Asian-Aust. J. Anim. Sci.
Vol. 21, No. 11 : 1629 - 1634
November 2008

www.ajas.info

Effect of Lowering Dietary Protein with Constant Energy to Protein Ratio on Growth, Body Composition and Nutrient Utilization of Broiler Chicks

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ABSTRACT : A trial was conducted to determine the effect of low crude protein (CP) diets with constant metabolizable energy to crude protein (ME:CP) ratio on growth, body composition and nutrient utilization of broiler chicks from 1 to 26 days of age. Four dietary treatments having four levels of CP and ME as 23, 22, 21 and 20% and 3,036, 2,904, 2,772 and 2,640 kcal/kg, respectively, were formulated and a ME:CP ratio of 132 was maintained in all the diets. Digestible lysine was maintained at 1.10 of the diet. A total of 1,760 day-old Hubbard broiler chicks were randomly divided into 16 experimental units and each diet was offered to four experimental units at random. Feed intake was increased ($p<0.05$) while weight gain and feed conversion ratio were adversely affected ($p<0.05$) when the diets with low CP and ME were fed to broilers. Total protein intake and total ME intake were linearly decreased ($p<0.05$) and protein efficiency ratio and energy efficiency ratio were lower ($p<0.05$) than in the chicks fed dietary regimen with 22% CP and 2,904 kcal/kg ME. The whole body analysis of the birds revealed that chicks fed the lowest dietary regimens retained less ($p<0.05$) nitrogen and more ether extract than chicks fed the control diet, however, body dry matter, total body ash and fat free body protein were not affected. Similarly, protein and energy utilization were also unaffected by the dietary treatments. In summary, chicks fed low CP diets with constant ME:CP ratio grew slower, used feed less efficiently and retained less protein and more body fat than chicks fed the control diet.
(**Key Words** : Broiler Chick, Low Protein Diet, Energy:Protein Ratio, Growth Performance, Nutrient Utilization, Whole Body Composition)

INTRODUCTION

The use of crystalline amino acids (AA) to lower the crude protein (CP) concentration in diets for broilers is effective in several ways. Nitrogen (N) retention efficiency may be increased if low CP diets are supplemented with crystalline AA in a pattern that matches the maintenance and tissue accretion needs of broilers (Chung and Baker, 1992). However, several workers have found that rate and efficiency of growth is lower and carcass composition becomes inferior in broilers fed low CP diets (Fancher and Jensen, 1989; Aletor et al., 2000; Bregendahl et al., 2002). In recent years, the influence of diet on carcass composition has attracted an increasing amount of attention. With the high cost of nutrients, efficiency of nutrient utilization and carcass composition is equally as important as growth performance. This is particularly true during early age growth period. Early age nutrition of broiler is crucial since, its carry-over effects on the overall performance are expected (Firman and Boling, 1998). Young animals grow to attain their lipid-free, mature body mass and then their inherent fatness. Subsequently, deposition of body fat accelerates. The degree of this acceleration depends to a great extent on the level and ratio between CP and ME of the diet during this period (Sell et al., 1985) as high metabolizable energy to crude protein (ME:CP) ratio causes increased fat retention.

It is of interest to determine whether the high rate of lipogenesis and poor growth performance resulting from low protein diets can be overcome by maintaining constant ME:CP ratio. Therefore, the present study was planned to

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Received October 9, 2007; Accepted March 17, 2008

determine whether a low CP, AA supplemented diet with constant ME:CP ratio can support growth, body composition and nutrient utilization equal to that of a high CP diet from 1 to 26 days of age.

MATERIALS AND METHODS

Birds and housing

The experiment was conducted in an environmentally controlled house. A total of 1,760 day-old straight-run Hubbard broiler chicks were randomly divided into 16 experimental units of 110 chicks each and each diet was offered to four experimental units at random. Birds were vaccinated for Newcastle disease on day 6 and 24, for Hydropericardium Syndrome on day 15 and for Gumboro disease on day 10 and 20. The brooding temperature was kept at 35°C during first week and it was gradually decreased by 2°C after each week. Twenty-four hours light was provided by electric tubelights in the broiler house throughout the experimental period. Each pen was equipped with three separate tube feeders and two bell waterers. On day 15, the tube feeders were replaced with four round-bottom feeders. Fresh water and feed were provided *ad libitum* throughout the experimental period.

Experimental diets

The feed ingredients used for the formulation of experimental diets were analyzed in triplicate for their dry matter (DM), CP, ether extract, crude fiber by the methods described by AOAC (1990) and for AA contents (Degussa AG, Germany). Four dietary treatments A, B, C and D were formulated having four levels of CP and ME as 23, 22, 21 and 20% and 3,036, 2,904, 2,772 and 2,640 kcal/kg, respectively and a ME:CP ratio of 132 was maintained in the diets. Digestible lysine was maintained at 1.10% of the diet and remaining limiting AA like methionine, threonine

Table 1. Ingredient and nutrient composition of broiler starter diets containing low protein with constant energy to protein ratio

Ingredient	A	B	C	D
	%			
Corn	43.96	50.51	49.78	49.04
Rice polishings	5.00	5.00	12.20	7.01
Wheat bran	-	-	-	8.41
Canola meal	11.99	12.00	12.00	13.01
Guar meal	2.00	2.00	2.00	2.00
Soybean meal	21.58	17.80	13.59	9.81
Fish meal 60%	5.00	5.00	5.00	4.00
Limestone	0.70	0.70	0.70	0.80
DCP	1.53	1.54	1.48	1.48
L-lysine	0.06	0.17	0.27	0.37
DL-methionine	0.12	0.14	0.17	0.19
L-threonine	-	0.02	0.07	0.11
Sodium chloride	0.19	0.18	0.17	0.19
Sodium bicarbonate	0.08	0.08	0.08	0.08
Vegetable oil	5.30	2.35	-	-
Vitamin/trace mineral premix[1]	0.50	0.50	0.50	0.50
Total	100	100	100	100
Nutrient composition (%)				
ME (kcal/kg)	3,036	2,904	2,772	2,640
Crude protein	23.0	22.0	21.0	20.0
Energy:protein ratio	132	132	132	132
Crude fiber	4.84	4.75	5.38	5.90
Ether extract	8.61	5.88	4.49	3.98
Calcium	1.01	1.01	0.98	0.99
Available phosphorus	0.50	0.50	0.49	0.49
Lysine[2]	1.10	1.10	1.10	1.10
Methionine[2]	0.49	0.49	0.49	0.49
Cystine[2]	0.35	0.35	0.35	0.35
Threonine[2]	0.73	0.73	0.73	0.73
Tryptophan[2]	0.21	0.21	0.21	0.21

[1] Supplied per kilogram of diet: vitamin A (as retinyl acetate), 14,000 IU; vitamin D_3 (as cholecalciferol), 3,500 IU; vitamin K (menadione sodium bisulfite), 2.8 mg; vitamin E (as d-α-tocopherol), 42 IU; biotin, 0.07 mg; folic acid, 1.7 mg; niacin, 35 mg; calcium pantothenate, 12.3 mg; pyridoxine, 3.4 mg; riboflavin, 7 mg; thiamin, 1.7 mg; vitamin B_{12}, 12.1 μg; Fe, 98 mg; Mn, 112 mg; Cu, 9.8 mg; Se, 0.07 mg; Zn, 70 mg; choline chloride, 550 mg; salinomycin (as Phibro coccidiostat), 60 mg; zinc bacitracin (as Albac 10%), 50 mg.

[2] Digestible.

Table 2. Weight gain, feed intake, feed conversion ratio and mortality of broilers fed different diets containing low protein with constant energy to protein ratio[1]

Item	Weight gain (g/bird)	Feed intake (g/bird)	Feed conversion ratio (g:g)	Mortality (%)
Diets[2]				
A	938.9[a]	1,756.9[c]	1.87[c]	3.4
B	953.9[a]	1,787.8[bc]	1.87[c]	5.9
C	878.2[b]	1,857.8[ab]	2.12[b]	2.7
D	860.0[b]	1,922.5[a]	2.24[a]	3.0
SEM	14.0	21.01	0.028	1.15
ANOVA	---------- Probability ----------			
Diet	0.001	0.001	<0.001	0.234
Linear	0.001	<0.001	<0.001	0.423
Quadratic	0.325	0.422	0.108	0.376

[a-c] Means within a column with different superscripts differ significantly ($p<0.05$). Linear and quadratic effects are for the overall reduction in energy and protein contents of the experimental diets.

[1] Means of 4 replicates with 110 birds in each replicate.

[2] Diet A contained 23% CP and 3,036 kcal/kg ME; diet B contained 22% CP and 2,904 kcal/kg ME; diet C contained 21% CP and 2,772 kcal/kg ME and diet D contained 20% CP and 2,640 kcal/kg ME.

and tryptophan were included according to Hubbard requirements. The nutrient composition of the diets either met or exceeded the Hubbard recommendations for broiler starter diets except for CP and ME which were reduced in other diets (Table 1). Analysis of diets for CP and other proximate components matched closely with the calculated values. The experimental diets were fed up to 26 days of age.

Data collection

Feed intake and weight gain were recorded at the end of the experiment and feed conversion ratio (FCR) was calculated. Total protein intake (TPI) and total ME intake were also calculated and were used to calculate protein efficiency ratio (PER) and energy efficiency ratio (EER). The TPI was calculated as protein fraction of a diet multiplied by its intake while total ME intake was calculated as ME of a diet in kcal multiplied by its intake during the whole experimental period. For whole body composition, after the chicks were weighed on day 26, they were fasted for 24 h (with free access to water) and reweighed on day 27. Subsequently, five chicks per pen representing average body weight were selected, killed by chloroform, and stored in vacuum plastic bags at -20°C for further analysis. The whole bodies of the birds were dried in a hot air oven at 65°C for two weeks by placing them in aluminium foiled trays. After the constant weight was achieved, the whole bodies of the birds were weighed and DM was calculated from the dry weight of the chicks. The dried chicks were ground in an electrical grinder and samples were taken for the analysis of CP and fat contents. The whole body CP and fat contents were analyzed in triplicate by the methods described by AOAC (1990). Protein utilization (PU) was calculated as percentage of total body protein to 26 days protein intake. Energy utilization (EU) was calculated as percentage of total body energy to total (26 day) ME intake (Cheng et al., 1997a, b). Complete record of mortality of experimental birds was maintained during the entire experiment.

Statistical analysis

The results were analyzed by General Linear Model (GLM) and Tukey's significant difference test was used to compare means (Steel et al., 1997). Linear and quadratic effects on the birds' response by reducing both energy and protein at constant energy-to-protein ratio were also estimated by quadratic response model of GLM using Minitab 13.2 (Minitab Inc. State College, PA).

RESULTS

There was a linear increase ($p<0.05$) in feed intake while weight gain and FCR were adversely affected ($p<0.05$) by the reduction in dietary CP and ME content (Table 2). The chicks fed diets C and D had lower ($p<0.05$) body weight gain as compared to those fed diets A and B. Mortality remained unaffected among the dietary treatments (Table 2). The TPI and total ME intake were decreased ($p<0.05$) in a linear pattern, however, PER and EER were not significantly different in the chicks fed two lowest dietary regimens as compared to the control but were lower ($p<0.05$) than the chicks fed diet with 22% CP and 2,904 kcal/kg ME (Table 3). The whole body analysis of the birds revealed that chicks fed the lowest dietary regimens retained ($p<0.05$) less N and more ether extract in a linear pattern than chicks fed the control diet, however, body DM, total body ash and fat free body protein were not affected by the dietary treatments (Table 4). Similarly, PU and EU were also unaffected by the dietary treatments (Table 5).

DISCUSSION

Although much work has been conducted on reducing

Table 3. Total protein intake, protein efficiency ratio, total ME intake and energy efficiency ratio of broilers fed different diets containing low protein with constant energy to protein ratio[1]

Item	Total protein intake (g/bird)	Protein efficiency ratio[2] (g:g)	Total ME intake (kcal/bird)	Energy efficiency ratio[3] (Gain/100 kcal)
Diets[4]				
A	404.1[a]	2.32[ab]	5,333.9[a]	17.60[ab]
B	393.3[ab]	2.43[a]	5,191.7[ab]	18.38[a]
C	390.1[ab]	2.25[b]	5,149.8[ab]	17.06[b]
D	384.5[b]	2.24[b]	5,075.3[b]	16.95[b]
SEM	4.44	0.03	58.56	0.233
ANOVA	Probability			
Diet	0.050	0.004	0.050	0.004
Linear	0.005	0.036	0.005	0.036
Quadratic	0.562	0.169	0.562	0.169

[a-b] Means within a column with different superscripts differ significantly ($p<0.05$). Linear and quadratic effects are for the overall reduction in energy and protein contents of the experimental diets.

[1] Means of 4 replicates with 110 birds in each replicate. [2] Calculated as weight gain divided by protein intake.

[3] Calculated as weight gain divided by 100 kcal energy intake.

[4] Diet A contained 23% CP and 3,036 kcal/kg ME; diet B contained 22% CP and 2,904 kcal/kg ME; diet C contained 21% CP and 2,772 kcal/kg ME and diet D contained 20% CP and 2,640 kcal/kg ME.

Table 4. Whole body composition of broilers fed different diets containing low protein with constant energy to protein ratio[1]

Item	Body dry matter (%)	Total body fat	Total body protein	Total body ash	Fat free body protein (%)
		% DM			
Diets[2]					
A	29.5	31.2[b]	59.8[a]	9.0	86.9
B	29.4	31.3[b]	59.8[a]	8.9	87.1
C	29.4	33.3[ab]	57.5[b]	9.2	86.3
D	29.9	35.0[a]	56.0[b]	9.0	86.2
SEM	0.50	0.60	0.52	0.30	0.40
ANOVA	Probability				
Diet	0.901	0.002	0.001	0.932	0.362
Linear	0.604	<0.001	<0.001	0.907	0.115
Quadratic	0.585	0.186	0.165	0.885	0.800

[a-b] Means within a column with different superscripts differ significantly ($p<0.05$). Linear and quadratic effects are for the overall reduction in energy and protein contents of the experimental diets.

[1] Means of 4 replicates with 5 birds from each replicate.

[2] Diet A contained 23% CP and 3,036 kcal/kg ME; diet B contained 22% CP and 2,904 kcal/kg ME; diet C contained 21% CP and 2,772 kcal/kg ME and diet D contained 20% CP and 2,640 kcal/kg ME.

the CP and ME content of broiler diets in open type houses using local nutrient requirements for subtropical region but very little experimentation has been done in environmentally controlled houses using nutrient recommendations for Hubbard strain. The duration of the experimental period was kept up to 26 days because early growth stage of birds is very important from biological point of view and its carry-over effects on the overall performance are expected. Therefore, the experiment was conducted in an environmentally controlled house using these CP levels for starter period.

Growth performance

Feed intake was found to be linearly increased with decreasing CP and ME contents in the diets. This observation was in agreement with reports by Golian and Maurice (1992), Leeson et al. (1993) and Kamran et al. (2008) in that birds consume feed to primarily meet energy requirements and increase their feed intake in response to dietary energy dilution. The chicks fed diet having the lowest CP and ME content had significantly poor body weight gain and FCR. Even though, the birds provided low CP and low ME diets had increased feed consumption but it could not compensate for the reduced growth and did not allow for complete recovery of final body weight. So, the difference in rate and efficiency of growth probably occurred due to an inadequate consumption of energy and CP. These results were in agreement with the findings of Tang et al. (2007) who reported increased live body weight with the increase in dietary energy content. Short duration of trial might also be a reason because it does not allow for compensatory growth. Sizemore and Siegel (1993) compared different ME and CP concentrations while maintaining a constant ME:CP ratio and observed that birds

Table 5. Protein and energy utilization of broilers fed different diets containing low protein with constant energy to protein ratio[1]

Item	Protein utilization[2] (%)	Energy utilization[3] (%)
Diets[4]		
A	36.0	28.8
B	37.9	30.3
C	36.9	31.0
D	35.5	30.9
SEM	1.30	1.07
ANOVA	---------------- Probability	---------------
Diet	0.592	0.466
Linear	0.689	0.141
Quadratic	0.209	0.459

Linear and quadratic effects are for the overall reduction in energy and protein contents of the experimental diets.

[1] Means of 4 replicates with 5 birds from each replicate.

[2] Calculated as percentage of total body protein to total (26 day) protein consumption.

[3] Calculated as percentage of carcass energy to total (26 day) ME intake. Body protein and fat were assumed to contain 5.66 and 9.35 kcal/g tissue, respectively.

[4] Diet A contained 23% CP and 3,036 kcal/kg ME; diet B contained 22% CP and 2,904 kcal/kg ME; diet C contained 21% CP and 2,772 kcal/kg ME and diet D contained 20% CP and 2,640 kcal/kg ME.

receiving the lower density starter diets were significantly lighter than those fed the higher density diets at three weeks of age, whereas at seven weeks of age, no treatment differences in body weight were apparent. Hidalgo et al. (2004) also found that weight gain and FCR were adversely affected when the broilers were fed diets formulated to contain suboptimum concentration of CP and ME from 1 to 17 days of age. There was a decrease in mortality with the reduction in CP and ME content; however it did not reach significant level on mortality.

The TPI and total ME intake were linearly decreased with the reduction of dietary CP and ME concentration. Although, the birds fed low CP and low ME diets increased their feed intake in an effort to maintain energy intake but this increase was not up to the extent of fulfilling the energy requirements of the birds for growth. It showed that birds were not efficient in maintaining their energy intake during the starter period and due to this reason protein intake was also lower for these diets. In the starter period, birds might have had a physical limitation when trying to consume the low density diets. This finding would agree with Griffiths et al. (1977) who suggested that a reduction in energy intake is due to physical limitations when feeding diets with low ME content during starter period. Due to less consumption of CP and ME, there was a significant depression in weight gain of the birds. So the PER and EER was decreased as compared to those fed diet B. The results regarding TPI and PER were consistent with the findings of Jackson et al. (1982) who observed a linear decrease in TPI and total ME intake with the lower dietary CP and ME levels. However, the results regarding PER were in contrast to the findings of Cheng et al. (1997a) who observed that PER was significantly increased with low CP diets.

Whole body composition

The whole body concentration of DM was unaffected by the reduction in dietary CP and ME content. These results were in line with the findings of Cheng et al. (1997a, b) who found no differences in body DM of chicks when different dietary CP and ME levels were fed. Decreasing the dietary CP and ME produced broilers with higher whole body fat and lower whole body protein content. This may be related to the fact that because of higher heat increment of the proteins, the net energy of a low protein AA fortified diet will be higher than the conventional broiler diets (Emmans, 1994). This increased energy availability might be the reason of higher whole body fat content of the birds fed low CP diets, although, a constant ME:CP ratio was maintained. Cheng et al. (1997a) and Bregendahl et al. (2002) reported a significant decrease in the whole body CP and increase in whole body fat content of chicks fed low CP diets as compared to the control. Although, significant differences in total body protein occurred due to the dietary treatments, the fat free body protein remained unchanged. It showed that the major effect on the body composition was due to more fat deposition. This may indicate, as previously mentioned by Jackson et al. (1982) that improvements in carcass composition would be best accomplished through manipulation of carcass fat rather than the protein component of the carcass. The constant percentage of fat free body protein was similar to the report of Hakansson et al. (1978) which suggested that the protein to ash ratio of growing birds remains constant during normal growth. However, Cheng et al. (1997a) reported a decrease in percent fat free body protein and an increase in percent body ash in broiler fed various CP and ME levels. This severe reduction in protein deposition compared to bone mineralization in that study was due to high temperature and may be related to the report by Beitz (1985) which showed that animal bone growth has priority over protein deposition.

Efficiency of nutrient utilization

Since, there was a linear decrease in total body protein as the TPI was linearly decreased; the PU remained unaffected by dietary treatments. However, Jackson et al. (1982) and Cheng et al. (1997a, b) found that PU was increased with low CP diets. The EU was numerically improved with low CP and low ME diets, however, the difference was nonsignificant. Although, the efficiency of PU can be predicted from dietary CP level and ME:CP ratio, the efficiency of EU is more dependent on carcass fat content than on the level of dietary ME or ME:CP ratio

(Jackson et al., 1982). So, this slight improvement in EU might be due to increased total body fat content of the broilers fed low CP and low ME diets.

CONCLUSIONS

Results of the present study suggested that lowering the dietary CP content with constant ME:CP ratio was not helpful in obtaining lean body composition and it resulted in rather increased fat deposition. In addition, growth performance was also adversely affected. In general, optimum broiler performance in present experiment was obtained by diet formulated to contain 22% CP and 2,904 kcal/kg ME. The performance suffered beyond that level and the potential reason for it further needs to be investigated.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of Muhammad Aslam, Chief Executive, Islamabad Feeds and Chicks, Rawalpindi (Pakistan) who provided chicks, feed, experimental and laboratory facilities at his research and development (R&D) farm for present trial.

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