Indian Journal of Animal Sciences **81** (11): 1165–1172, November 2011

Effect of low crude protein diets with constant metabolizable energy on performance of broiler chickens from one to thirty-five days of age

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Received: 17 March 2011; Accepted: 5 June 2011

ABSTRACT

A trial was conducted to study the effect of lowering dietary crude protein (CP) on the performance of broilers from 1 to 35 d of age. Four experimental broiler diets were formulated. Diet A served as control with 23, 22 and 20% CP in starter, grower and finisher periods, respectively while in diets B, C and D, the CP was reduced to 22, 21 and 20% in starter; 21, 20 and 19% in grower and 19, 18 and 17% in finisher period, respectively. All diets were isocaloric within a phase (2,925, 3,075 and 3,125 kcal/kg ME for starter, grower and finisher periods, respectively). Weight gain, feed intake, feed conversion ratio (FCR), total ME intake and energy efficiency ratio were similar across treatments. However, total protein intake decreased and protein efficiency ratio increased with low CP diets during all growth periods. The carcass characteristics were similar among treatments. In conclusion, the dietary CP level could be reduced without harmful effects on the performance of broilers when supplemented with limiting AA.

Key words: Amino acids supplementation, Broilers, Carcass characteristics, Growth performance, Low CP diets

Protein is generally considered one of the major cost components of the poultry diets (Kamran *et al.* 2004). In recent years, the use of low CP diets with AA supplementation in broilers increased due to the reasons of feed cost, feed efficiency and flexibility in feed formulation (Kidd and Kerr 1996, Kamran *et al.* 2008). However, the balance of AA is important while reducing CP to ensure optimum performance (Ojano-Dirain and Waldroup 2002). Although, there is a biological limit to which dietary CP content can be reduced, some attempts have been made to reduce dietary CP level with no adverse effect on broiler performance (Moran and Stilborn 1996, Ayasan *et al.* 2009, Maksoud *et al.* 2010, Widyaratne and Drew 2011). However, some researchers have found that growth rate, feed efficiency and carcass composition is affected in broilers fed low CP diets although the levels of essential AA and other nutrients were kept to meet requirements (Aletor *et al.* 2000, Bregendahl *et al.* 2002 and Waldroup *et al.* 2005).

In Pakistan, usually low nutrient density diets are formulated for open type farming. The environmentally controlled farming has increased rapidly with rearing of Hubbard strain during the past few years. However, very little work has been done on low CP diets in environmentally controlled farming using nutrient recommendations for Hubbard strain. Due to already present discrepancies and a limited number of studies under these conditions, the present study was planned to examine the effect of low CP diets adequate in limiting AA on broilers performance and carcass characteristics from 1 to 35 d of age.

MATERIALS AND METHODS

The experiment was conducted in an environmentally controlled house. Hubbard broiler strain was used in the experiment and nutrient recommendations for Hubbard strain were used as control (Hubbard 2004). The whole experimental period was divided into 3 phases: starter (1 to 10 d), grower (11 to 26 d) and finisher (27 to 35 d) according to Hubbard (2004).

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Birds and housing: Day-old straight-run Hubbard broiler chicks (1 760) were randomly divided into 16 experimental units of 110 chicks each. Each replicate pen was 4.57 m × 2.74 m in measurement and the pens were allotted randomly to different experimental units. Birds were vaccinated for Newcastle disease on d 6 and 24, for hydropericardium syndrome on d 15 and for Gumboro disease on d 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. Light (24 h) was provided by electric tube lights in the broiler house throughout the experimental period. Fresh water and feed were provided *ad lib.* throughout the experimental period (Kamran *et al.* 2008).

Experimental diets: Before the formulation of experimental diets, ingredients were analyzed in triplicate for their DM (No. 930.15), CP (No. 988.05), EE (No. 920.39), CF (No. 978.10) (AOAC 1990) and AA contents (Degussa AG, Germany). Four experimental broiler diets were formulated. Diet A served as control with 23, 22 and 20% CP in starter, grower and finisher periods, respectively. In diets B, C and D, the CP was reduced to 22, 21 and 20% in starter; 21, 20 and 19% in grower and 19, 18 and 17% in finisher period, respectively. All the diets were isocaloric within a phase (2,925, 3,075 and 3,125 kcal/kg ME for starter, grower and finisher periods, respectively). Digestible lysine was maintained at 1.10, 1.02 and 0.90% of the diet in starter, grower and finisher periods, respectively, and other limiting AA were given according to Hubbard recommended AA requirements. The nutrient composition of control and other diets either met or exceeded the Hubbard recommendations for broiler diets (Tables 1, 2, 3) except CP, which was reduced in other diets. Each experimental diet was offered randomly to 4 replicates and the experimental diets were fed up to 35 d of age.

Data collection: Average weight gain and feed intake were recorded at the end of each phase for each experimental unit. The data on feed intake and weight gain were used to calculate FCR. Total protein intake (TPI) and total ME intake were also calculated and were used to further calculate protein efficiency ratio (PER) and energy efficiency ratio (EER). Complete record of mortality of experimental birds was maintained during the entire experiment. At the end of the experiment, 5 birds per replicate (with no visible abnormalities) were randomly selected. These birds were slaughtered to obtain the data on carcass yield (including skin and giblets and calculated as % of live weight), breast meat yield, thigh yield, abdominal fat and relative weights of liver and heart (Calculated as% of carcass weight) (Kamran *et al.* 2008).

Statistical analysis: The results were analyzed by GLM ($P<0.05$) and Tukey's significant difference test was used to compare means (Minitab 13.1). Linear and quadratic regression analyses were also done to estimate birds' response to various CP levels (Steel *et al.* 1997).

Table 1. Ingredient and nutrient composition of broiler starter diets with different levels of CP (1 to 10 days)

Ingredients (%)	A (23% CP)	B (22% CP)	C (21% CP)	D (20% CP)
Corn	46.53	50.04	53.48	57.00
Rice polishings	5.00	5.00	5.00	5.00
Rapeseed meal 35%	2.00	2.00	2.00	2.00
Canola meal	12.01	12.00	12.00	12.00
Guar meal	2.00	2.00	2.00	2.00
Soybean meal 45%	21.01	17.90	14.79	11.60
Fish meal 60%	5.00	5.00	5.00	5.00
Limestone	0.70	0.70	0.70	0.70
Di-calcium phosphate	1.52	1.55	1.57	1.59
L-Lysine	0.08	0.17	0.25	0.34
DL-Methionine	0.12	0.15	0.17	0.19
L-Threonine	-	-	0.06	0.11
Sodium chloride	0.19	0.18	0.18	0.18
Sodium bicarbonate	0.08	0.08	0.08	0.08
Vegetable oil	3.26	2.73	2.22	1.71
Vitamin/mineral premix[1]	0.50	0.50	0.50	0.50
Total	100	100	100	100
Nutrient composition (%)				
ME, kcal/kg	2925	2925	2925	2925
CP	23.0	22.0	21.0	20.0
CP[2]	22.79	21.85	20.69	19.75
Energy: Protein ratio	127	133	139	146
Crude fiber[2]	4.90	4.85	4.75	4.55
Ether extract[2]	6.65	6.19	5.90	5.45
Total ash[2]	7.36	7.26	7.15	6.99
Calcium	1.01	1.01	1.01	1.00
Available phosphorus	0.50	0.50	0.50	0.50
Lysine[3]	1.10	1.10	1.10	1.10
Methionine[3]	0.49	0.49	0.49	0.49
Cystine[3]	0.34	0.34	0.34	0.34
Threonine[3]	0.73	0.73	0.73	0.73
Tryptophan[3]	0.21	0.21	0.21	0.21

[1]Supplied per kg 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, 12.32 mg; pyridoxine, 3.36 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]Analyzed values; [3]Digestible

Table 2. Ingredient and nutrient composition of broiler grower diets with different levels of CP (11 to 26 days)

Ingredients (%)	A (23% CP)	B (22% CP)	C (21% CP)	D (20% CP)
Corn	47.40	51.00	54.56	58.12
Rice polishings	5.00	5.00	5.00	5.00
Canola meal	12.10	11.99	11.99	12.00
Guar meal	2.00	2.00	2.00	2.00
Soybean meal 45%	20.00	16.90	13.79	10.60
Fish meal 60%	5.00	5.00	5.00	5.00
Limestone	0.70	0.70	0.70	0.70
Di-calcium phosphate	1.56	1.59	1.61	1.63
L-Lysine	0.14	0.23	0.32	0.41
DL-Methionine	0.13	0.14	0.15	0.16
L-Threonine	-	-	-	-
Sodium chloride	0.19	0.19	0.19	0.19
Sodium bicarbonate	0.08	0.08	0.08	0.08
Vegetable oil	5.21	4.67	4.13	3.60
Vitamin/mineral premix[1]	0.50	0.50	0.50	0.50
Total	100	100	100	100
Calculated nutrient composition (%)				
ME, kcal/kg	3075	3075	3075	3075
CP	22.0	21.0	20.0	19.0
CP[2]	21.65	20.95	19.63	18.76
Energy: Protein ratio	140	146	154	162
Crude fiber[2]	4.66	4.53	4.47	4.33
Ether extract[2]	8.65	8.03	7.62	7.31
Total ash[2]	7.19	7.13	6.89	6.85
Calcium	1.01	1.00	1.00	1.00
Available phosphorus	0.50	0.50	0.50	0.50
Lysine[3]	1.02	1.02	1.02	1.02
Methionine[3]	0.46	0.46	0.46	0.46
Cystine[3]	0.35	0.35	0.35	0.35
Threonine[3]	0.69	0.69	0.69	0.69
Tryptophan[3]	0.18	0.18	0.18	0.18

[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, 12.32 mg; pyridoxine, 3.36 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]Analyzed values; [3]Digestible

Table 3. Ingredient and nutrient composition of broiler finisher diets with different levels of CP (27 to 35 days)

Ingredients (%)	A (23% CP)	B (22% CP)	C (21% CP)	D (20% CP)
Corn	55.18	58.61	62.14	65.50
Rice polishings	5.00	5.00	5.00	5.00
Canola meal	9.00	9.00	9.01	9.00
Guar meal	2.00	2.00	2.00	2.00
Soybean meal 45%	16.60	13.50	10.31	7.20
Fish meal 60%	5.00	5.00	5.00	5.00
Limestone	0.80	0.80	0.80	0.90
Di-calcium phosphate	1.05	1.07	1.09	1.11
L-Lysine	0.04	0.13	0.22	0.31
DL-Methionine	0.10	0.11	0.13	0.14
L-Threonine	-	0.04	0.08	0.12
Sodium chloride	0.13	0.13	0.13	0.13
Sodium bicarbonate	0.09	0.09	0.09	0.09
Vegetable oil	4.52	4.01	3.50	3.00
Vitamin/mineral premix[1]	0.50	0.50	0.50	0.50
Total	100	100	100	100
Calculated nutrient composition (%)				
ME, kcal/kg	3125	3125	3125	3125
CP	20.0	19.0	18.0	17.0
CP[2]	20.15	18.65	17.91	16.81
Energy: protein ratio	156	164	174	184
Crude fiber[2]	4.11	4.13	3.99	3.88
Ether extract[2]	7.96	7.76	7.38	6.98
Total ash[2]	6.52	6.37	6.29	6.11
Calcium	0.89	0.88	0.88	0.92
Available phosphorus	0.41	0.41	0.41	0.41
Lysine[3]	0.90	0.90	0.90	0.90
Methionine[3]	0.44	0.44	0.44	0.44
Cystine[3]	0.34	0.34	0.34	0.34
Threonine[3]	0.64	0.64	0.64	0.64
Tryptophan[3]	0.16	0.16	0.16	0.16

[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, 12.32 mg; pyridoxine, 3.36 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]Analyzed values; [3]Digestible

RESULTS AND DISCUSSION

Growth performance: Although there was no significant difference in feed intake and weight gain among treatments during any growth period, there was an increasing trend in these parameters with the reduction in dietary CP during starter phase (Table 4). The increasing trend in feed intake might be due to slightly low nonessential: essential AA ratio during this period and was not observed during later growth periods showing higher CP/AA requirements during early age. This resulted in similar trend in weight gain during this period. In general, there was no effect on the weight gain of birds fed low CP diets. It is well known that birds primarily eat for their energy intake and after that, the second limiting factor regulating feed intake is protein/AA intake. These results might be due to proper levels of CP or limiting AA in the diets. This may be supported by the fact that since ME content was the same for all the diets, there was no effect on feed intake and thus, on weight gain of chicks with the reduction in dietary CP content. The results of feed intake and weight gain were in close agreement with the findings of Han *et al.* (1992), Moran *et al.* (1992), Moran (1994) and Maksoud *et al.* (2010) who found no differences in feed intake and weight gain of broilers when the CP content of the diet was decreased from 23 to 20% and 20 to 17% during 0 to 3 and 3 to 6 wk of age, respectively. Similarly, Widyaratne and Drew (2011) reported that highly digestible low CP diets could result in equal performance to that of high CP diets in terms of weight gain and feed intake. On the other hand, Cheng *et al.* (1997a,b) reported a significant increase in feed intake when the CP content of the diet was decreased from 24% to 22, 20 and 18%, in spite of AA supplementation. Bregendahl *et al.* (2002) found significantly increased feed intake and lower weight gain of broilers fed 20% AA supplemented diet as compared to those fed a 23% CP diet. Feed intake of the birds was increased to meet their AA requirements in those experiments but this increase could not maintain the weight gain of chicks. In the present study, the AA profile was close to the requirements in the low CP diets, due to which the feed intake was not increased to counterbalance the reduction in CP and to meet the AA requirements.

There was no effect of low CP diets on FCR during any growth period (Table 4). Decrease in dietary CP was not associated with over consumption of feed; hence there was not any increase in FCR. Our results were in line with the findings of Hulan *et al.* (1980) and Hulan and Proudfoot (1981) who fed the lowest dietary protein during the starter (16%), grower (18%) and finisher (14%) periods to the birds and observed that the birds had the best FCR as a result of decreasing protein level to 16, 20 and 16% during starter, grower and finisher periods, respectively. The results are also in agreement with the findings of Hai and Blaha (1998) who found no significant differences in FCR when the protein level of the isoenergetic diets was reduced from 20 to 16% and supplemented with essential AA. However, Moran *et al.* (1992) found an increase in FCR with the decrease in CP (23 to 20% and 20 to 17% in starter and grower periods, respectively) by AA supplementation. Neto *et al.* (2000) also reported a 13% increase in FCR of birds fed 17% CP diets as compared to those fed 24% CP diet. The increased FCR in these experiments might be the result of the birds fed low CP diets consuming more feed and growing more slowly. This increased feed intake was considered to be due to the deficiency of some critical AA and so the efficiency of protein

Table 4. Weight gain, feed intake and feed conversion ratio of broilers as influenced by different dietary CP levels during starter, grower, finisher and overall experimental period[1]

Item	Weight gain (g/bird)				Feed intake (g/bird)				Feed conversion ratio (g:g)			
	Starter 1-10 d	Grower 11-26	Finisher d 27-35 d	Overall 1-35 d	Starter 1-10 d	Grower 11-26 d	Finisher 27-35 d	Overall 1-35 d	Starter 1-10 d	Grower 11-26 d	Finisher 27-35 d	Overall 1-35 d
Diets[2]												
A	157	735	690	1582	261	1458	1492	3212	1.66	1.99	2.16	2.03
B	170	745	680	1594	268	1454	1459	3181	1.58	1.95	2.15	2.00
C	171	731	685	1587	273	1441	1461	3175	1.60	1.97	2.14	2.00
D	175	731	666	1572	276	1411	1434	3120	1.58	1.93	2.15	1.99
SEM	5.1	14.3	8.5	21.5	4.0	21.8	21.5	37.1	0.04	0.03	0.04	0.02
ANOVA												
					Probability							
CP	0.068	0.876	0.210	0.745	0.050	0.255	0.219	0.243	0.356	0.620	0.909	0.507
Linear	0.029	0.694	0.083	0.663	0.015	0.115	0.076	0.093	0.213	0.320	0.843	0.263
Quadratic	0.383	0.739	0.638	0.531	0.608	0.565	0.905	0.746	0.458	0.945	0.701	0.704

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

[2]Diet A contained 23, 22 and 20% CP; diet B contained 22, 21 and 19% CP; diet C contained 21, 20 and 18% CP and diet D contained 20, 19 and 17% CP for starter, grower and finisher periods, respectively

Table 5. Overall mortality, total protein intake and protein efficiency ratio of broilers as influenced by different dietary CP levels during starter, grower, finisher and overall experimental period[1]

Item	Total protein intake (g/bird)				Protein efficiency ratio[2] (g:g)				Mortality (%)
	Starter 1-10 d	Grower 11-26 d	Finisher 27-35 d	Overall 1-35 d	Starter 1-10 d	Grower 11-26 d	Finisher 27-35 d	Overall 1-35 d	Overall 1-35 d
Diets[3]									
A	60^{a}	321^{a}	298^{a}	679^{a}	2.62^{c}	2.29^{c}	2.32^{c}	2.33^{d}	6.6
B	59^{a}	305^{ab}	277^{b}	641^{b}	2.87^{bc}	2.44^{bc}	2.45^{bc}	2.48^{bc}	5.0
C	57^{ab}	288^{b}	263^{b}	608^{c}	2.99^{ab}	2.54^{b}	2.61^{ab}	2.61^{bc}	5.0
D	55^{b}	268^{c}	244^{c}	567^{d}	3.16^{a}	2.73^{a}	2.73^{a}	2.77^{a}	5.9
SEM	0.9	4.5	4.0	7.2	0.069	0.040	0.047	0.032	0.80
ANOVA									
				Probability					
CP	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.265
Linear <0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.585	
Quadratic	0.536	0.618	0.819	0.798	0.565	0.616	0.899	0.906	0.131

[a-d]Means within a column with different superscripts differ significantly ($P < 0.001$) ; [1]Means of 4 replicates with 110 birds in each replicate ; [2]Calculated as weight gain divided by protein intake ; [3]Diet A contained 23, 22 and 20% CP; diet B contained 22, 21 and 19% CP; diet C contained 21, 20 and 18% CP and diet D contained 20, 19 and 17% CP for starter, grower and finisher periods, respectively.

utilization was decreased. There might also be differences in AA digestibilities of diets because there were various levels of corn, soybean meal and synthetic AA resulting in different availabilities of AA and increased feed intake and FCR.

The TPI during all the periods decreased linearly ($y = -37x + 716.5$; $R^2 = 0.99$) ($P<0.001$) as the level of CP was decreased (Table 5). A significant ($P<0.01$) positive correlation was observed between feed intake and TPI ($r = 0.68$). Since, the feed intake remained the same on all the diets; the decrease in TPI was only due to reduction in CP levels. The results depicted a nonsignificant correlation between TPI and the weight gain ($r = 0.26$) of chicks. That's why weight gain remained the same on all the diets although TPI was decreased as a result of decreasing CP level in the diet. A significant linear ($y = 0.145x + 2.185$; $R^2 = 0.99$) ($P<0.001$) effect of dietary CP level was also found on PER during all the periods which was improved as a result of lowering the dietary CP content (Table 5). Although the birds fed the low CP diets consumed less protein, the AA profile of the low CP diets was such that there was no effect on weight gain of the birds. So the PER was increased indicating that the efficiency of protein utilization was better with low CP diets. The improvement in PER with low CP diets may be due to increased fat deposition in some cases but in the present study, this was not the case because the abdominal fat was similar among dietary treatments (Table 7). The results regarding TPI and PER were consistent with the findings of Cheng *et al.* (1997a,b) who observed a linear decrease in TPI and a linear increase in PER with the reduction in dietary CP content. Aletor *et al.* (2000) also reported improved PER with reduced CP diets. No significant differences in mortality occurred due to dietary treatments (Table 5).

The total ME intake was same for all the diets during all growth periods (Table 6). Since, all the diets were isocaloric within a phase, the feed intake of the birds was similar among treatments. This is because birds primarily eat for their energy intake. So, the total ME intake of the birds was not affected by the dietary treatments ($P<0.05$). Similarly, EER was also not affected during different growth periods due to similar weight gain among different dietary treatments (Table 6). However, Cheng *et al.* (1997b) reported higher ME intake and EER with low CP diets. In their study, birds fed isocaloric low CP diets increased their feed intake and thus consumed more energy and gained more weight resulting in higher EER.

Carcass characteristics: It was observed that the yields of carcass, breast meat and thigh were not affected by lowering the dietary CP content (Table 7). It is known that higher dietary levels of lysine, methionine and threonine are required to optimize breast meat yield and carcass yield than those required for weight gain. These 3 AA are exclusively used for protein accretion in the body and breast meat yield in particular, is very sensitive to dietary lysine, threonine and methionine levels (Si *et al.* 2001, Ayasan *et al.* 2009). Therefore, these results might be due to the higher Hubbard recommended dietary AA levels than the levels normally used. Sterling *et al.* (2002, 2006) found that dietary CP level had no significant effect on carcass yield and breast meat yield. Similarly, Moran and Stilborn (1996) and Khajali and Moghaddam (2006) also found no effect on the carcass yield of broilers fed low CP diets adequate in essential AA. However, Rezaei *et al.* (2004) found that carcass yield significantly decreased with low CP diets while there was no effect on the breast meat yield. In contrast, Widyaratne

Table 6. Total ME intake and energy efficiency ratio of broilers as influenced by different dietary CP levels during starter, grower, finisher and overall experimental period[1]

Item	Total ME intake (kcal)				Energy efficiency ratio[2] (gain/100 kcal ME)			
	Starter 1-10 d	Grower 11-26 d	Finisher 27-35 d	Overall 1-35 d	Starter 1-10 d	Grower 11-26d	Finisher 27-35 d	Overall 1-35d
Diets[3]								
A	764	4485	4662	9911	20.60	16.39	14.82	15.97
B	785	4470	4560	9815	21.61	16.66	14.91	16.24
C	798	4431	4566	9794	21.47	16.50	15.01	16.21
D	806	4440	4480	9625	21.64	16.84	14.86	16.32
SEM	11.8	67.2	67.2	115.0	0.494	0.274	0.277	0.203
ANOVA								
				Probability				
CP	0.126	0.452	0.339	0.399	0.425	0.677	0.964	0.655
Linear	0.015	0.115	0.076	0.090	0.184	0.325	0.852	0.251
Quadratic	0.608	0.565	0.905	0.751	0.399	0.891	0.655	0.697

[1]Means of 4 replicates with 110 birds in each replicate ; [2]calculated as weight gain divided by 100 kcal energy intake ; [3]diet A contained 23, 22 and 20% CP; diet B contained 22, 21 and 19% CP; diet C contained 21, 20 and 18% CP; and diet D contained 20, 19 and 17% CP for starter, grower and finisher periods, respectively.

and Drew (2011) reported that breast meat yield is lower with low CP diets.

As a result of increased fat synthesis, birds fed the low CP diets are expected to deposit more abdominal fat. However, in the present study, it was not the case and abdominal fat remained similar among different dietary treatments (Table 7). This might be due to the reason that although CP content of the diet was decreased, the ME and AA pattern provided in the diet exactly met the requirements of birds for gain; hence there was not any noticeable increase in abdominal fat. Our results were in agreement with the findings of Han *et al.* (1992) and Kamran *et al.* (2004) who found that body fat levels of the birds fed 20% CP diets were comparable to those fed 23% CP diet. However, these findings were not consistent with those of Sterling *et al.* (2002). Neto *et al.* (2000) observed that abdominal fat pad weight increased by 104% when the birds were fed 17% CP diet as compared to those fed 24% CP diet. Although, the increased liver weight was expected due to increased de novo lipogenic activity in the liver of low protein fed chickens, the per cent liver and heart weights of broilers were not affected by reducing the dietary CP level (Table 7). These results were in accordance with the findings of Cheng *et al.* (1997a) and Sterling *et al.* (2006) who did not find any effect of dietary CP levels on liver weights.

Economics: The data regarding the economic aspect of

Table 7. Carcass characteristics of broilers as influenced by different dietary CP levels from 1 to 35 days of age[1]

Item	Carcass yield[2] (%)	Breast meat yield[3] (%)	Thigh yield[3] (%)	Abdominal fat[3] (%)	Liver weight[3] (%)	Heart weight[3] (%)
Diets[4]						
A	64.0	20.2	14.5	2.3	4.3	1.02
B	65.7	21.6	14.3	2.5	3.7	0.88
C	64.4	21.5	14.6	2.3	4.1	0.99
D	64.0	21.8	13.9	2.4	4.2	0.98
SEM	0.86	0.90	0.20	0.50	0.19	0.07
ANOVA						
Probability						
CP	0.491	0.446	0.148	0.993	0.316	0.633
Linear	0.711	0.270	0.112	0.987	0.982	0.945
Quadratic	0.265	0.513	0.247	0.912	0.136	0.349

[1]Means of 4 replicates with 5 birds from each replicate; [2]calculated by carcass weight including skin and giblets; [3]calculated as percent of carcass weight; [4]diet A contained 23, 22 and 20% CP; diet B contained 22, 21 and 19% CP; diet C contained 21, 20 and 18% CP, and diet D contained 20, 19 and 17% CP for starter, grower and finisher periods, respectively.

Table 8. Economic evaluation of different dietary CP levels fed to broilers from 1 to 35 days of age

Item	Cost of feed[1] (Rs)	Cost/kg live weight[2] (Rs)
Diets[3]		
A	13.2	25.5
B	13.1	24.6
C	12.9	24.4
D	12.7	23.7

[1] Rs per kg feed; [2] Rs per kg live weight gain; [3]diet A contained 23, 22 and 20% CP; diet B contained 22, 21 and 19% CP; diet C contained 21, 20 and 18% CP; and diet D contained 20, 19 and 17% CP for starter, grower and finisher periods, respectively.

the use of the low CP diets showed that cost per kg of feed and cost per kg of live weight gain decreased as the CP content of the diet was reduced (Table 8). Therefore, maximum economic returns were observed in groups fed the low CP diets and it clearly indicated that this approach is useful for economical broiler production. These results were in close agreement with the findings of the Hulan and Proudfoot (1981) and Hai and Blaha (1998) who reported that the feed cost per kg of live weight gain was reduced without affecting the growth performance as isoenergetic low CP diets adequate in levels of essential AA were fed to the broiler chicks.

Reducing the dietary CP level provided substantial economic savings without affecting the growth performance and carcass characteristics of broilers provided that limiting AA contents were considered. It was also observed that low levels of CP used in the present study were satisfactory for broiler performance in environmentally controlled housing and the levels recommended in the Hubbard management guide are higher for this type of farming. In general, the lowest levels of dietary CP in present experiment (20, 19 and 17% for starter, grower and finisher periods, respectively); while maintaining the optimal balance of limiting AA, were found adequate for the optimum performance of broiler chickens. Further research is needed to determine the lowest level of CP after which the performance suffers under these conditions.

ACKNOWLEDGMENTS

The support of the Islamabad Feeds and Chicks, Rawalpindi (Pakistan) is gratefully acknowledged for providing chicks, feed and experimental facilities at its research and development (R&D) farm for the present trial.

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