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Comparison of Growth Performance and Carcass Characteristics of Broiler Chickens Fed Diets with Various Energy and Constant Energy to Protein Ratio

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Abstract: This experiment was conducted to compare the effect of diets with various energy constant ME: CP ratio on performance, nutrients efficiency and carcass characteristics of broiler chickens. In a completely randomized design experiment, five starter, grower and finisher diets were formulated to have 2800, 2,900, 3,000, 3,100 and 3,200 kcal of ME kg^{-1} whereas the CP in starter diets (0-7 day) were 20.14, 20.84, 21.56, 22.28 and 23%, in grower diets (8-28 days) were 17.5, 18.13, 18.75, 19.38 and 20 and in finisher diets (29-42 days) were 15.75, 16.31, 16.85, 17.43 and 18%, respectively. About 200 day old Arbor acres broiler chickens were randomly assigned to 20 groups of 10 birds each. The ME: CP ratio and other nutrients such as Ca, P and amino acid per CP ratio were fixed over all diets in every period. Feed and water were fed *ad libitum*. Body weight and feed consumption were measured weekly and carcass characteristics were evaluated at the termination of experiment. Two birds (1 male and 1 female) from each pen were randomly selected and slaughtered to weigh carcass yield, gizzard, heart, liver, abdominal fat, breast meat and thigh meat at the end of experiment. Body weight was greater in birds fed diets contained >3000 kcal kg^{-1} compared to those fed <3000 kcal ME kg^{-1}. The feed intake was not affected by dietary treatment during growing and finishing periods. Birds fed diets contained lower energy and protein had a higher FCR during all periods. The Energy Efficiency Ratio (EER) and Protein Efficiency Ratio (PER) were decreased in birds fed diets with low CP and ME content during growing period but not affected throughout starter and and finisher periods. Dietary treatments did not influence relative weight of thigh, breast bile, gizzard and abdominal fat but the relative weight of liver and heart increased ($p<0.05$) when chickens fed diet contained higher ratio of ME: CP. The gender did not affect percentage weight of liver, Gallbladder, gizzard and abdominal fat but the percentage of breast, thigh and heart were influenced by sex of birds. It is concluded that the high nutrients density and high energy diets may improve the nutrients efficiency, carcass characteristics and performance of broiler chickens.

Key words: Energy, protein, nutrient efficiency, ME:CP ratio, broiler chickens, carcass characteristics

INTRODUCTION

Energy and protein are two main nutrients that can affect all production parameters in broiler chickens (Nieto *et al*., 1997; Collin *et al*., 2003; Kamran *et al*., 2008). These nutrients are the major factors that influence the cost of chicken ration. Lowering percentage of dietary protein may decrease the charge of ration. Increasing dietary ME significantly increased the body weight gain (Zaman *et al*., 2008). The growth rate and Feed Conversion Ratio (FCR) of broilers were improved by increasing the dietary energy concentration (Hutagalung *et al*., 1980; Sizemore and Siegel, 1993). They also observed that FCR was improved by increasing the concentration of protein in diets but the best growth rate was reported in birds fed diets with high energy and low protein (Hutagalung *et al*., 1980). Kamran *et al*. (2008) reported that weight gain was linearly decreased whereas feed intake and feed conversion ratio were increased as dietary protein and energy decreased during experimental

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periods. Dilution of dietary energy and protein significantly influenced growth rate (Lesson *et al*., 1996). Macronutrients in diet affect performance and body composition of chickens (Collin *et al*., 2003). Feeding a high-energy starter diet during 21st day post hatch resulted in higher carcass fat percentages at final body weight (Sizemore and Siegel, 1993). The higher concentration of energy induced a higher content of abdominal fat (Shrivastav and Panda, 1991; Ayorinde, 1994; Raju *et al*., 2004; Nahashon *et al*., 2005). Diet energy dilution had a trifle influence on carcass weight or yield of breast meat, although it was lessened the abdominal fat of male broiler chickens (Lesson *et al*., 1996). However, the carcass weight and breast meat yield of male broiler was linearly decreased as the diet was diluted for both energy and protein (Lesson *et al*., 1996).

Two percentage decreases in diet protein did not significantly affect abdominal fat of broiler (Kerr and Kidd, 1999; Azarnik *et al*., 2010). There are many reports that indicated that carcass composition of broilers are affected by CP and Amino Acid (AA) status of diets and decrease in dietary CP causes an increase in carcass fat and a decrease in carcass protein content (Si *et al*., 2001).

The carcass yield, breast meat yield, thigh yield, liver and heart and abdominal fat were not influenced by the concentration of dietary energy and protein (Kamran *et al*., 2008). The abdominal fat and liver weights and protein and fat contents of the carcass were significantly increased by increasing dietary ME (Zaman *et al*., 2008). In grower and finisher diets, Energy Efficiency Ratio (EER) and Protein Efficiency Ratio (PER) were linearly decreased when dietary CP and energy content were reduced, however EER and PER were not affected by starter diet (Kamran *et al*., 2008). Although the PER were increased with reduced concentration of CP and energy in diets when the ME:CP was not constant (Cheng *et al*., 1997a).

This suggested that lowering the nutrient density to 3000 kcal kg^{-1} can improve the growth performance and abdominal fat. Today, the efficiency of nutrients and carcass characteristics are as much important as productive parameters. Therefore, the purpose of this study was to compared the effect of diets with various energy and constant ME: CP on nutrient efficiency, carcass characteristics and performance of broiler chickens.

MATERIALS AND METHODS

Birds and diets: This trial was conducted in an environmentally controlled house. In a completely randomized design expriment, 200 days old Arbor acres broiler chicks (1/2 males and 1/2 females) were randomly divided into 20 groups of 10 chicks each. Five starter, grower and finisher diets were formulated to have 2800, 2,900, 3,000, 3,100 and 3,200 kcal of ME kg^{-1} whereas the CP in starter diets (0-7 days) were 20.14, 20.84, 21.56, 22.28 and 23% in grower diets (8-28 days) were 17.5, 18.13, 18.75, 19.38 and 20 and in finisher diets (29-42 days) were 15.75, 16.31, 16.85, 17.43 and 18%, respectively. The ME: CP ratio and other nutrients such as Ca, P and amino acids per CP were similar in all diets for energy period. The ME:CP ratio was maintained at 139, 160 and 178 for starter, grower and finisher diets, respectively. The ingredient composition of five diets and calculated nutrients in starter, grower and finisher periods are shown in Table 1-3, respectively (NRC, 1994). The nutrient compositions of diets either met or exceeded the Arbor acres broiler chickens recommendations. The birds were

Table 1: Composition of starter diets containing various energy (ME kcal kg^{-1}) with constant ME:CP ratio (0-7 days)

Ingredient	3200 ME 23.00% CP	3100 ME 22.28% CP	3000 ME 21.56% CP	2900 ME 20.84% CP	2800 ME 20.14% CP
Corn	45.960	51.750	56.790	58.960	58.170
Soy bean	34.380	32.340	30.490	30.990	29.010
Fish meal	6.500	6.000	5.000	3.860	3.000
Vegetable oil	9.230	6.240	3.860	2.140	1.160
Wheat bran	0.000	0.000	0.000	0.000	3.000
Limestone	0.832	0.794	0.798	0.817	0.796
D.C.P	1.272	1.232	1.297	1.311	1.312
Sodium chloride	0.200	0.200	0.200	0.200	0.200
Min permix[1]	0.500	0.500	0.500	0.500	0.500
Vit permix[1]	0.500	0.500	0.500	0.500	0.500
Anzemit	0.400	0.400	0.400	0.400	0.400
MET	0.200	0.070	0.130	0.064	0.120
LYS	0.000	0.000	0.000	0.000	0.000
Nutrient composition (%)					
ME (kcal kg^{-1})	3200.000	3100.000	3000.000	2900.000	2800.000
CP (%)	23.000	22.280	21.260	20.840	20.130
Available P (%)	0.450	0.440	0.420	0.410	0.390
Ca (%)	1.320	0.970	0.940	0.910	0.880
Met+Cys (%)	0.710	0.750	0.710	0.700	0.670
Lys (%)	1.330	1.300	1.260	1.200	1.140

[1]Supplied per kilogram of diet: vitamin A (as retinyl acetate), 14,000 IU; vitamin D3 (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 B12, 12.1 g; Fe, 98 mg ; Mn, 112 mg; Cu, 9.8 mg; Se, 0.07 mg; Zn, 110 mg and choline chloride, 550 mg

Table 2: Composition of grower diets containing various energy (ME kcal kg^{-1}) with constant ME:CP ratio (8-28 days)

Ingredient	3200 ME 20.00% CP	3100 ME 19.38% CP	3000 ME 18.75% CP	2900 ME 18.13% CP	2800 ME 17.50% CP
Corn	55.22	60.432	64.890	68.430	65.110
Soy bean	30.52	28.168	25.940	23.570	21.980
Fish meal	3.00	3.000	3.000	3.000	2.410
Vegetable oil	7.556	4.737	2.290	0.128	0.250
Wheat bran	0.00	0.000	0.000	0.980	6.450
Limestone	0.7845	0.775	0.796	0.817	0.796
D.C.P	1.26	1.232	1.282	1.311	1.332
Sodium chloride	0.20	0.200	0.200	0.200	0.200
Min permix[1]	0.50	0.500	0.500	0.500	0.500
Vit permix[1]	0.50	0.500	0.500	0.500	0.500
Anzemit	0.40	0.400	0.400	0.400	0.400
MET	0.059	0.058	0.038	0.064	0.070
LYS	0.00	0.000	0.000	0.000	0.000
Nutrient composition (%)					
ME (kcal kg^{-1})	3200	3100.000	3000.000	2900.000	2800.000
CP (%)	20	19.380	18.750	18.130	17.500
Available P (%)	0.35	0.340	0.330	0.320	0.310
Ca (%)	0.92	0.870	0.840	0.820	0.790
Met+Cys (%)	0.728	0.710	0.677	0.646	0.656
Lys (%)	1.17	1.107	1.050	0.991	0.914

[1]Supplied per kilogram of diet: vitamin A (as retinyl acetate), 14,000 IU; vitamin D3 (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 B12, 12.1 g; Fe, 98 mg; Mn, 112 mg; Cu, 9.8 mg ; Se, 0.07 mg; Zn, 110 mg and choline chloride, 550 mg

Table 3: Composition of finisher diets containing various energy (ME kcal kg^{-1}) with constant ME:CP ratio (29-42 days)

Ingredient	3200 ME 18% CP	3100 ME 17.43% CP	3000 ME 16.85% CP	2900 ME 16.31% CP	2800 ME 15.75% CP
Corn	56.030	61.910	66.340	70.110	65.910
Soy bean	30.760	28.110	26.110	23.980	21.910
Wheat bran	0.000	0.000	0.000	0.620	6.260
Vegetable oil	9.200	6.000	3.540	1.270	1.840
Limestone	0.850	0.850	0.850	0.860	0.870
D.C.P	1.300	1.300	1.310	1.310	1.330
Sodium chloride	0.210	0.200	0.210	0.210	0.210
Min permix[1]	0.510	0.510	0.510	0.520	0.520
Vit permix[1]	0.510	0.510	0.510	0.520	0.520
Anzemit	0.410	0.410	0.410	0.410	0.420
MET	0.210	0.200	0.210	0.210	0.210
LYS	0.000	0.000	0.000	0.000	0.000
Nutrient composition (%)					
ME (kcal kg^{-1})	3200.000	3100.000	3000.000	2900.000	2800.000
CP (%)	18.000	17.440	16.870	16.310	15.750
Available P (%)	0.350	0.340	0.330	0.320	0.310
Ca (%)	1.104	0.870	0.840	0.820	0.790
Met+Cys (%)	0.728	0.710	0.677	0.646	0.660
Lys (%)	1.166	1.107	1.050	0.991	0.913

[1]Supplied per kilogram of diet: vitamin A (as retinyl acetate), 14,000 IU; vitamin D3 (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 B12, 12.1 g ; Fe, 98 mg; Mn, 112 mg; Cu, 9.8 mg; Se, 0.07 mg; Zn, 110 mg and choline chloride, 550 mg

raised under standard management conditions and feed and water were supplied *ad libitum* throughout the experimental period.

Data collection: Body weight and feed consumption were measured weekly and Feed Conversation Ratio (FCR) was calculated for each week and period. Energy Efficiency Ratio (EER) and Protein Efficiency Ratio (PER) were also calculated for starter and grower periods. The EER was computed as grams of weight gain×100 divided by total ME intake whereas the PER was computed as grams of weight gain per gram protein intake. Two birds (1 male and 1 female) from each replicate were randomly selected and scarified to weigh the breast, thigh, liver, gizzard, heart and abdominal fat at the end of experiment.

Statistical analysis: Data were pooled and analyzed using the general linear model of SAS and means were separated by Duncan's multiple range test ($p<0.05$) (SAS, 1998). The percentage data were transformed using arcsine square root (x+1) prior to statistical analysis.

RESULTS AND DISCUSSION

There were significant differences ($p<0.05$) in growth performance parameters among birds fed diets with arious energy and constant ME:CP ratio (Table 4). Feed intake was not significantly affected by dietary treatments during growthing and finishing periods, however it was increased significantly with increasing the concentration of CP and ME ($p<0.05$) during starter period. It seems that

Table 4: Effect of dietary ME with constant ME:CP ratio on growth performance of broiler chickens

ME (kcal kg^{-1})	CP (%)			Body weight (g/bird)			Feed intake (g/bird)			Feed: gain (g:g)		
	S[1]	G	F	7 days	28 days	42 days	0-7 days	8-28 days	29-42 days	0-7 days	8-28 days	29-42 days
3200	23.00	20.00	18.00	91.2750^{a}	879.9000^{a}	1966.2800^{a}	112.7750^{a}	2130.8000	4087.7000	1.2401^{b}	2.4250^{c}	2.0770^{b}
3100	22.28	19.38	17.43	83.0500^{a}	834.2300^{a}	1990.9500^{a}	103.4250^{ab}	2110.5000	4102.7000	1.2520^{ab}	2.5430^{bc}	2.0640^{b}
3000	21.56	18.75	16.85	82.5250^{a}	798.7000^{a}	1880.5300^{ab}	102.0250^{b}	2120.6500	4058.0000	1.2420^{b}	2.6551^{bc}	2.1560^{b}
2900	20.84	18.13	16.31	82.7000^{a}	795.5500^{a}	1773.2500^{b}	108.5000^{ab}	2169.4800	4056.9000	1.3190^{ab}	2.7280^{b}	2.2880^{a}
2800	20.14	17.50	15.75	70.2750^{b}	661.5000^{b}	1648.8300^{c}	98.5000^{b}	2072.8800	3854.2000	1.4000^{a}	3.1550^{a}	2.3380^{a}
SEM	-	-	-	54.4630	1412.2100	3824.6710	15.0800	3548.2410	4754.7000	0.0088	0.0307	0.0064
Pr>F	-	-	-	0.0187	0.0013	<0.0001	<0.0007	0.7292	0.4357	0.1217	<0.0004	<0.0005^{a}

$^{a-c}$Means within each column with no common superscripts differ significantly ($p<0.05$). [1]S: Statrter diet (0-7 days), G: Grower diet (8-28 daya) and F: Finisher diet (29-42 days); Diets: CP = Crude Protein

there is a physical limitation for FI in very young chicks (Griffiths *et al*., 1977). The diet with higher energy and protein had higher oils and fish meal but the diets with lower energy and protein had higher wheat bran and higher physical volume or lower nutrients density (Table 1-3), therefore the later one may cause a more physical limitation on FI.

This finding showed that birds fed with diets contained <3000 kcal ME kg^{-1} might not had enough nutrient intakes especially protein. Tooci *et al*. (2009) reported that chicks received diluted diet, physical trend has been occurred before providing required energy which has caused a trifle increase in feed intake. The ME and CP dilution did not affect on feed intake (Han *et al*., 1992; Bartov and Plavnik, 1998; Kamran *et al*., 2004; Nawaz *et al*., 2006). Other investigators reported that diets with lower energy and protein, the feed intake were increased to fulfil their demands for calories (Golian and Maurice, 1992; Hidalgo *et al*., 2004; Kamran *et al*., 2008).

Body weight was elevated with increased in CP and ME content of diet in every periods of experiment ($p<0.05$). The differences were more pronounced in finisher period and the lowest body weight was observed when birds fed diet contained 2800 kcal ME. Birds fed diets contained 2800 kcal ME and 15.75% CP did not have enough feed intake to fulfil their nutrient requirements. These findings were in accordance with Kamran *et al*. (2008) who found that the same trend for all periods in experiment, however they observed significant differences in grower and finisher periods.

Sizemore and Siegel (1993) observed lighter body weight when birds fed lower density-starter diets compared to those fed higher density diets at 3 weeks of post hatch. The feed conversion ratio was decreased with elevated dietary energy. The lower FCR were observed for bird's receiving diets contained >3000 kcal kg^{-1}. The differences among dietary treatments were more shown in grower period, however the same trend was observed for all periods ($p<0.05$). Moran *et al*. (1992) noted that the FCR was significantly increased when CP was decreased from 230-210 g kg^{-1} and 210-170 g kg^{-1} in the starter and grower diets, respectively. Similar findings were reported in other studies (Hutagalung *et al*., 1980; Sizemore and Siegel, 1993; Kamran *et al*., 2008). The growth rate and feed conversion ratio of broiler chickens were improved by increasing the dietary energy concentration (Hutagalung *et al*., 1980; Sizemore and Siegel, 1993; Kamran *et al*., 2008). The increase in dietary ME is one of the possible ways to meet the bird's energy requirement under hot climate (Zaman *et al*., 2008).

The EER and PER were decreased as a result of lowering the dietary CP and ME content in grower period (Table 5). The EER and PER values were not significantly decreased ($p<0.05$) in starter and finisher periods, however the same trend were observed for all periods. The EER and PER values were decreased with lowering the ME and CP content of diets (Kamran *et al*., 2008). These results were also in agreement with findings of Cheng *et al*. (1997b) with regard to EER but they observed a linear gain in PER values with reduction in concentration of CP in diet which is in contrast with the observations. These differences may be due to the concentration of energy and protein or the ratio of ME:CP that was used in different studies.

The effects of dietary protein and energy content on carcass characteristic of broiler chickens were shown in Table 6. The dietary treatments did not influence the relative weight of thigh, breast, gallbladder, gizzard and abdominal fat. These results were in agreement with the reports of some other investigations whom did not observe any changes in carcass yields of broiler chicken fed diet varying in energy and protein concentration (Kamran *et al*., 2008; Hidalgo *et al*., 2004).

Feeding birds with diets formulated to contain suboptimum concentrations of CP and ME impaired the weight and yield of carcass parts (Dozier and Moran, 2001, 2002). The relative weight of liver did not significantly affected by feeding low protein diets (Han *et al*., 1992; Kamran *et al*., 2004; Nawaz *et al*., 2006). The relative weight of liver and heart increased ($p<0.05$) when broiler chickens fed diets

Table 5: Effect of dietary ME with constant ME:CP ratio on energy and protein efficiency ratio of diets in broiler chickens

	CP (%)			Energy efficiency ratio (%)[1]			Protein efficiency ratio (g/g)[2]		
ME (kcal kg^{-1})	S[3]	G	F	0-7 days	8-28 days	29-42 days	0-7 days	8-28 days	29-42 days
3200	23.00	20.00	18.00	25.292	12.8940^{a}	15.0600	3.5190	2.0630^{a}	2.4100
3100	22.28	19.38	17.43	25.886	12.7500^{a}	15.6530	3.6020	2.0390^{a}	2.5040
3000	21.56	18.75	16.85	26.940	12.5710^{a}	15.4680	3.7490	2.0110^{a}	2.4750
2900	20.84	18.13	16.31	26.263	12.6460^{a}	15.0890	3.6550	2.0230^{a}	2.4140
2800	20.14	17.50	15.75	25.598	11.3970^{b}	15.2840	3.5590	1.8230^{b}	2.4450
SEM	-	-	-	3.604	0.5340	0.3247	0.0698	0.0136	0.0083
Pr>F	-	-	-	0.769	0.0365	0.0479	0.7650	0.0370	0.1830

$^{a-b}$Means within each column with no common superscripts differ significantly ($p<0.05$). [1]Calculated as weight gain *100/total ME consumption. [2]Calculated as weight gain/protein consumption. [3]S: Statrter diet (0-7 days), G: Grower diet (8-28 days) and F: Finisher diet (29-42 days); Diets: CP = Crude Protein

Table 6: Relative weight of organs in broiler chickens fed diets with different concentration ME and constant ME:CP ratio

	CP (%)			Percent of live Body Weight (BW)						
ME (kcal kg^{-1})	SP[1]	GP	FP	Breast	Thigh	Gallbladder	Liver	Heart	Gizzard	Abdominal fat
3200	23.00	20.00	18.00	29.7500	31.7700	0.1540	2.6230^{c}	0.7100^{b}	2.5810	3.2730
3100	22.28	19.38	17.43	29.1300	31.1800	0.1800	2.7360^{bc}	0.6600^{b}	2.5040	3.0840
3000	21.56	18.75	16.85	29.0600	31.7700	0.1310	2.9340^{abc}	0.7600^{ab}	2.5080	3.0320
2900	20.84	18.13	16.31	28.1600	32.2900	0.1680	3.1260^{ab}	0.8880^{a}	2.4660	3.1240
2800	20.14	17.50	15.75	27.9100	31.3700	0.1410	3.2800^{a}	0.7980^{ab}	2.5550	3.2670
Sex										
Male	-	-	-	30.0900^{a}	30.8100^{b}	0.1640	2.9750	0.7075^{b}	2.4190	3.3800
Female	-	-	-	27.5100^{b}	32.5400^{a}	0.1460	2.9050	0.8185^{a}	2.6260	2.9320
SEM	-	-	-	6.5889	2.2720	0.0050	0.2008	0.2176	0.1235	0.6581
Probability										
Treatment	-	-	-	0.6010	0.6364	0.6594	0.0355	0.0429	0.9685	0.9642
Sex	-	-	-	0.0032	0.0009	0.4415	0.6270	0.0231	0.0708	0.0898

$^{a-c}$Means within each column with no common superscripts differ significantly ($p<0.05$). [1]S: Statrter diet (0-7 days), G: Grower diet (8-28 days) and F: Finisher diet (29-42 days); Diets: CP = Crude Protein

contained higher concentration of ME and CP. It is postulated that the enhanced de novo lipogenesis in the liver of birds fed the low-CP, seems to have increase liver weights and deposit more abdominal fat due to increased in ME:CP ratio of diet.

The gender did not affect percentage weight of liver, gallbladder, gizzard and abdominal fat of chickens but the percentage of breast, thigh and heart were significantly changed by the sex of birds. The relative weight of thigh and heart were significantly higher in female and breast was higher in male broiler chickens. These findings were in accordance with the reports of Hutagalung *et al.* (1980) who observed that the relative weight of breast meat and heart were higher in male broilers but the thigh meat were higher in female broilers.

CONCLUSION

It was concluded that the high concentration of energy and protein in diets especially >3000 kcal ME kg^{-1} may improve the performance parameters and carcass characteristic of broilers but diets with <3000 kcal ME kg^{-1} has produce lower growth performance parameters. The gender also affect breast, thigh and heart weight of broiler chickens fed diets with different nutrients density.

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