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Original Research Article

Effects of low dietary energy, with low and normal protein levels, on broiler performance and production characteristics

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ABSTRACT

The study was conducted to investigate the effect of low metabolizable energy diets with normal or narrow metabolizable energy to crude protein ratios (ME:CP) on performance, carcass characteristics, body composition and blood parameters in broilers fed from 1 to 42 days of age. The chicks were divided into 7 groups. The birds were fed starter & grower diets. Seven experimental diets were formulated in each phase; one control and 6 tested diets. The control diet was formulated according to the NRC of poultry (1994) and the other six diets fed three different levels of low energy diets (2900, 2700 & 2500 kcal/kg; one level for each 2 groups). The first three tested groups named ''normal calorie-protein ratio” groups in which the CP decreased in proportion to the decrease in ME, keeping the normal NRC ratio. In the second three tested groups, termed “narrow calorie-protein ratio” groups, the dietary protein was kept at the NRC levels leading to ratios narrower than that of the NRC. Results showed that chicks fed low ME diets with normal energy to protein ratio had lower body weight and feed utilization efficiency than the chicks fed the control diets. While, birds fed the low ME diets with normal protein NRC-levels and narrow ratios had nearly equal weight and feed conversion to the control. The body composition and carcass characteristics were not affected by the dietary treatments. Moreover, the blood parameters had no significant variations among the groups, except for total protein, ALT and AST which had an increased response to decreased dietary energy density. In conclusion, decreasing the dietary ME level without decreasing the crude protein level was more efficient economically and had no any adverse effect on the performance. However, decreasing of dietary ME with normal ME:CP ratio resulted in decreased performance and low economic efficiency.

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1. Introduction

Global poultry production has been significantly improved over the past fifty years to accommodate rising request. Broilers make up a large part of the industry with chicken meat representing 86% of the world poultry meat production (Economic Research Service/USDA, 2001).

New challenges to the industry as the slowing of production and increasing feed and energy costs have led to increases in marketing price for poultry products which are more closely following increases in food price (MacDonald, 2010). In order to maintain growth and profitability, it is becoming progressively important to find new methods to stay competitive within the industry and decrease the expenses of production as much as possible while producing a high quality product. Meeting the nutritional requirements for broilers constitutes the majority of costs in poultry production (May et al., 1998). Cost of the feed reaches about 70% of the total cost of production in most poultry production initiatives (Kamran et al., 2010), and certainly is becoming a matter of even greater significance as the prices of feed ingredients continue to increase.

Energy and protein are the two main nutrients that can affect all production limits in broiler chickens (Kamran et al., 2008a). Such nutrients are the most important factors that affect the cost of chicken diets. Decreasing the percentage of dietary protein and density of energy may decrease the cost of the diets and give the possibility of achieving significant cost savings.

Dietary crude protein is the most expensive constituent in broilers diets. So, great efforts were done to reduce feeding cost using the optimum levels of crude protein and metabolizable energy. Low protein diets were tried to be supplemented with essential and/or nonessential amino acids. Some trials to decrease dietary protein level had been carried out by many investigators (El–Sherbiny et al., 1997; El-Khimsawy et al., 2002) who reported that broilers fed low protein diets supplemented with essential or nonessential amino acids could grow equally_to those fed on higher or optimal levels of crude protein. While, Fancher and Jensen (1989) and Pinchasov et al. (1990) recorded that the ideal broiler performance cannot be reached when low-protein diets supplemented with amino acids were fed to broiler chicks. Metabolizable energy is another essential aspect which plays a part in lipogenesis in birds fed low crude protein diets. Metabolizable energy in excess of that required for protein deposition leads to a higher carcass fat content. On the other hand, if dietary energy availability becomes limiting, the dietary crude protein will be deposited less proficiently (Eits et al., 2002). Henceforward, not only dietary energy and CP but also a specific calorie to protein ratio is important for maximum growth rate and carcass composition (Buyse et al., 1992; Nieto et al., 1997; Collin et al., 2003). Still many poultry investigators are trying to find out new methods for an economical poultry production by increasing the returns, especially through reducing the consumption of energy and protein (EL-Sheikh, 2002).

Hence, the aim of the present study was to investigate the effect of diets containing low-energy with low and normal protein levels on broiler performance. Furthermore, its effects on carcass characteristics, body composition, blood parameters and economic efficiency were evaluated.

2. Materials and methods

2.1. Birds and management

A total of 280 one-day old broiler chicks (Ross 308) were procured from the "Egyptian company", Egypt, with an average weight of 50 g. The chicks were randomly assigned into 7 floor pens of 6.25 m^2 (2.5×2.5 m) each, with 40 chicks/pen. Each of the seven pens was equipped with one feeder, an incubation dish - 45 cm in diameter and made of plastic. The dish was suitable for chicks aging from day to ten days. After this age one manual feeder was used. One manual drinker of 5 liter - capacity was also available in each pen. Wood shaving was used as a litter with a thickness of 10 cm and mixed with limestone for absorbing any increased moisture and eventually preventing any increase in humidity. A total lightening period of 23 h. per day was provided.

Chicks were raised for 6 weeks and were allowed free access to feed and water along the experimental period. Temperature was set at 32ºC at the age of one day and then gradually reduced with age to be about 20ºC at the end of the experiment. During the experimental period, the chicks were treated with standard vaccination and a medication program for prophylaxis.

2.2. Experimental design and diets

Seven groups were established, the first fed the control diet, and the other six groups fed three levels of low energy diets (2900, 2700, 2500, kcal/ kg; one level for each 2 groups). The first three tested groups were pointed for as the "normal calorie-protein ratio" groups in which the dietary protein decreased in relation to the decrease in ME, keeping the normal NRC of poultry (1994) ratio. In the second three tested groups the dietary protein was kept at the NRC level leading to ratios narrower than that of the NRC. The NRC recommendation was chosen as a basis as it has a fixed energy density all over the three phases of feeding, the factor tested. While, recommendations in Ross 308 catalogue differ in energy density according to the phase of feeding and target live weight needed. Thus, NRC recommendations are supposed to be suitable for most of chick breeds, and for the advices to be general and not confined to the breed fed.

The present experiment extended for only 6 weeks as it is an age sufficient for the bird to be marketed and a finisher phase of feeding needs logically higher energy density not a lower one. In the control group (1), the two diets fed, starter and grower, satisfied the NRC recommendations for energy at 3200 kcal ME/kg for all and for protein at 23% and 20 %, respectively. This makes a calorie - protein ratio of 139 and 160 for the two diets respectively. Regarding to the other six groups, the first three tested groups (2, 3 and 4) of the normal calorie-protein ratio diets, were treated with two diets having 2900 kcal ME/kg and 20.84 and18.13% crude protein in group 2, 2700 kcal ME/kg and 19.41 and 16.88 % crude protein in group 3, and 2500 kcal ME/kg and 17.97 and 15.63 % crude protein in group 4. The decrease in energy and protein forms 9.38%, 15.63% and 21.88% compared to the NRC density, for the three levels respectively, keeping the normal calorie-protein ratios 139 and 160 constant for starter and grower, respectively. The three levels of low energy were expressed by the letters LE for the " low-energy" in the first level of decrease, MLE for the "moderately low-energy" in the second, and HLE for the "highly low-energy" in the third one. LP denotes to the "low protein" decreased with the same degree used in its diet energy, so MLE-LP has a moderately low level of protein, and HLE-LP has a highly low level of protein.

In the second three tested groups (5, 6 and 7) of the narrow calorie-protein ratios, the chicks were fed the same diets with the three levels of low energy 2900, 2700 and 2500 kcal ME/kg, while the CP was kept at the NRC levels 23& 20% in the two stage-diets making a ME/CP ratio of 126.09, 145.00 in starter and grower in group 5; 117.39, 135.00 in group 6 and 108.70, 125.00 in group 7.

Concerning amino acids contents of diets, their levels followed the dietary protein level. Consequently, the amino acids concentrations in "normal calorie-protein ratio" groups were decreased in the same proportions of dietary protein. However, the amino acids levels in "narrow calorie-protein ratio" groups were kept at the NRC levels as the protein content of the diets.

The experimental diets were formulated from feeding stuffs available in the area of study. They can be grouped into energy feeds represented mainly by yellow corn and vegetable oil, and protein feeds by soybean meal and corn gluten. Wheat bran was used to dilute the dietary energy, in addition to the omission of oil. Macrominerals were supplemented using common salt for Na, limestone for Ca, and dicalcium phosphate for Ca and P. Amino acids were supplemented using DL-methionine and L-lysine, while trace minerals and vitamins by adding broiler premix. An "Anti-mold" product was added, at the rate instructed, to prevent mold growth in the mixed diets.

The ingredients were analyzed for its proximate composition using the standard methods according to AOAC (2005). The diets were formulated according to the analysis of ingredients (Table 1). The amino acids methionine, cystine, and lysine were estimated as related to the crude protein content of the feeds using regression equations mentioned in NRC for poultry (1994). Salt, Ca, and P needs were corrected to follow the energy level. Physical and chemical compositions of diets are displayed in Tables 2 and 3 for starter and grower phases. Birds were fed *ad libitum* with free access to water throughout the experiment. Tested parameters were chick performance, blood chemistry, carcass characteristics, and body composition.

2.3. Data collection

2.3.1. Performance of broilers

The experiment was subjected to several measurements to trace the effect of the low energy, and the two protein levels on broiler performance.

The diets were offered to the chicks daily in the morning and feed intake per day was calculated after removal of the refused one. The birds were weighed at the start of the experiment and at weekly intervals; accordingly the weekly weight gain was calculated. Based on feed intake, energy intake, protein intake and weight gain, the feed conversion ratio, and energy and protein efficiency ratios, in each group, were calculated. Feed conversion ratio was calculated as feed intake (g) divided by weight gain (g) (MacDonald, 2010). The total protein intake was calculated as protein percentage of the diet multiplied by its feed intake while total metabolizable energy intake was calculated as metabolizable energy density of the diet in kcal multiplied by its feed intake during each phase of the experimental period. Energy efficiency ratio was calculated as weight gain (g) divided by 100 kcal of the metabolizable energy intake, while protein efficiency ratio was calculated as weight gain (g) divided by total protein intake (g) (Kamran et al., 2008b).

Table 1. Energy value (kcal/kg) and chemical composition (%) of feed ingredients used in formulating diets.

Ingredient	Dry matter (%)	Metabolizable energy (kcal/kg)	Crude protein (%)	Crude fiber (%)	Ether extract (%)	Calcium (%)	Available phosphorus (%)	Sodium (%)
Yellow corn, ground	89.96	3350	8.66	2.30	4.80	0.02	0.08	0.02
Soybean meal	89.62	2230	44.00	5.80	1.10	0.29	0.27	0.01
Corn gluten meal	90.00	3720	60.00	1.60	2.60	-	0.14	0.02
Wheat bran, fine	92.08	1300	11.92	11.00	3.30	0.14	0.20	0.05
Molasses , cane[1]	75.00	1930	4.40	-	-	0.75	0.04	-
Vegetable oil[2]	99.90	8500	-	-	99.90	-	-	-
Common salt	99.70	-	-	-	-	-	-	39.00
Dicalcium phosphate	99.00	-	-	-	-	22.00	18.00	-
Limestone	99.00	-	-	-	-	38.00	-	-

NOTE: The metabolizable energy and mineral content are cited from NRC (1994) for poultry.

The prices of the ingredients as yellow corn, soybean oil meal, corn gluten meal, wheat bran, molasses and vegetable oil were 2500, 4600, 7000, 2250, 6000, and 7500 L.E. / ton, while the prices of the other supplements common salt, dicalcium phosphate, and limestone were 1, 0.5, and 6 L.E. / kg in respective order. The amino acids used were 30 L.E. /kg for methionine and 20 L.E. /kg for lysine, premixes were added for 5 L.E. /kg each of mineral and the same for vitamin ones.

[1]Cited from Central Lab for Food & Feed (CLFF), Agriculture Research Center, Ministry of Agriculture, Egypt (2001).

[2]Consists of equal amounts of soybean oil and rapeseed oil.

2.3.2. Protein and energy utilization percentages

In addition, protein and energy utilization percentages were calculated, for protein as a percentage of total body protein to total protein consumption, and for energy as a percentage of carcass energy to total ME intake, assuming body protein to contain 5.66 kcal/g and fat to contain 9.35 kcal/g tissue (Kamran et al., 2008b).

2.3.3. Blood parameters

Five birds were selected at the end of the experiment (42 days), in each group, to determine the effect of low energy and protein on protein, carbohydrate, and fat metabolism as well as to evaluate its effect on liver and kidney functions. Blood samples were collected from the wing vein to measure some blood parameters. Specimens were allowed to clot, and then centrifuged at 3000 rpm for ten minutes. Serum samples were separated and stored at -20^{o} C, in a deep freezer, until chemical analyses. At the time of analysis, the samples were thawed and analyzed for albumin (Drupt, 1977), total protein (Weichselbaum, 1946), glucose (Trinder, 1964), triglycerides (Werner et al., 1981), urea (DiacetylMonoxime "DAM" Method; Martinek, 1969), creatinine (Roscoe, 1953), aspartate amino-transferase (AST) and alanine amino-transferase (ALT) after Reitman and Frankel (1957). All the biochemical parameters of blood were determined colorimetrically using commercial kits.

Table 2. Physical and chemical composition (%) of starter diets.

Ingredient	Diet / Group						
	Control	Normal ME-CP ratio			Narrow ME-CP ratio		
	NE-NP	LE-LP	MLE-LP	HLE-LP	LE-NP	MLE-NP	HLE-NP
	1	2	3	4	5	6	7
Physical composition							
Yellow corn, ground	45.720	56.330	55.850	48.350	54.270	44.840	38.630
Soybean meal (44%)	34.940	36.080	30.762	25.330	33.230	32.170	31.020
Corn gluten meal	6.000	-	-	-	6.000	6.000	6.000
Vegetable oil	7.400	2.000	-	-	0.980	0.930	-
Wheat bran, fine	-	-	8.200	21.460	-	10.830	19.520
Molasses, cane	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Common salt	0.490	0.430	0.400	0.370	0.440	0.410	0.370
Limestone, ground	1.350	1.210	1.130	1.070	1.220	1.160	1.110
Dicalcium phosphate	1.730	1.500	1.330	1.120	1.510	1.270	1.050
DL-Methionine[1]	0.120	0.130	0.110	0.100	0.120	0.110	0.100
L-Lysine[2]	-	-	-	-	-	0.070	-
Mineral premix[3]	0.100	0.091	0.084	0.078	0.091	0.084	0.078
Vitamin premix[4]	0.100	0.091	0.084	0.078	0.091	0.084	0.078
Anti-mold[5]	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Chemical composition (calculated)							
Metabolizable energy, kcal /kg	3200	2900	2700	2500	2900	2700	2500
Crude protein %	23.000	20.850	19.410	17.978	23.009	23.107	23.009
Calorie/ protein ratio	139.13	139.16	139.10	139.12	126.09	117.39	108.70
Methionine %	0.509	0.460	0.420	0.405	0.514	0.510	0.510
Lysine %	1.121	1.118	0.930	0.807	1.097	1.100	1.100
Methionine & cystine %	0.891	0.665	0.640	0.616	1.018	0.912	0.923
Crude fiber %	3.171	3.390	3.971	4.942	3.272	4.148	4.931
Ether extract %	10.126	5.100	3.290	3.308	4.106	3.949	2.996
Calcium %	1.019	0.910	0.840	0.781	0.918	0.853	0.793
Available phosphorus %	0.452	0.417	0.380	0.352	0.414	0.383	0.352
Sodium %	0.205	0.190	0.170	0.167	0.187	0.179	0.166

[1]DL-Methionine is patent commercial product of Decosta Company USA, contains 99% methionine.
[2]L-Lysine is a high quality commercial product of Nutricorn Company Limited Shandong, China, contains 98.5% lysine.
[3]Mineral premix of Agrivet Company: 1.00 kg supplies 100,000 mg Mn; 60,000 mg Zn; 30,000 mg Fe; 10,000 mg Cu; 1000 mg I; 100 mg Co; 200 mg Se. It is added at the rate of 1 kg/100 kg diet.
[4]Vitamin premix of Agrivet Company: 1.00 kg supplies 12,000,000 IU Vit. A; 3,000,000 IU Vit. D; 40,000 mg Vit. E; 3,000 mg Vit. K_3; 2,000 mg Vit. B_1; 6,000 mg Vit. B_2; 5,000 mg Vit. B6; 20 mg Vit. B12; 45,000 mg niacin; 75,000 mg biotin; 2,000 mg folic acid; 12,000 mg pantothinic acid; 260,000 mg choline. It is added at the rate of 1 kg/100 kg diet.
[5]Lasalocid was used as anti-mold at the rate of 0.5 kg per ton.
N: Normal, E: Energy, P: Protein, L: Low, M: Moderately, H: Highly.

Table 3. Physical and chemical composition (%) of grower diets.

Ingredient	Diet / Group						
	Control	Normal ME-CP ratio			Narrow ME-CP ratio		
	NE-NP	LE-LP	MLE-LP	HLE-LP	LE-NP	MLE-NP	HLE-NP
	1	2	3	4	5	6	7
Physical composition							
Yellow corn, ground	52.420	66.750	58.992	51.224	60.790	54.750	45.272
Soybean meal (44%)	34.930	27.738	22.910	18.140	33.300	32.192	31.132
Vegetable oil	7.370	-	-	-	0.970	-	-
Wheat bran, fine	-	0.510	13.410	26.230	-	8.420	19.290
Molasses, cane	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Common salt	0.350	0.330	0.280	0.260	0.330	0.300	0.250
Limestone, ground	1.410	1.340	1.250	1.200	1.318	1.240	1.190
Dicalcium phosphate	1.200	1.050	0.900	0.700	1.000	0.820	0.600
DL-Methionine	0.070	0.050	0.040	0.040	0.060	0.060	0.060
Mineral premix	0.100	0.091	0.084	0.078	0.091	0.084	0.078
Vitamin premix	0.100	0.091	0.084	0.078	0.091	0.084	0.078
Anti-mold	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Chemical composition (calculated)							
Metabolizable energy, kcal /kg	3200	2900	2700	2500	2900	2700	2500
Crude protein %	20.000	18.130	16.880	15.630	20.000	20.000	20.000
Calorie/ protein ratio	160.00	160.00	160.00	160.00	145.00	135.00	125.00
Methionine %	0.380	0.340	0.320	0.300	0.380	0.380	0.380
Lysine %	1.080	0.920	0.850	0.780	1.050	1.060	1.070
Methionine & cystine %	0.743	0.598	0.579	0.561	0.645	0.655	0.668
Crude fiber %	3.230	3.200	4.160	5.120	3.330	4.050	4.970
Ether extract %	10.260	3.530	3.530	3.520	4.250	3.260	3.150
Calcium %	0.900	0.820	0.760	0.700	0.820	0.760	0.700
Available phosphorus %	0.350	0.320	0.300	0.270	0.320	0.300	0.270
Sodium %	0.150	0.140	0.130	0.120	0.140	0.130	0.120

2.3.4. Carcass characteristics

Five birds from each group, close to the average live body weight, were selected at the end of the experiment to determine the carcass yield and characteristics. Birds were weighed to the nearest gram, subjected to 24h-feed withdrawal with free access to water, reweighed and slaughtered by cutting the neck. After five minutes of bleeding, each bird was scalded, defeathered, and eviscerated after removal of head, neck and legs. The carcass without giblets was weighed, expressed as a percentage of its live weight and considered as the carcass yield, in addition to the separate weight of breasts, thighs, and total giblets (gizzard, liver and heart). The visible fat was removed from around the viscera, gizzard, and subcutaneously then weighed to the nearest gram and also expressed as a percentage of the live weight of the birds.

2.3.5. Body composition

Three birds per group, with a body weight close to the overall mean, were selected at the end of the experiment (42 days). The birds were weighed after being subjected to 24 h.-feed withdrawal with free access to water and killed by neck dislocation, avoiding loss of blood, to determine the whole body composition. The whole bodies of the birds were dried in a hot air oven at 65°C for two weeks (Kamran et al., 2008a) by placing them, individually, in aluminum foiled trays. After achieving a constant weight, the whole bodies were weighed and DM was calculated. The whole dried bodies of the birds were ground in an electrical grinder, homogenized, and a representative samples were taken for chemical analysis. At the analyses, the samples were analyzed for dry matter, ether extract and ash according to the methods of AOAC (2005), while crude protein was calculated by difference neglecting the small amount of carbohydrate present which reaches less than 1% in the whole body (Maynard et al., 1981).

2.3.6. Economic efficiency

To determine the economic efficiency for meat production, the cost of each one kg body weight gain was calculated, in each feeding phase and at the overall of the experimental period. In each feeding phase, the cost of the diets consumed was divided by the weight gain, or the price of each kg food was multiplied by the rate of feed conversion, to get the cost of each kg gain. Overall the experiment, the cost of the diets consumed in each treatment was calculated and divided by the total weight gain of the chicks to get the cost of each kg gain produced. The cost of the experimental diets was estimated depending upon the local current prices, of the different ingredients, and additives, at the time of the experiment.

2.4. Statistical analyses

The statistical analyses were performed using SPSS statistical program (IBM, version 20, Chicago, USA). Data were subjected to one-way ANOVA accompanied by Duncan's multiple range test to detect the differences among treatments. Results were considered significantly different at P<0.05.

3. Results and discussion

3.1. Growth performance

3.1.1. Body weight development

Growth performance data are displayed in Table 4. In the normal ME/CP ratio groups the body weight was slightly decreased in the starter period and the decrease ranges between 24 and 41 g, while in the grower period the decrease ranges between 136 and 303 g. The third group is the most get affected due to the low energy level and protein percentage. The current findings were in agreement with Hidalgo et al. (2004), Waldroup et al. (2005) and Kamran et al. (2008 a, b) who found that weight gain was decreased as dietary protein and energy decreased. The body weight in the narrow ratio groups is approximately the same as that of the control. The differences range between 5 g decrease and 20 g increase in the starter and 2 and 52 g increase in the grower. The differences are not statistically significant. So, decreasing the energy and keeping the ratio at its normal NRC level causes a weight decrease and leaving the protein percentage at its NRC level has no effect on body weight. These results indicated that the energy density can be decreased up to 2500 kcal, making mixtures completely free of oil but with normal protein levels.

Results of the narrow ratio groups were in accordance with Nkwocha et al. (2014) who suggested that broilers could tolerate till 2880 kcal/kg of metabolizable energy with constant protein with no deleterious effects on the growth performance.

3.1.2. Feed intake

In the normal ME/CP groups there was slight increase in feed intake ranged from 53 to 118 g in the three weeks of the starter period and in the grower period the increase was 57 and 80 g in groups 2 & 3 while it was a decrease of 61 in group 4 (Table 4). The decrease in feed intake of the highly low energy group was in agreement with the finding of Newcombe and Summers (1985) who suggested that broilers eat to almost full-gut capacity, thus suggesting that appetite was the main factor controlling feed intake of the broiler. The cumulative intake in the six weeks was slightly more than that of the control with 116, 132 and 57 g increase (4.1, 4.6 and 2.0% more than the control). These results indicate that feeding low energy diets till 2500 kcal/kg has a very slight effect on feed intake on the reverse of what commonly known saying "the birds eats for calories". Moreover, Peterson et al. (1954) showed that chicks attempt to eat to satisfy their energy requirements but are unsuccessful at low dietary ME concentrations. This has also been confirmed by many authors (Rand et al., 1956; Mraz et al., 1957; Sibbald et al., 1960; Golian and Maurice, 1992; Lesson et al., 1993; Kamran et al., 2008 a, b).

Feeding the same levels of energy with keeping the crude protein in fixed at the NRC levels, makes slight increase of feed intake at the end of the starter period (34, 57 & 100 g). At the end of the grower period the three groups (5, 6 and 7) showed slight increase in feed intake.

At the end of the sixth week the groups of the two ME/CP ratios show an increase ranging from 21 to 177g. These findings concurred with some works demonstrated that feed intake is influenced by dietary crude protein and amino acid levels (Aletor et al., 2000; Sklan and Plavnik, 2002). While, other studies (Ferguson et al., 1998; Kermanshahi et al., 2011) showed that CP content had no significant effect on feed intake.

3.1.3. Feed conversion ratio

In the normal ME/CP ratio groups, the feed conversion was adversely affected by decreasing the energy till 2500 kcal/kg (Table 4). Each kg gain in the control group costed 1.66 kg feed at 0-3 weeks period the groups 2, 3 and 4 reached 1.89, 1.95 and 2.07 with the 4^{th} the most adversely affected. In the 3-6 weeks period, the conversion was 2.03 in the control and 2.34, 2.04 and 2.67 in groups 2, 3 and 4 with the 4^{th} group also the most adverse.

In the whole period from 0-6 weeks the conversion cumulatively was 2.20, 2.27 and 2.46 in the three groups compared with 1.92 in the control. So as the energy and crude protein decrease, the conversion is numerically increased, so decreasing the energy with normal ME/CP ratio should not be advised. This observation was in agreement with previous studies of Hidalgo et al. (2004), Waldroup et al. (2005), Kamran et al.(2008a, b) that reported an increased feed conversion ratio as dietary protein and energy decreased.

In the narrow ME/CP ratio groups the conversion ratio slightly increased numerically in the three groups in the starter (0-3 weeks) period. On the reverse in the grower (3-6 weeks) period the conversion is improved except in group 7 which was higher than the control. Consequently, in the whole period (0-6 weeks) the result was a slight improvement in conversion except group 7. Nkwocha et al. (2014) conducted a feeding trial to determine the effect of feeding variable levels of dietary energy with constant protein on performance of broiler. Results showed significant differences in feed conversion ratio.

3.2. Energy and protein intake, efficiency, and utilization

3.2.1. Energy intake

As a result of decreasing the energy density it was expected for the birds to increase the feed consumption in order to satisfy energy needs. In the normal ME/CP groups the difference, compared with the control, reached 520, 1071 and 1857 kcal, respectively in the three groups with the third, with the least energy density, the most failing in increasing the consumption (Table 5). No relation between energy density or protein percentage and food or energy consumption could be extracted except that the decrease in energy consumption followed the degree of energy decrease. This result was in agreement with Jackson et al. (1982) and Kamran et al. (2008 a, b) who reported that total ME intake were linearly decreased with the reduction of dietary CP and ME concentration. The same happened in the narrow ME/CP ratio groups, where the difference in consumption at the end of the experiment, compared with the control, was 795, 1160 and 1556 kcal in the three groups; respectively with the very low energy group the least of consumption. 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; this could be due to that chicks might have a physical limitation when trying to consume the low density diets. This finding agreed with Griffiths et al.

(1977), and Kamran et al. (2008 a, b) who suggested that a reduction in energy intake was due to physical limitations when feeding diets with low ME content. Due to less consumption of CP and ME, there was a significant depression in weight gain of the birds.

Table 4. Performance characteristics of broiler chickens fed seven regimes of energy and protein during starter and grower phases (Mean ± SEM).

Parameters	Group						
	Control	Normal ME-CP ratio			Narrow ME-CP ratio		
	NE-NP	LE-LP	MLE-LP	HLE-LP	LE-NP	MLE-NP	HLE-NP
	1	2	3	4	5	6	7
Starter phase							
Live weight (g)	491.09[cd] ± 7.30	466.95[abc] ± 5.46	450.29[a] ± 11.70	459.05[ab] ± 12.73	486.46[bcd] ± 12.66	499.22[d] ± 8.12	511.32[d] ± 8.77
Weight gain (g)	439.19	416.08	399.60	408.33	436.47	448.50	461.49
Feed intake (g)	728.47	787.40	781.19	846.29	761.53	785.05	827.94
Feed conversion ratio	1.66	1.89	1.95	2.07	1.74	1.75	1.68
Feed cost (L.E./kg)	4.00	3.49	3.25	3.09	3.65	3.60	3.49
Feed cost of production (L.E./kg)	6.64	6.60	6.34	6.40	6.35	6.30	5.86
Grower phase							
Live weight (g)	1536.83[c] ± 32.98	1400.83[b] ± 24.66	1369.00[b] ± 31.13	1233.89[a] ± 37.25	1570.00[c] ± 35.76	1589.00[c] ± 32.16	1539.00[c] ± 33.43
Weight gain (g)	1045.74	932.88	918.72	774.84	1083.54	1089.78	1027.68
Feed intake (g)	2128.09	2185.31	2207.64	2067.43	2116.34	2171.03	2206.00
Feed conversion ratio	2.03	2.34	2.40	2.67	1.95	1.99	2.15
Feed cost (L.E/kg)	3.72	3.19	3.05	2.91	3.36	3.26	3.21
Feed cost of production (L.E./kg)	7.55	7.46	7.32	7.77	6.55	6.49	6.90
The overall period							
Live weight (g)	1536.83[c] ± 32.98	1400.83[b] ± 24.66	1369.00[b] ± 31.13	1233.89[a] ± 37.25	1570.00[c] ± 35.76	1589.00[c] ± 32.16	1539.00[c] ± 33.43
Weight gain (g)	1484.93	1348.95	1318.30	1183.16	1520.00	1538.27	1489.17
Feed intake (g)	2856.56	2972.72	2988.83	2913.71	2877.87	2956.08	3033.94
Feed conversion ratio	1.92	2.20	2.27	2.46	1.89	1.84	2.04
Total cost (L.E. /gain)	10.82	9.71	9.26	8.63	9.87	9.90	9.79
Feed cost of production (L.E./kg)	7.29	7.20	7.02	7.29	6.49	6.44	6.57

[a,b,…] Means within the same row, with different superscripts, are significantly different ($P<0.05$).

3.2.2. Energy efficiency ratio

In the normal ratio groups the efficiency ratio was adversely affected in group 2 (15.65 vs. 16.24), while the other two groups are nearly equal to the control. In the narrow groups there was an improvement in the three groups were it reached 18.21, 19.27 and 19.63 in respective order compared with 16.24 in the control, with the least two groups in energy the most improving. So feeding low energy without decreasing the crude protein is the most successful from the energy conversion point of view. While, Cheng et al. (1997a), observed that EER was decreased with low-ME diets.

Table 5. Energy and protein efficiency and utilization percentages.

Parameter	Group						
	Control	Normal ME-CP ratio			Narrow ME-CP ratio		
	NE-NP	LE-LP	MLE-LP	HLE-LP	LE-NP	MLE-NP	HLE-NP
	1	2	3	4	5	6	7
Energy intake, kcal ME	9141.00	8620.86	8069.85	7284.31	8345.83	7981.42	7584.85
Body energy, kcal ME	2463.55	2156.37	1992.24	1946.62	2477.77	2558.04	2560.92
Energy efficiency ratio[1]	**16.24**	**15.65**	**16.34**	**16.47**	**18.21**	**19.27**	**19.63**
Energy utilization %[2]	**26.95**	**25.01**	**25.34**	**26.72**	**29.69**	**32.05**	**33.76**
Protein intake, g	593.17	560.30	524.28	475.23	598.43	614.78	631.63
Body protein, g	233.62	202.04	212.17	187.76	234.13	227.31	241.41
Protein efficiency ratio[1]	**2.50**	**2.41**	**2.51**	**2.49**	**2.54**	**2.50**	**2.36**
Protein utilization %[2]	**39.38**	**36.06**	**37.77**	**39.51**	**39.12**	**36.97**	**38.22**

[1]Energy efficiency ratio was calculated as the weight gain, in grams, divided by 100 kcal of the metabolizable energy intake. Protein efficiency ratio was calculated as the weight gain, divided by total protein intake, in grams.
[2]The energy utilization percentage is the percentage of carcass energy to total ME intake, assuming body protein to contain 5.66 kcal /g and fat to contain 9.35 kcal/g tissue. The protein utilization percentage is the percentage of the total body protein to total protein consumption.

3.2.3. Protein intake

Protein intake in the normal ratio groups the protein intake is slightly lower when compared with the control. The negative differences in the whole six weeks were 32.87, 68.89 & 117.94 g with the third group the lowest. This result was in agreement with Jackson et al. (1982) and Kamran et al. (2008 a,b) who reported that total protein intake were linearly decreased with the reduction of dietary CP and ME concentration.

On the other hand, in the narrow ratio group, it was either equal to the control or slightly higher. Collectively in the six weeks the increase was 21.61 and 38.46 g in groups 6 and 7and nearly equal in 5.

3.2.4. Protein efficiency ratio

Protein efficiency ratio the normal ME/CP groups showed slight change in the protein cost of the gain. The difference did not exceed 0.10 g body gain for each gram crude protein consumed.

On the other hand, the narrow ratio groups showed slight decrease, resulted in efficiency nearly equal to the control except in group 7 where the efficiency was lower by 0.14 g. Previous literature (Jackson et al., 1982; Cheng et al., 1997a; Kamran et al., 2008 a, b) reported that protein efficiency ratio were linearly decreased with the reduction of dietary CP and ME concentration. However, Cheng et al. (1997b) observed that protein efficiency ratio was significantly increased with low CP diets.

3.2.5. Energy and protein utilization

The utilization of energy decreased in groups 2 and 3 and nearly equal in 4 in normal ME/CP groups and the utilization percentages increased in all the three groups of narrow ME/CP ratio. It was 25.01, 25.34 and 26, 72 in groups 2, 3 and 4, respectively, and 29.69, 32.05 and 33.76 in groups 5, 6 and 7, while it was 26.95 in the control one. Normal protein levels increased the utilization in spite of the decreased energy density. The utilization percentage of protein reached in the second group 36.06 and the third 37.77 compared with the control (39.38), while group 4 was nearly equal (39.51). In the narrow ME/CP ratio groups, it was nearly equal in the groups 5 and 7 (39.12 and 38.22) and it was lower in group 6 (36.97). So, normal protein level helps in keeping the protein utilization normal in spite of the low energy density. On the contrary, some studies (Jackson et al., 1982; Whitehead, 1990; Cheng et al., 1997a, b) found that protein utilization was increased with low CP diets. Although, efficiency of energy utilization has been shown to be improved with the decrease in dietary protein, results on efficiency of protein utilization have been less consistent. Jackson et al. (1982) observed that although protein intake increased with each increment of dietary protein, a level of 20% CP was sufficient for maximum protein deposition in the carcass. It is tempting to recommend a reduced dietary protein concentration on this basis provided that the diet is economically sound.

3.3. Serum biochemical indices

There were no significant differences between control and other groups in glucose, triglycerides, albumen, urea, and creatinine (Table 6). Swennen et al. (2006) found no effect of the diet on plasma glucose concentration. While, Swennen et al. (2005) reported that in low CP fed chickens urea was decreased which indicate a sparing effect on body proteins of these low CP fed chickens. Moreover, total protein level increased significantly in all the six groups; while ALT increased only in the narrow ratio groups. Still we are fixed to the healthy active birds to be indicative to the levels registered to be physiologically normal. Also, Nkwocha et al. (2014) suggested that broiler finisher birds could tolerate till the level of 2880 kcal ME/kg decrease with no deleterious effects on hematological characteristics.

Table 6. Serum biochemical indices in experimental groups at the end of grower period (Mean ± SEM).

Parameter	Group						
	Control	Normal ME-CP ratio			Narrow ME-CP ratio		
	NE-NP	LE-LP	MLE-LP	HLE-LP	LE-NP	MLE-NP	HLE-NP
	1	2	3	4	5	6	7
Glucose, mg/dl	273^{a} ± 2.65	266^{a} ± 4.00	289^{a} ± 3.22	264^{a} ± 4.00	269^{a} ± 6.08	267^{a} ± 7.94	277^{a} ± 7.94
Triglycerides, mg/dl	74.00^{abc} ± 3.06	81.00^{c} ± 4.36	80.00^{c} ± 4.58	79.00^{bc} ± 3.61	87.00^{c} ± 4.36	63.00^{a} ± 3.79	66.00^{ab} ± 5.13
Total protein, g/dl	3.70^{a} ± 0.25	5.20^{b} ± 0.21	5.10^{b} ± 0.21	5.35^{b} ± 0.35	4.85^{b} ± 0.33	4.50^{ab} ± 0.25	7.30^{c} ± 0.33
Albumen, g/dl	1.51^{a} ± 0.09	1.57^{a} ± 0.12	1.53^{a} ± 0.07	1.60^{a} ± 0.13	1.58^{a} ± 0.09	1.62^{a} ± 0.11	1.61^{a} ± 0.10
ALT, U/L	10.57^{a} ± 0.72	11.70^{a} ± 0.67	10.10^{a} ± 1.00	9.20^{a} ± 0.66	24.10^{c} ± 1.16	18.10^{b} ± 0.49	19.10^{b} ± 0.49
AST, U/L	308.33^{a} ± 5.61	371.00^{c} ± 4.04	373.00^{c} ± 4.04	344.33^{b} ± 5.61	376.67^{c} ± 4.49	385.00^{c} ± 4.04	401.33^{e} ± 3.84
Urea, mg/dl	9.00^{a} ± 1.19	8.00^{a} ± 1.57	9.50^{a} ± 1.11	7.70^{a} ± 1.26	9.70^{a} ± 1.33	8.70^{a} ± 1.47	10.70^{a} ± 1.57
Creatinine, mg/dl	0.31^{a} ± 0.02	0.33^{a} ± 0.02	0.35^{a} ± 0.03	0.37^{a} ± 0.06	0.34^{a} ± 0.03	0.33^{a} ± 0.03	0.33^{a} ± 0.02

[a,b,…]Means within the same row, with different superscripts, are significantly different ($P< 0.05$).

Note: The normal serum biochemical indices values ranged from glucose 200-500 mg/dl, triglycerides 5-100 mg/dl, total protein 2-4.5 g/dl, albumen 0.8-3.0 g/dl, ALT 5-50 U/L, AST 150-350 U/L, urea 8-10 mg/dl and creatinine 0.2-0.5mg/dl. (Mary et al., 2005).

ALT: Alanine aminotransferase

AST: Aspartate aminotran

3.4. Carcass characteristics

There was no effect for the different diets either in the normal ME/CP groups or the narrow ones on the carcass traits even on the visible fat (Table 7). Also, some research (Hai and Balha, 2000; Hidalgo et al., 2004; Moosavi et al., 2012) found that carcass weight, percentage of carcass, breast, thigh and other parameters of carcass such as liver, heart weight and abdominal fat did not get affected by energy and protein. This might be due to a constant ME:CP ratio that was maintained across all the dietary treatments. On the other hand, it was reported that a balanced energy- to-protein ratio was important to achieve optimum broiler carcass yield and meat quality (Jackson et al., 1982; MacLeod, 1997; Kidd et al., 2004; Kamran et al., 2008a & b).

Table 7. Carcass characteristics of experimental groups (Mean ± SEM).

Parameters (%)*	Group						
	Control	Normal ME-CP ratio			Narrow ME-CP ratio		
	NE-NP	LE-LP	MLE-LP	HLE-LP	LE-NP	MLE-NP	HLE-NP
	1	2	3	4	5	6	7
Dressing value	67.00[a] ± 1.00	66.00[a] ± 1.53	65.00[a] ± 1.00	65.70[a] ± 0.51	66.60[a] ± 0.81	66.98[a] ± 1.52	65.89[a] ± 0.58
Breast muscle	20.11[a] ± 0.36	18.78[a] ± 0.89	19.65[a] ± 0.68	17.90[a] ± 0.72	18.67[a] ± 1.92	18.00[a] ± 1.15	18.30[a] ± 1.15
Thighs	25.00[a] ± 1.00	24.16[a] ± 0.54	25.33[a] ± 0.59	24.90[a] ± 0.71	24.50[a] ± 0.87	26.21[a] ± 0.12	25.96[a] ± 0.55
Liver	1.90[a] ± 0.21	2.00[a] ± 0.10	1.87[a] ± 0.14	2.11[a] ± 0.11	1.97[a] ± 0.05	2.20[a] ± 0.15	1.89[a] ± 0.11
Gizzard	1.50[a] ± 0.15	1.44[a] ± 0.12	1.59[a] ± 0.06	1.47[a] ± 0.05	1.55[a] ± 0.15	1.46[a] ± 0.10	1.60[a] ± 0.26
Heart	0.59[a] ± 0.10	0.54[a] ± 0.07	0.60[a] ± 0.08	0.61[a] ± 0.08	0.55[a] ± 0.05	0.57[a] ± 0.09	0.49[a] ± 0.07
Visible fat**	1.43[a] ± 0.10	1.44[a] ± 0.05	1.50[a] ± 0.14	1.30[a] ± 0.15	1.62[a] ± 0.09	1.33[a] ± 0.10	1.70[a] ± 0.17

* Calculated as a percentage of the live body weight before slaughtering at the end of the experiment.
** It is the fat found subcutaneously and around the viscera
[a,b,….] Means within the same row, with different superscripts, are significantly different (P< 0.05).

3.5. Body composition

The diets, either with normal ME/CP ratio or narrow, had no effect on body composition except the low fat percentage on dry matter in group 3 (Table 8). It seems that it is differences among individual birds more than a dietary effect. Moreover, Cheng et al. (1997a) found no differences in body dry matter of chicks when dietary CP levels were reduced to 16 %. Also, Hai and Balha (2000) observed that a decrease in dietary CP level had no negative effect on carcass protein. Similarly, Bregendahl et al. (2002) did not find any significant difference in the whole body CP content of chicks fed low CP diets. However, Cheng et al. (1997b) reported that total body protein decreased while total body fat increased linearly as the dietary CP content was reduced from 24 to 16%. Some other studies have also reported inferior carcass composition with reduced CP diets (Fancher and Jensen, 1989; Pinchasov et al., 1990; Aletor et al., 2000).

3.6. Economic efficiency

In the normal ME/CP ratio groups the cost of production at the end was nearly equal, compared with the control, except a low value for group 3 (Table 4). In the narrow ratio diets, the cost of production was advantageously decreased. In the overall period, in total it was the second group of the normal ratios and the first and second of the narrow which showed a saving in production cost. Moosavi et al. (2011) reported that the cost (kg) of feed decreased with decreasing protein and energy in diets. Reducing CP and ME did not affect the growth performance. However, efficiency of growth became inferior in broilers fed diets with low protein and energy with constant ratio (Kamran et al., 2008a, b).

Table 8. Body composition of chicken groups at the end of the experimental period on DMB (Mean ± SEM).

Parameter (%)	Group						
	Control	Normal ME-CP ratio			Narrow ME-CP ratio		
	NE-NP	LE-LP	MLE-LP	HLE-LP	LE-NP	MLE-NP	HLE-NP
	1	2	3	4	5	6	7
Dry matter	26.59^{a}	25.84^{a}	25.52^{a}	27.11^{a}	26.16^{a}	26.89^{a}	27.45^{a}
	± 0.33	± 0.42	± 0.56	± 0.26	± 0.52	± 0.67	± 0.66
Crude protein	59.16^{a}	57.98^{a}	58.89^{a}	58.54^{a}	58.87^{a}	54.96^{a}	59.06^{a}
	± 1.52	± 1.96	± 1.21	± 2.03	± 1.75	± 2.52	± 0.33
Ether extract	30.90^{ab}	31.09^{ab}	29.40^{c}	29.47^{b}	30.99^{ab}	32.88^{a}	31.26^{ab}
	± 0.54	± 0.21	± 1.33	± 0.26	± 0.68	± 0.32	± 0.51
Ash	9.93^{a}	10.96^{a}	11.77^{a}	11.10^{a}	10.12^{a}	12.14^{a}	9.68^{a}
	± 0.40	± 0.33	± 0.30	± 0.40	± 0.54	± 0.43	± 0.32

[a,b,….] Means within the same row, with different superscripts, are significantly different ($P< 0.05$).

4. Conclusion:

It was concluded that feeding diets containing low ME and low CP with normal ME/CP ratio adversely affect the growth performance, without affecting body composition and carcass characteristics and without any significant decrease in the visible fat content. These diets may show a degree of cost saving. The adverse effect can be avoided by keeping the protein at the normal levels of NRC. So, the energy density in diets can be decreased to 2500 kcal/kg, making mixtures completely free of oil, but with constant normal protein level. Feeding diets with low ME and normal protein NRC-levels had no any adverse effect on the performance, and showed a higher economic efficiency than the normal ME/CP ratio groups**.** Also, these diets did not affect carcass characteristics or body composition.

References:

A.O.A.C. (2005). Official Methods of Analysis, Association of Official Analytical Chemists, 18th Ed., Washington, D.C, USA.

Aletor VA, Hamid II, Niess E, Pfeffer E (2000). Low protein amino acids supplemented diets in broiler chickens: Effects on performance, carcass characteristics, whole body composition and efficiencies of nutrient utilization. J. Sci. Food Agric., 80: 547–554.

Bregendahl K, Sell JL, Zimmerman DR (2002). Effect of low-protein diets on growth performance and body composition of broiler chickens. Poult. Sci., 81: 1156–1167.

Buyse J, Decuypere E, Berghman L, Kühn ER, Vande-sande F (1992). The effect of dietary protein content on episodic growth hormone secretion and on heat production of male broilers. Br. Poult. Sci., 33:1101–1109.

Cheng TK, Hamre ML, Coon CN (1997a). Effect of environmental temperature, dietary protein, and energy levels on broiler performance. J. Appl. Poult. Res., 6: 1–17.

Cheng TK, Hamre ML, Coon CN (1997b). Responses of broilers to dietary protein levels and amino acid supplementation to low protein diets at various environmental temperatures. J. Appl. Poult. Res., 6: 18–33.

Collin A, Malheiros RD, Moraes VMB, Van As P, Darras VM, Taouis M, Decuypere E, Buyse J (2003). Effects of dietary macronutrient content on energy metabolism and uncoupling protein mRNA expression in broiler chickens. Br. J. Nutr., 90: 261–269.

Drupt F (1977). Colorimetric method for determination of albumin. Pharm. Biol., 9: 777–779.

Economic Research Service/USDA (2001). Patterns of world poultry consumption and production. www.ers.usda.gov/media/1725855/wrs0302b

Eits RM, Kwakkel RP, Verstegen MWA, Stoutjesdijk P, De Greef KH (2002). Protein and lipid deposition rates in male broiler chicken: Separate responses to amino acids and protein-free energy. Poult. Sci., 81:472–480.

El-Khimsawy KA, Amer AA, El-Sharkawy SI, Ali MF (2002). Effect of amino acids fortifying in low protein diet on broiler performance. Al-Azhar J. Agri. Res., 25: 1–18.

El-Sheikh TM (2002). Effect of strain, flock age and their interaction on hatched chick weight under different season. Egypt Poult. Sci., 22 (3): 879–896.

El-Sherbiny AE, Moahmed MA, Hamza AS, ElAfifi TM (1997). Response of broiler chicks to low protein diets supplemented with lysine and methionine. Egypt Poult. Sci., 17: 23–28.

Fancher BI, Jensen LS (1989). Influence on performance of three to six week old broilers of varying dietary contents with supplementation of essential amino acid requirements. Poult. Sci., 68:113–123.

Ferguson NS, Gates RS, Taraba JL, Cantor AH, Pescatore AJ, Ford MJ, Burnham DJ (1998). The effect of dietary protein and phosphorus on ammonia concentration and litter composition in broilers. Poult. Sci., 77: 1085–1093.

Golian A, Maurice DV (1992). Dietary poultry fat and gastrointestinal transit time of feed and fat utilization in broiler chickens. Poult. Sci., 71:1357–1363.

Griffiths L, Leeson S, Summers JD (1977). Influence of energy system and level of various fat sources on performance and carcass composition of broilers. Poult. Sci., 56:1018-1026.

Hai DT, Blaha J (2000). Effect of low-protein diets adequate in levels of essential amino acids on broiler chicken performance. Czech. J. Anim. Sci., 45: 429-436.

Hidalgo MA, Dozier WA, Davis AJ, Gordon RW (2004). Live performance and meat yield responses to progressive concentrations of dietary energy at a constant metabolizable energy-to-crude protein ratio. J. Appl. Poult. Res., 13: 319–327.

Jackson S, Summer JD, Leeson S (1982). Effect of dietary protein and energy on broiler performance and production costs. Poult. Sci., 61: 2232–2240.

Kamran Z, Sarwara M, Nisa M, Nadeem MA, Mushtaq T, Ahmed T, Babar ME, Mushtaq MMH (2008a). Effect of low levels of dietary protein on growth, protein utilization and body composition of broiler chicks from one to twenty-six days of age. Avian Biol. Res., 1 (1): 19–25.

Kamran Z, Sarwar M, Nisa M, Nadeem MA, Mahmood S, Babar ME, Ahmed S (2008b). Effect of low-protein diets having constant energy-to-protein ratio on performance and carcass characteristics of broiler chickens from one to thirty-five days of age. Poult. Sci., 87: 468–474.

Kamran Z, Sarwar M, Nisa M, Nadeem MA, Mahmood S (2010). Effect of low levels of dietary crude protein with constant metabolizable energy on nitrogen excretion, litter composition and blood parameters of broilers. Int. J. Agric. Biol., (12): 401–405.

Kidd MT, McDaniel CD, Branton SL, Miller ER, Boren BB, Fancher BI (2004). Increasing amino acid density improves live performance and carcass yields of commercial broilers. J. Appl. Poult. Res., 13: 593–604.

Kermanshahi H, Ziaei N, Pilevar M (2011). Effect of dietary crude protein fluctuation on performance, blood parameters and nutrients retention in broiler chicken during starter period. Glob. Vet., 6 (2): 162–167.

Lesson S, Summers JD, Caston L (1993). Growth response of immature brown-egg strain pullet to varying nutrient density and lysine. Poult. Sci., 72: 1349–1358.

MacDonald JM (2010). The economic organization of U.S. broiler production. Economic Information Bulletin No. 38. Economic Research Service, USDA.

MacLeod MG (1997). Effects of amino acid balance and energy: Protein ratio on energy and nitrogen metabolism in male broiler chickens. Br. Poult. Sci., 38: 405–411.

Martinek RG (1969). Review of methods for determining urea nitrogen in biologic fluid. J. Am. Med. Tech., 31: 678-683.

May JD, Lott BD, Simmons JD (1998). The effect of environmental temperature and body weight on growth rate and feed: gain of male broilers. Poult. Sci., 77: 499–501.

Maynard LA, Loosli JK, Hintz HF, Warner RG (1981). Animal Nutrition, 7th Ed. New Delhi. Tata McGraw–Hill Publishing Company Limited.

Moosavi M, Eslami M, Chaji M, Boujarpour M (2011). Economic value of diets with different levels of energy and protein with constant ratio on broiler chickens. J. Anim. Vet. Adv., 10 (6): 709–711.

Moosavi M, Chaji M, boujarpour M, Rahimnahal S, Kazemi AR (2012). Effect of different levels of energy and protein with constant ratio on performance and carcass characteristics in broiler chickens. Int. Res. J. Appl. Bas. Sci., 3 (12): 2485–2488.

Mraz FR, Boucher RV, Mc-Cartney MG (1957). The influence of the energy: volume ratio on growth response in chickens. Poult. Sci., 36: l2l7–1221.

National Research Council, NRC (1994). Nutrient Requirements of Poultry.9th revised edition. National Academy Press. Washington, D.C., USA.

Newcombe M, Summers JD (1985). Effect of increasing cellulose in diets fed as crumbles or mash on the food intake and weight gain of broiler and Leghorn Chicks. Br. Poult. Sci., 26: 35–42.

Nieto R, Aguilera JF, Fernandez- Figares I, Prieto C (1997). Effect of a low protein diet on the energy metabolism of growing chickens. Arch. Tierernahr, 50: 105–109.

Nkwocha GA, Agbabiaka LA, Anukam KU, Beketin TO (2014). Growth response, carcass and blood characteristics of finisher broilers fed sorghum offal meal as dietary supplement. Int. J. Agri Sci., 4(7): 392–398.

Rand NT, Scott HM, Kummerow FA (1956). The relationship of protein, fiber and fat in the diet of the growing chick (Abstracts of Papers Presented at the 45th Annual Meeting of the Poultry Science Association). Poult. Sci. 35: 1166.

Reitman S, Frankel S (1957). A colorimetric method for the determination of serum glutamic oxaloacetic and glutamic pyruvic transaminases. Am. J. Clin. Pathol. 28: 56–63.

Roscoe MH (1953). The estimation of creatinine in serum. J. Clin. Pathol., 6: 201–207.

Peterson DW, Grau CR, Peekn F (1954). Growth and food consumption in relation to dietary levels of protein and fibrous bulk. J. Nutr., 52: 241–257.

Pinchasov Y, Mendonca CX, Jensen LS (1990). Broiler chick response to low protein diets supplemented with synthetic amino acids. Poult. Sci., 69: 1950–1955.

Sibbald IR, Slinger SJ, Ashton GC (1960). The weight gain and feed intake of chicks fed a ration diluted with cellulose or kaolin. J. Nutr., 72: 441–446.

Sklan D, Plavink I (2002). Interactions between dietary crude protein and essential amino acid intake on performance in broilers. Br. Poult Sci. J., 43 (3): 442–449.

Trinder P (1964). Determination of glucose in blood using glucose oxidase with an alternative oxygen acceptor. Ann. Clin. Biochem., 6: 24–27.

Swennen Q, Janssens GPJ, Millet S, Vansant G, Decuypere E, Buyse J (2005). Effects of substitution between fat and protein on feed intake and its regulatory mechanisms in broiler chickens: Endocrine functioning and intermediary metabolism. Poult. Sci., 84: 1051–1057.

Swennen Q, Janssens GPJ, Collin A, Bihan-Duval EL, Verbeke K, Decuypere E, Buyse J (2006). Diet-induced thermogenesis and glucose oxidation in broiler chickens: Influence of genotype and diet composition. Poult. Sci., 85: 731–742.

Waldroup PW, Jiang Q, Fritts CA (2005). Effects of supplementing broiler diets low in crude protein with essential and nonessential amino acids. Int. J. Poult. Sci., 4 (6): 425–431.

Weichselbaum TE (1946). An accurate and rapid method for the determination of proteins in small amounts of blood serum and plasma. Am. J. Pathol., 16, 40-49.

Werner M, Gabrielson DG, Eastman G (1981). Ultramicro determination of serum triglycerides by bioluminescent assay. Clin. Chem., 27: 268–271.

Whitehead CC (1990). Responses of body composition, growth and food efficiency to dietary protein in genetically lean and fat broilers up to seven weeks of age. Br. Poult. Sci., 31: 163–172.