replicates of 2 birds each).
2The interaction between crude protein level and energy content was not significant (P > 0.10).

CONCLUSION

No interaction between CP and energy concentration were detected on any of the variables studied. The inclusion of CP up to 22% in diet did not affect any of the variables studied. An increase in the level of energy up to 3100 kcal/kg in the diet tended to reduced ADFI and improved FCR for the entire experiment. However, increase energy concentration in the diet did not affect gastrointestinal traits or carcass relative weight. The data indicate that broilers might benefit from inclusion of CP and energy concentration in amounts inclusion in this research without any negative effect on variables studied.

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تركيز الطاقة و ادراج البروتين في علائق فروج اللحم: التاثيرات على اداء النمو

هشام عبد الستار داود مندلاوي

قسم علوم الحيوان- كلية علوم الهندسة الزراعية- جامعة السليمانية- العراق

الخلاصة

الكلمات المفتاحية:
تركيز الطاقة، الجهاز الهضمي، أداء النمو،البروتين

درسنا تأثير ادراج البروتين الخام و تركيز الطاقة في العلائق على اداء النمو, صفات الجهاز الهضمي, ووزن الذبيحة في فروج اللحم من عمر0 الى 42 يوم. تم أختيار التصميم التجريبي بشكل عشوائي ستة معاملات تغذوية مجتمعة كمعامل 2 ×3 مع مستويين من البروتين الخام (20 مقابل 22%) وثلاثة مستويات من الطاقة (2900, 3000, 3100 كيلو سعرة/كغم). تم تكرار كل معاملة اربع مرات وكانت الوحدة التجريبية على شكل أكنان وكل مكرر يحتوي على 20 طائر. مكونات العلائق الغذائية من الذرة , فول الصويا, الحنطة وزيت عباد الشمس. بالنسبة للفترة التجريبية الكاملة, لم يؤثر ادراج البروتين الخام في العليقة على أداء النموو المتغيرات الاخرى المدروسة. من عمر 0 الى 42 يوم, تميل زيادة تركيز الطاقة 3100 كيلو سعرة/كغم في العليقة الى تقليل متوسط الاستهلاك اليومي من العلف ($P = 0.053$) وتحسين معامل التحويل الغذائي ($P < 0.01$) مقارنة بتركيز الطاقة عند مستوى 2900 كيلو سعرة/كغم. مع ذلك, لم يتاثر متوسط الزيادة الوزنية اليومية. لوحظت معظم فوائد زيادة تركيز الطاقة على نمو الافراخ من عمر 14 الى 21 يوم ومن عمر 28 الى 35 يوم, وهي الفترة التى ادى فيها تركيز الطاقة الى تحسين متوسط الاستهلاك اليومي من العلف وتحسين معامل التحويل الغذائي ($P < 0.01$) على التوالي. في عمر 42 يوم, لم تؤثرزيادة مستويات الطاقة في العليقة على الجهاز الهضمي او الوزن النسبي للذبيحة, باستثناء الوزن النسبي للكبد حيث كانت اثقل وزننا ($P< 0.05$) عندما تم ادراج تركيز الطاقة 3000 كيلو سعرة/كغم في العليقة. تم الاستنتاج ان تركيز الطاقة استخدم بشكل جيد من قبل فروج اللحم, في المستويات المستخدمة.