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Original Research Article

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

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ABSTRACT

This study was conducted to investigate the effect of high metabolizable energy diets with normal or wide metabolizable energy to crude protein ratios (ME:CP) on the performance, carcass characteristics, body composition and blood parameters of broilers fed from 1 to 56 days of age. The chicks were allotted into 7 groups; one control and 6 tested. The birds were fed starter, grower and finisher diets. The control diet was formulated according to the NRC of poultry (1994) and the other six diets contained three different levels of high energy diets (3275, 3350 & 3425 kcal/kg; one level for each two groups). The first three tested groups were pointed for as the ''normal calorie-protein ratio" groups in which the CP increased in relation to the increased ME, keeping the normal NRC ratio. In the second three tested groups, named "wide calorie-protein ratio" groups, the dietary protein was kept at the NRC levels leading to ratios wider than that of the NRC. Results showed that chicks fed high ME diets with normal energy to protein ratio grew faster, and used feed more efficiently than chicks fed the control diets. However, feeding diets with high ME and normal protein NRC-levels slightly improved the weight and feed conversion. The visible fat and fat retained in the body was higher in all tested groups compared to the control. However, the blood parameters had no significant variations among the treatments, except for ALT which had an increased response to increased dietary energy density. In conclusion, increasing the dietary ME level without increasing the crude protein level provided moderately economic returns and lesser improvement in the performance of broilers. However, increasing of dietary ME with normal ME:CP ratio resulted in increased broiler performance and higher economic return.

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1. Introduction

Protein and energy are two important components of food that generates a lot of interest and challenge to nutritionists. They are determinants in the evaluation of performance and production coefficients of farm animals and poultry. The relationship between protein and energy requirements has been discussed by many scientists around the world. It is obvious that protein requirements have little meaning unless energy requirements have been considered. Several workers have chosen to express these nutrient requirements in terms of protein and energy ratios. In spite of diets with varying protein and energy levels have been recommended for the different stages in broiler growth by many researchers, these different protein and energy levels are however not in consonance among the various researchers. As an example for the inconsistent recommendations, The National Research Council (1994) for poultry recommended 23% crude protein and 3200 kcal/kg metabolizable energy for broiler chickens at the starter stage, while the Agricultural Research Council (1973) recommended 18.8% crude protein and energy level of 3,100 kcal/kg metabolizable energy. This apparent lack of agreement calls for further research work in this area.

Dietary energy and protein levels are very important due to their associative effect in the diets especially the energy level, as it determines the extent of the uptake of other nutrients. Umar (2001) ran a study on broilers fed a single phase ad libitum diet with graded levels of protein and energy and reported that energy levels affected the growth pattern of broilers. This is in respect of birds being able to adjust intake of feed to satisfy their energy requirement. Also, some studies (Jackson et al., 1982; Yan et al., 2010) observed that body weight and feed efficiency improved with increasing the levels of energy and protein in broiler diets. However, Tion et al. (2005) tested the effect of calorie to protein ratio of practical diets on performance and carcass quality of broiler chicken and found that calorie -protein ratio had no significant effect on feed intake, weight gain and feed to gain ratio where they used calorie- protein ratios varying from 140:1 to 160:1. The physiological and practical implications of the link between energy intake and protein metabolism and between protein intake and energy metabolism must then be considered when the dietary requirements for either nutrient is assessed. Moreover, there is a lack of sufficient information about the effect of dietary energy density and crude protein level on the performance of broiler chickens. Therefore, the aim of this investigation was to study the effect of feeding high dietary energy with high and normal protein levels on productive performance of broiler chickens. Furthermore, its effects on carcass characteristics, body composition, blood parameters and economical efficiency were tested.

2. Materials and methods

2.1. Birds and management

Two hundred eighty 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 pen was equipped with one feeder, an incubation plastic dish of 45 cm diameter. The dish was suitable for chicks aging one day to ten days. After this age one manual feeder was used. Also manual drinker of 5 liter - capacity was also available in each pen. Wood shavings were 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.

The chicks were raised for 8 weeks, and they were allowed free access to feed and water along the experimental period. Temperature was set at 32˚C at the age of one day and then gradually reduced with age to be about 20˚C 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 chick groups were established, the first fed the control diet, and the other six groups fed three levels of high energy diets (3275, 3350, 3425, kcal / kg; one level for each two groups). The first three tested groups were pointed for as the "normal calorie-protein ratio" groups in which the dietary protein increased in relation to the increase in ME, keeping the normal ratio recommended by NRC of poultry (1994). In the second three tested groups the dietary protein was kept at the NRC level leading to ratios wider 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.

In the control group (1), the three diets fed, starter (0-3 wks), grower (3-6 wks) and finisher (6-8 wks), satisfied the NRC recommendations for energy at 3200 kcal/kg for all and for protein at 23, 20, and 18 %, respectively. This makes a calorie - protein ratio of 139, 160, and 178 for the three diets, respectively. Regarding the other six groups, the first three tested groups (2, 3 & 4) of the normal calorie-protein ratio diets, the chicks were treated with three diets having 3275 kcal ME/kg and 23.54, 20.47, and 18.42 % crude protein in group 2, 3350 kcal ME/kg and 24.08, 20.94, 18.84 % crude protein in group 3, and 3425 kcal ME/kg and 24.62, 21.41, 19.27 % crude protein in group 4. The increase in energy and protein compared to the NRC requirements forms 2.34% in group 2, double and triple this amount in groups 3 and 4 in respective order, keeping the normal ratios 139, 160 and 178 constant. The three levels of high energy were designated by the letters HE for the " high-energy" in the first level of increase, MHE for the "moderately high-energy" in the second, and VHE for the "very high-energy" in the third one.HP denotes to the "high protein" increased with the same degree used in its diet mate energy, so MHE-HP has a moderately high level of protein.

In the second three tested groups (5, 6 & 7) of the wide calorie-protein ratio, the chicks were fed the same diets with the three levels of high energy 3275, 3350 & 3425 kcal ME/kg, while the CP was kept at the NRC levels 23, 20 & 18% in the three stage-diets making a ME/CP ratio of 142.39, 163.75, 181.94 in starter, grower and finisher in group 5; 145.65, 167.50, 186.11 in group 6 and 148.91, 171.25, 190.28 in group 7.

Concerning the amino acids contents of the diets, their levels followed the dietary protein level. Consequently, the amino acids concentrations in “normal calorie-protein ratio” groups were increased in the same proportions of dietary protein. However, the amino acids levels in “wide 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 meal. Macrominerals were supplemented using common salt for sodium, limestone for Ca, and dicalcium phosphate for Ca and available phosphorus. Amino acids were supplemented using DL-Methionine and lysine L–Lysine, while trace minerals and vitamins by adding broiler premix. Antioxidant was not added as the diets were mixed daily. A mold inhibitor 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 based on the analysis of the 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 available phosphorus needs were corrected to follow the energy level. The physical and chemical compositions of the different diets are displayed in Tables 2 to 4 for the three phases starter, grower, and finisher.

The birds were fed ad libitum, with free access to water, throughout the experiment. The tested parameters were chick performance, blood chemistry, carcass characteristics and body composition.

2.3. Data collection

2.3.1. Broiler performance

The experiment was subjected to several measurements to trace the effect of the high energy, and the two protein levels on broiler performance. The diets were offered daily to the chicks in the morning. Feed intake was calculated per day 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). Energy efficiency ratios were 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., 2008).

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., 2008).

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
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, molasses and vegetable oil were 2500, 4600, 7000, 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.*

2.3.3. Blood parameters

Blood samples were collected from the wing vein of 5 chicks, in each group, at the end of the experiment (56 days) to measure some blood parameters. The samples were allowed to clot, and then centrifuged at 3000 r.p.m. for ten minutes. The serum samples were separated and stored at -20º C, in a deep freezer, until chemical analysis. 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 (Diacetyl Monoxime “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.

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. Birds were weighed to the nearest gram, subjected to 24h-feed withdrawal with free access to water, reweighed and slaughtered by neck cutting. 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 breast, thigh, 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.

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 (56 days). The birds were weighed after being subjected to 24 h-feed withdrawal with free access to water and killed by neck dislocation 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., 2008) 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).

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

Ingredient	Diet / Group						
	Control	Normal ME-CP ratio			Wide ME-CP ratio		
	NE-NP	HE-HP	MHE-HP	VHE-HP	HE-NP	MHE-NP	VHE-NP
	1	2	3	4	5	6	7
Physical composition							
Yellow corn, ground	49.510	45.360	41.350	37.300	47.300	45.170	43.050
Soybean meal (44%)	28.700	30.730	32.750	34.780	29.130	29.540	29.980
Corn gluten meal	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Vegetable oil	5.770	7.760	9.690	11.640	7.410	9.030	10.630
Molasses, cane	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Common salt	0.490	0.490	0.510	0.510	0.490	0.510	0.510
Limestone, ground	1.316	1.400	1.461	1.456	1.406	1.429	1.454
Dicalcium phosphate	1.780	1.830	1.830	1.890	1.830	1.890	1.940
DL-Methionine[1]	0.084	0.089	0.093	0.110	0.085	0.082	0.087
L-Lysine [2]	0.100	0.087	0.056	0.050	0.095	0.089	0.085
Mineral premix[3]	0.100	0.102	0.105	0.107	0.102	0.105	0.107
Vitamin premix[4]	0.100	0.102	0.105	0.107	0.102	0.105	0.107
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	3275	3350	3425	3275	3350	3425
Crude protein %	23.000	23.540	24.080	24.620	23.000	23.000	23.000
Calorie/ protein ratio	139.13	139.13	139.13	139.13	142.39	145.65	148.91
Methionine %	0.500	0.510	0.520	0.540	0.500	0.500	0.500
Lysine %	1.100	1.130	1.150	1.180	1.100	1.100	1.100
Methionine & cystine %	1.012	1.023	1.034	1.045	1.009	1.007	1.005
Crude fiber %	2.963	2.986	3.011	3.035	2.937	2.912	2.889
Ether extract %	8.716	10.528	12.285	14.061	10.253	11.774	13.276
Calcium %	1.000	1.020	1.050	1.070	1.020	1.050	1.070
Available phosphorus %	0.450	0.460	0.470	0.480	0.460	0.470	0.480
Sodium %	0.200	0.205	0.213	0.212	0.205	0.213	0.213

[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; 100(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 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 r 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, H: High, M: Moderately, V: Very

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

Ingredient	Diet / Group						
	Control	Normal ME-CP ratio			Wide ME-CP ratio		
	NE-NP	HE-HP	MHE-HP	VHE-HP	HE-NP	MHE-NP	VHE-NP
	1	2	3	4	5	6	7
Physical composition							
Yellow corn, ground	52.420	48.780	44.940	41.190	50.446	48.330	46.260
Soybean meal (44%)	34.930	36.721	38.550	40.360	35.330	35.749	36.143
Vegetable oil	7.370	9.220	11.140	13.020	8.930	10.530	12.130
Molasses, cane	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Common salt	0.350	0.360	0.380	0.380	0.360	0.380	0.380
Limestone, ground	1.410	1.360	1.380	1.410	1.370	1.380	1.420
Dicalcium phosphate	1.200	1.230	1.270	1.290	1.240	1.300	1.330
DL-Methionine	0.070	0.075	0.080	0.086	0.070	0.071	0.073
Mineral premix	0.100	0.102	0.105	0.107	0.102	0.105	0.107
Vitamin premix	0.100	0.102	0.105	0.107	0.102	0.105	0.107
Anti-mold	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Chemical composition (calculated)							
Metabolizable energy, kcal /kg	3200	3275	3350	3425	3275	3350	3425
Crude protein %	20.000	20.470	20.940	21.410	20.000	20.000	20.000
Calorie/ protein ratio	160.00	160.00	160.00	160.00	163.75	167.50	171.25
Methionine %	0.380	0.390	0.400	0.410	0.380	0.380	0.380
Lysine %	1.000	1.020	1.050	1.070	1.000	1.000	1.000
Methionine & cystine %	0.636	0.646	0.655	0.665	0.634	0.632	0.629
Crude fiber %	3.232	3.252	3.27	3.288	3.209	3.185	3.16
Ether extract %	10.263	11.956	13.71	15.428	11.731	13.233	14.736
Calcium %	0.900	0.920	0.940	0.960	0.920	0.940	0.960
Available phosphorus %	0.350	0.360	0.370	0.378	0.360	0.370	0.378
Sodium %	0.150	0.154	0.160	0.161	0.154	0.160	0.161

2.3.6. Economic efficiency

To determine the economical 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 the treatments. The results were considered significantly different at $P<0.05$.

Table 4. Physical and chemical composition (%) of the finisher diets

Ingredient	Diet / Group						
	Control	Normal ME-CP ratio			Wide ME-CP ratio		
	NE-NP	HE-HP	MHE-HP	VHE-HP	HE-NP	MHE-NP	VHE-NP
	1	2	3	4	5	6	7
Physical composition							
Yellow corn, ground	60.690	57.160	53.570	49.931	58.652	56.550	54.610
Soybean meal (44%)	28.760	30.417	32.070	33.771	29.170	29.580	29.950
Vegetable oil	5.730	7.570	9.430	11.310	7.310	8.910	10.460
Molasses, cane	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Common salt	0.270	0.280	0.300	0.300	0.280	0.300	0.290
Limestone, ground	1.330	1.270	1.310	1.340	1.270	1.310	1.313
Dicalcium phosphate	0.940	1.010	1.020	1.040	1.020	1.040	1.080
DL-Methionine	0.030	0.039	0.040	0.044	0.044	0.050	0.033
Mineral premix	0.100	0.102	0.105	0.107	0.102	0.105	0.107
Vitamin premix	0.100	0.102	0.105	0.107	0.102	0.105	0.107
Anti-mold	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Chemical composition (calculated)							
Metabolizable energy, kcal /kg	3200	3275	3350	3425	3275	3350	3425
Crude protein %	18.000	18.420	18.840	19.270	18.000	18.000	18.000
Calorie/ protein ratio	177.78	177.78	177.78	177.78	181.94	186.11	190.28
Methionine %	0.320	0.330	0.335	0.340	0.320	0.320	0.320
Lysine %	0.850	0.870	0.890	0.910	0.850	0.850	0.850
Methionine & cystine %	0.587	0.595	0.603	0.612	0.585	0.582	0.580
Crude fiber %	3.64	3.079	3.092	3.107	2.041	3.16	2.993
Ether extract %	8.954	10.641	12.345	14.067	10.439	11.941	13.58
Calcium %	0.800	0.820	0.840	0.860	0.820	0.840	0.860
Available phosphorus %	0.300	0.310	0.314	0.320	0.310	0.314	0.320
Sodium %	0.120	0.123	0.130	0.130	0.123	0.130	0.130

3. Results & discussion:

3.1. Growth performance

3.1.1. Body weight development

Body weight development data are displayed in table 5, for body weight and weight gain. The increase in dietary energy increased the weight from 2224.0 g in the control to 2458.9 g, the highest weight, in VHE with normal ME/CP ratio (group 5). Increasing the energy but fixing the crude protein at NRC rate resulted in non significant weight compared to that of control group except in the group with VHE which reached 2370.0 g at the end of the experiment. The body weight gain also followed similar trend as final live weight. In the starter period the body gain was about 25% of the total gain in the control and 22, 21, 21 & 23 in the significant four groups (2, 3, 4 & 7). In the grower period the increase was 40% in the control and 40, 43, 40 & 42 in the four groups, while in the finisher period was 35% in the control and 38, 37, 38 & 35 in the four groups, respectively. This means that the grower and finisher periods are the most important in showing diet effect, with rapid growth reflected in more energy and more protein consumed.

These results were in agreement with the findings of Tang et al. (2007); and Dewi et al. (2010) who reported increased live body weight with the increase in dietary energy and protein content. Moreover, some researchers (Holsheimer and Veerkamp, 1992, and Chachar et al., 2014) showed that increasing CP content more than NRC (1994) requirements may increase theperformance of broilers. These findings are inconsistent with the research conducted by Mushraf and Latshaw (1999), Dirain and Waldroup (2002), who reported that high dietary crude protein was harmful for broilers raised under high ambient temperatures, due to higher heat increment.

Table 5. Performance characteristics of broiler chickens fed seven regimes of energy and protein during starter, grower and finisher phases

Parameters	Group						
	Control	Normal ME-CP ratio			Wide ME-CP ratio		
	NE-NP	HE-HP	MHE-HP	VHE-HP	HE-NP	MHE-NP	VHE-NP
	1	2	3	4	5	6	7
Starter phase							
Live weight (g)	596.44[a] ± 18.43	566.31[a] ± 16.72	550.19[a] ± 19.33	559.07[a] ± 18.39	573.15[a] ± 12.01	577.03[a] ± 13.33	584.82[a] ± 8.89
Weight gain (g)	544.59	515.10	499.38	507.07	520.91	526.35	532.82
Feed intake (g)	789.81	695.88	631.58	626.49	776.02	815.93	755.90
Feed conversion ratio	1.45	1.35	1.26	1.24	1.49	1.55	1.42
Feed cost (L.E./kg)	4.0	4.14	4.26	4.40	4.07	4.16	4.26
Feed cost of production(L.E./kg)	5.80	5.59	5.37	5.46	6.06	6.45	6.05
Grower phase							
Live weight (g)	1460.58[a] ± 18.82	1501.46[ab] ± 29.53	1569.82[b] ± 27.75	1533.17[ab] ± 34.78	1501.34[ab] ± 21.17	1560.71[b] ± 21.97	1556.94[b] ± 29.83
Weight gain (g)	864.13	935.15	1019.63	974.09	928.18	1012.39	972.12
Feed intake (g)	1830.30	1689.04	1887.04	1757.07	1839.04	1867.02	1806.31
Feed conversion ratio	2.12	1.81	1.85	1.80	1.98	1.84	1.86
Feed cost (L.E./kg)	3.72	3.86	3.99	4.13	3.81	3.90	3.99
Feed cost of production (L.E./kg)	7.89	6.99	7.38	7. 43	7.54	7.18	7.42
Finisher phase							
Live weight (g)	2224.60[a] ± 36.43	2401.00[bcd] ± 37.58	2447.78[cd] ± 32.25	2458.89[d] ± 38.79	2281.10[ab] ± 45.61	2329.74[abc] ± 39.24	2370.00[bcd] ± 38.62
Weight gain (g)	764.03	899.54	877.96	925.72	779.76	769.02	813.05
Feed intake (g)	2234.86	2091.41	1978.41	2090.20	2057.41	2052.44	2162.37
Feed conversion ratio	2.93	2.32	2.25	2.26	2.64	2.67	2.66
Feed cost (L.E./kg)	3.49	3.63	3.75	3.88	3.59	3.68	3.77
Feed cost of production (L.E./kg)	10.23	8.42	8.44	8.77	9.48	9.83	10.03
The overall period							
Live weight (g)	2224.60[a] ± 36.43	2401.00[bcd] ± 37.58	2447.78[cd] ± 32.25	2458.89[d] ± 38.79	2281.10[ab] ± 45.61	2329.74[abc] ± 39.24	2370.00[bcd] ± 38.62
Weight gain (g)	2172.75	2349.79	2396.97	2406.88	2228.85	2307.76	2317.99
Feed intake (g)	4854.97	4476.33	4497.03	4473.76	4672.47	4735.39	4724.58
Feed conversion ratio	2.23	1.90	1.88	1.86	2.10	2.05	2.04
Total cost (L.E. /gain)	17.80	16.97	17.61	18.13	17.55	18.22	18.58
Feed cost of production (L.E./kg)	8.19	7.22	7.35	7.53	7.87	7.90	8.02

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

3.1.2. Feed intake

The cumulative feed intake in the 8 weeks decreased by about 3 % as energy increased in the groups 2, 3 & 4 with normal ME/CP ratios. The decrease in consumption started in the starter period by about 12 to 21 % and continued in the grower and finisher at a lesser extent except in group 3 (MHE) in the grower period where there was a little increase. So generally, increasing the energy density with normal ME/CP ratios resulted in a decreased consumption but the decrease did not pass linearly with the increase in energy but on reverse it was fixed in spite of energy increase. In the groups with wide ME/CP ratios (5, 6 &7) there was a decrease in the cumulative amount reaching 3.8 % on maximum compared with that of the control. The decrease started slightly in the starter period while in the grower period the chicks returned back to normal consumption. Most of the decrease was in the finisher period.

So, the crude protein is one of the effective factors controlling the response of the chicks to the increased density of energy. Generally feed intake is influenced by dietary crude protein and amino acid levels (Aletor et al., 2000; Sklan and Plavnik, 2002). However, Ferguson et al. (1998) reported that increasing CP content of the diets from 22% to 26.4% had no significant effect on feed intake but the feed to gain ratio increased when crude protein of the diet decreased. However, Magala et al. (2012) performed a study on layers and found that feed intake was not significantly affected by the dietary regimes. These findings were in agreement with those of Ndegwa et al. (2001) who reported that growth performance of Kenyan local chickens fed diets of 18–24% CP and 2842–3200 kcal/kg ME, between 6-19 weeks of age, was not significantly different.

3.1.3. Feed conversion ratio

The feed conversion ratio was improved in normal ME/CP ratio groups (2, 3 & 4). The improvement in feed conversion started from the starter and continued along to the finisher periods. The decrease in feed intake and increased growth rate are the main factors resulted in better conversion ratio and economic production of meat from the food consumption point of view. In the wide ME/CP ratio groups (5, 6 & 7) the improvement in feed conversion was not so clear and even the response only started in the grower period. So, increasing the energy density should be joined with increasing crude protein achieving normal ME/CP ratio. The normal ME/CP ratio of diets was found to play a prominent role in the performance of broiler chicken (NRC, 1994; and Aftab et al., 2006). Holsheimer and Veerkamp, 1992; Dewi et al., 2010; Kermanshahi et al., 2011; Chachar et al., 2014; Saleh et al., 2004; and Dozier et al., 2007 reported that increasing the energy and protein density improved the feed conversion ratio.

3.2. Energy and protein intake, efficiency and utilization

3.2.1. Energy intake and efficiency

As to the energy intake at the end of the experimental period the decrease in consumption was 876, 471 & 213 kcal in the groups 2, 3 & 4 compared with the control (Table 6). In the groups 5, 6 & 7 consumption decreased in 5 by about 234 kcal and increased in 6 & 7 by 328 and 646 kcal, respectively. In this study, the birds were not so successful in adjusting the amount of feed consumption for the needed energy and the failure resulted in a slight decrease (5.6, 3.0 & 1.4 % less than the control) in spite of normal calorie/protein ratio. When the ratio was wider than normal, birds consumed food nearly at the same rate and so get slightly more energy especially in moderately high and very high diets (1.5, 2.1 & 4.2 % more than control). So, the bird correction for the feed intake is not so precise, usually as in biology- nothing is 100 %, with slight decrease of energy intake in case of increased protein, and slight decrease or slight increase when the protein is normal. It seems that protein has a significant role. Neglecting the slight increase or slight decrease in energy this result was in agreement with Golian and Maurice (1992) and Leeson et al. (1993), who reported that birds consume feed to primarily meet their energy requirements.

As to the energy efficiency ratio the amount of weight gain for every 100 kcal made in the eight weeks an average of 13.99 g. In the control group in the normal ME/CP groups it increased by 1.72 g in group 4 to 2.04 g in group 2. So increasing the energy increased the efficiency when keeping the ME/CP at the normal ratio. The increase did not follow the increase in energy linearly and had no clear trend. In the wide ME/CP ratio groups the increase in the efficiency in the 8 weeks was small ranging from 0.33 to 0.58.

Still, keeping the ME/CP ratio at the normal NRC level is the main factor in improving the energy efficiency with the increased densities. Dozier et al.

(2006) reported that caloric use was not reduced to a great extent as dietary AME increased from 3265 to 3310 kcal/kg (without increased CP and amino acids).

Table 6. Energy and protein efficiency and utilization percentages

Parameters	Group						
	Control	Normal ME-CP ratio			Wide ME-CP ratio		
	NE-NP	HE-HP	MHE-HP	VHE-HP	HE-NP	MHE-NP	VHE-NP
	1	2	3	4	5	6	7
Energy intake, kcal ME	15535.90	14659.98	15065.05	15322.63	15302.34	15863.56	16181.69
Body energy, kcal ME	3737.80	4082.98	4281.46	4218.81	3924.62	4091.76	4017.95
Energy efficiency ratio[1]	**13.99**	**16.03**	**15.91**	**15.71**	**14.57**	**14.55**	**14.32**
Energy utilization %[2]	**24.06**	**27.85**	**28.42**	**27.53**	**25.65**	**25.79**	**24.83**
Protein intake, g	949.99	894.79	919.96	933.21	916.63	930.51	924.35
Body protein, g	361.76	351.06	375.13	399.06	351.71	392.78	384.79
Protein efficiency ratio[1]	**2.29**	**2.63**	**2.61**	**2.58**	**2.43**	**2.48**	**2.51**
Protein utilization %[2]	**38.08**	**39.23**	**40.78**	**42.76**	**38.37**	**42.21**	**41.63**

[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.

3.2.2. Protein intake and efficiency

The birds in all the experimental six groups consumed nearly the same amount of protein as the control group in the whole experimental period ranging from 895-950 g. It seems that birds eat for protein and not for calories. The intake in the normal ME/CP ratio groups was less than the control (895, 920 and 933 vs. 950) while the wide ME/CP groups were nearly equal to the control (917, 931& 924).

The protein efficiency ratio varies among the normal ratio groups between 2.58 to 2.63 compared with the control which reached 2.29. So, better efficiency with increasing the energy and protein, both together. In the wide ratio groups it ranges between 2.43 to 2.51, still we have better efficiency but lesser than with increasing the protein.

3.2.3. Energy and protein utilization

It is the carcass energy to the total ME intake and the total body protein to the total protein consumption, all expressed in percentage. The utilization of energy increased in the high energy six groups especially in the normal ME/CP ratio. The percentage in the control groups reached 24.06 compared with 27.93 in the wide ME/CP ratio ones. The utilization percentage of protein reached 38.08 in the control, while it reached 40.92 in the normal ME/CP ratio and 40.74 in the wide ones. Increasing energy increases energy utilization, especially in the normal ME/CP groups and does not pass parallel with the level of energy, while protein utilization increased in accordance with the level of energy.

On the other hand, the efficiency of protein utilization is better with low CP diets a fact concluded by Whitehead (1990), and in a study of Jackson et al. (1982) they 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.

3.3. Serum biochemical indices

Serum from the chicks of different groups was analyzed for eight measurements, glucose and triglycerides to test the effect of high energy diets on energy metabolism; albumen and total protein to test the effect of high or normal protein level, in relation to energy, on the nitrogen metabolism (Table 7). To detect the liver and kidney functions the enzymes AST and ALT for liver, and urea and creatinine for kidney were measured. The tests were performed at the end of the experiment. The measurements of all the analyses except ALT enzyme were not significantly different, and also the range of the readings was to a certain extent narrow. This agrees with Swennen et al. (2006) who did not observe any effect of the diet on plasma glucose concentration. Moreover, Riyazi et al. (2011) found that energy increasing and protein lowering have no beneficial effects on serum biochemical parameters.

Table 7. Serum biochemical indices in the different experimental groups at the end of finisher period (Mean ± SEM)

Parameter	Group						
	Control	Normal ME-CP ratio			Wide ME-CP ratio		
	NE-NP	HE-HP	MHE-HP	VHE-HP	HE-NP	MHE-NP	VHE-NP
	1	2	3	4	5	6	7
Glucose, mg/dl	267.00[a] ± 4.73	266.00[a] ± 4.04	258.00[a] ± 6.08	279.00[a] ± 3.51	270.00[a] ± 3.51	269.00[a] ± 3.06	272.00[a] ± 3.61
Triglycerides, mg/dl	83.00[a] ± 3.79	80.00[a] ± 3.79	80.00[a] ± 3.79	77.00[a] ± 3.79	79.00[a] ± 3.79	102.00[b] ± 6.11	89.00[a] ± 3.79
Total protein, g/dl	4.60[a] ± 0.50	4.30[a] ± 0.50	4.40[a] ± 0.50	4.00[a] ± 0.50	4.40[a] ± 0.50	3.90[a] ± 0.50	4.10[a] ± 0.50
Albumen, g/dl	1.79[a] ± 0.12	2.10[a] ± 0.15	1.80[a] ± 0.12	2.03[a] ± 0.19	1.97[a] ± 0.22	2.11[a] ± 0.15	2.13[a] ± 0.14
ALT, U/L	12.00[a] ± 1.73	18.20[bc] ± 1.59	19.10[bc] ± 2.25	22.15[c] ± 0.71	18.10[bc] ± 2.80	15.00[ab] ± 1.15	11.30[a] ± 1.45
AST, U/L	371.00[a] ± 4.04	273.00[a] ± 4.04	344.33[a] ± 5.36	376.67[a] ± 6.17	368.00[a] ± 4.04	397.00[a] ± 36.02	389.00[a] ± 3.51
Urea, mg/dl	11.90[a] ± 0.51	15.70[a] ± 1.46	13.33[a] ± 1.20	14.70[a] ± 1.60	15.00[a] ± 1.00	14.20[a] ± 1.56	14.80[a] ± 1.92
Creatinine, mg/dl	0.39[a] ± 0.03	0.48[a] ± 0.03	0.47[a] ± 0.03	0.48[a] ± 0.04	0.39[a] ± 0.04	0.46[a] ± 0.03	0.44[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 aminotransferase

3.4. Carcass characteristics

The carcass characteristics include seven traits, all except the visible fat are no significantly different and no effect was shown due to energy increasing either with normal or wide ME/CP ratio (Table 8). For this finding we found no logical interpretation from the nutritional or physiological point of view. These results are in agreement with the findings of previous researchers (Moosavi et al., 2012; Hidalgo et al., 2004; Magala et al., 2012; Nguyen and Bunchasak, 2005; Kamran et al., 2008) who found no significant difference in carcass characteristics when broilers were fed on diets with different levels of energy and protein. 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., 2008).

The visible fat in the tested groups with the high energy density diets, except number 2, is statistically different. But even with statistical significance, the difference in amount of fat is not so large to adversely affect the quality of carcass it is a matter of several grams more. Also, Zhuge et al. (2009) observed increasing viscera fat deposition when dietary energy was increased from 2900 to 3100 kcal/kg ME in the diets of growing broiler chickens. On the contrary, Dozier et al. (2006) reported that the high apparent metabolizable energy diet did not affect abdominal fat.

Table 8. Carcass characteristics of the different experimental groups (Mean ± SEM)

Parameters (%)*	Group						
	Control	Normal ME-CP ratio			Wide ME-CP ratio		
	NE-NP	HE-HP	MHE-HP	VHE-HP	HE-NP	MHE-NP	VHE-NP
	1	2	3	4	5	6	7
Dressing value	73.00[a] ± 2.31	75.30[a] ± 1.27	75.44[a] ± 1.28	74.91[a] ± 1.03	75.00[a] ± 2.89	73.90[a] ± 1.15	74.70[a] ± 0.58
Breast muscle	20.00[a] ± 0.58	20.24[a] ± 0.58	21.00[a] ± 0.58	21.80[a] ± 0.58	20.67[a] ± 0.58	20.54[a] ± 0.58	21.20[a] ± 0.58
Thighs	28.18[a] ± 0.58	27.14[a] ± 0.58	28.50[a] ± 0.58	29.11[a] ± 0.58	27.80[a] ± 0.58	27.47[a] ± 0.58	28.60[a] ± 0.58
Liver	2.00[a] ± 0.29	2.30[a] ± 0.17	2.70[a] ± 0.17	2.56[a] ± 0.32	2.34[a] ± 0.20	2.60[a] ± 0.23	2.30[a] ± 0.17
Gizzard	1.90[a] ± 0.23	1.70[a] ± 011	1.66[a] ± 0.13	1.56[a] ± 0.58	1.70[a] ± 0.58	1.71[a] ± 0.58	1.54[a] ± 0.58
Heart	0.44[a] ± 0.06	0.36[a] ± 0.06	0.42[a] ± 0.01	0.38[a] ± 0.01	0.39[a] ± 0.01	0.47[a] ± 0.01	0.49[a] ± 0.01
Visible fat**	1.99[a] ± 0.12	2.11[a] ± 0.06	2.56[b] ± 0.06	2.33[b] ± 0.06	2.80[c] ± 0.06	2.40[b] ± 0.06	2.36[b] ± 0.06

** 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

Body composition had no significant differences in the seven groups except the ether extract, a fact which reflects the increase in the carcass visible fat (Table 9). The ether extract was higher in all the groups especially the normal ratio ones and the first wide. Any how it was so indicative for the ether extract to reach more than one third of the DM of the body (29.92 % to 34.44%). However, increasing dietary CP has been shown to increase carcass protein in broilers (Jackson et al., 1982; Whitehead, 1990). While, Bartov (1979) and Jackson et al. (1982) reported that increasing the dietary CP or amino acids to ME ratio decreased the body fat percent of broilers.

3.6. Economic efficiency

The end result in the whole experimental period was an improvement in the cost of production more clear, to certain extent, in the normal ME/CP ratio groups, with group 2 the cheapest, and slight in the wide ratio groups (Table 5). In this respect, Dozier et al. (2006) demonstrated that no economic benefit was realized by increasing dietary AME beyond 3220 kcal/kg with changing diet and meat prices. Also, Abdel-Samai et al. (2007) reported that economical efficiency as determined by feed cost/kg weight gain was decreased linearly as energy increased in the diets.

Table 9. Body composition of chicken groups at the end of the experimental period on DMB (Mean ± SEM)

Parameter (%)	Group						
	Control	Normal ME-CP ratio			Wide ME-CP ratio		
	NE-NP	HE-HP	MHE-HP	VHE-HP	HE-NP	MHE-NP	VHE-NP
	1	2	3	4	5	6	7
Dry matter	27.82[a] ± 0.44	27.71[a] ± 0.88	28.19[a] ± 0.58	27.72[a] ± 0.35	27.44[a] ± 0.57	28.20[a] ± 0.44	27.90[a] ± 0.29
Crude protein	59.83[a] ± 1.31	53.91[a] ± 2.11	55.52[a] ± 1.51	59.81[a] ± 1.11	57.51[a] ± 2.65	60.36[a] ± 0.95	59.50[a] ± 0.87
Ether extract	29.92[a] ± 0.84	34.44[c] ± 0.52	34.16[bc] ± 0.36	31.43[abc] ± 0.92	33.83[bc] ± 0.62	30.71[ab] ± 1.07	30.43[ab] ± 1.31
Ash	10.25[a] ± 0.45	11.65[a] ± 0.33	10.33[a] ± 0.51	8.78[a] ± 0.67	8.69[a] ± 0.44	8.93[a] ± 0.40	10.07[a] ± 0.53

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

4. Conclusion:

Feeding diets containing high ME and high CP with normal ME/CP ratio had a significant increasing effect on the growth performance, without affecting carcass characteristics and body composition except for the visible fat and ether extract content of broilers but not so large to adversely affect the quality of carcass. These diets were accompanied by more clear economic return. However, feeding diets with high metabolizable energy and normal protein NRC-levels had a lesser improvement effect on performance, also without affecting carcass or body composition except an increased visible fat and a slight increase in ether extract. These diets had a lesser economic efficiency than the normal ME/CP ratio groups. Especially, the use of diets containing the energy density of 3350 kcal/kg and protein concentration of 24, 21 &19% at starter, grower and finisher, respectively, can be recommended.

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