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Effect of Measured Energy Restriction and Age Intervals on Growth, Nutrient Digestibility, Carcass Parameters, Bone Characteristics and Stress in Broiler Breeders during the Rearing Period

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ABSTRACT : This study aimed at targeting fixed increases in body weight (100 g/wk) by quantitatively regulating energy allowances (ME) in broiler breeders from 5 to 20 wks of age. Four energy regimes were tested: 1. The energy required for maintenance, activity and growth was calculated for 100 g increases in body weight/wk and a measured quantity of grower diet (160 g protein and 2,600 kcal ME/kg) was offered to the control group (ME-100) to achieve the anticipated weight gain. The energy allowances increased with age from 132 to 294 kcal/d. 2. Additionally, three energy regimes were considered, quantitatively reducing ME by 10% (ME-90) or 20% (ME-80) and increasing by10% (ME-110) over the control group. Each test group had 23 replicates×5 female chicks housed in cages. The influence of energy regimes and age on growth, nutrient digestibility, carcass attributes, bone parameters and stress was evaluated at 4 wk intervals. Quantitative ME restriction by 10% (119-265 kcal/d) produced an average weight gain of 98.1 g/wk, which was closer to the targeted increase of 100 g/wk, whereas the control group attained it nine days earlier. Restriction of energy by 10 or 20% produced better conversion efficiency of feed, energy and protein and apparent digestibility of protein, Ca and P than 10% excess ME. Energy regimes did not influence eviscerated meat yield, but higher energy allowances (ME-110) significantly increased abdominal fat pad and liver weights and decreased giblet weight, percent muscle protein and tibia ash. Relatively higher stress was recorded in ME-restricted groups, as reflected by wider heterophil and lymphocyte ratios and increased bursa weight. Early age (5-12 wk) significantly influenced bone mineralization, conversion efficiency of feed, energy and protein and apparent digestibility of protein, Ca and P, while later ages (13-20 wk) increased eviscerated meat yield, abdominal fat, tibia weight and muscle protein and reduced stress. Energy regime x age interactions were significant and are discussed. In conclusion, the synthetic broiler line used in our study responded positively to controlled energy feeding during the rearing period. Breeders offered 119-265 kcal/d, a reduction of 10% energy over the control group, were more effective in regulating grower performance than the latter. In addition to energy regimes, age intervals also exhibited significant influence on specific parameters during the grower phase. (**Key Words :** Age, Energy Restriction, Broiler Growers, Performance)

INTRODUCTION

In broiler breeders, controlled feeding is one of the most critical managemental practices in regulating body weight gain (BWG) and carcass composition, as they are sensitive to even marginal increases in feed or energy surpluses leading to obesity and loss of productivity (Robinson et al., 1995). Eating behavior in broiler breeders is controlled more by the satiety mechanism than the hunger mechanism (Bokkers and Koene, 2003). Therefore, feed allocations are reduced by 60-80% during rearing period to restrict weight gain (WG) to 45-50% of full fed breeders (Katanbaf et al., 1989a). In female breeders, sexual maturity is governed by the age of bird, carcass fat, lean body mass and photoperiod during rearing period (Robinson et al., 1993). A potential consequence of excess energy intake is increased accumulation of hepatic lipid and abdominal fat pad. Robinson et al. (1991) observed 700 g difference in BW between *ad libitum* and the feed restricted groups at sexual maturity, out of which 62% was fat. Feed restricted birds are not free from hunger, but they have the welfare benefit of reduced metabolic disorders and mortality (Whitehead, 2000). However, feed restriction-induced stress in birds, particularly during early phase of growth, when metabolic

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Table 1. Ingredient and nutrient composition (g/kg) of broiler grower diet

Ingredients	
Yellow maize	540.0
Soybean meal	150.0
Sun-flower cake	50.0
De-oiled rice bran	214.4
Salt	4.0
Oyster shell grit	15.0
Dicalcium phosphate	20.0
L-lysine HCl	1.0
DL-methionine	0.7
Choline chloride (50%)	2.6
Constants[1]	2.34
Nutrients	
ME (kcal/kg)[2]	2,600
Crude protein[3]	163.0
Lysine [2]	8.6
Total sulphur amino acids[2]	6.5
Calcium[3]	12.5
Avail. phosphorus[3]	5.5
Choline[2]	1.3

[1] Contained per kg diet: Retinol acetate 9.08 mg, cholecalciferol 0.08 mg, tocopherol acetate 12 mg, vitamin K 2 mg, riboflavin 10 mg, thiamine 1.2 mg, pyridoxine 2.4 mg, calcium pantothenate12 mg, cyanocobalamine 12 mg, trace mineral mixture contained Fe 81 mg, Mn 60 mg, Zn 40 mg, Cu 8 mg, I 2.28 mg, Se 0.15 mg, coccidiostat (Monensin sodium 100 g/kg) 0.5 g and Zn bacitracin (10% w/w) 0.5 g.
[2] Calculated values. [3] Estimated values.

requirements are high (Mench, 2002). The stress indices like heterophil: lymphocyte ratios and corticosterone concentrations get elevated due to feed deprivation (Hocking, 1993; Hocking et al., 1996). Calorie intake is a critical factor in regulating BWG and obesity in broiler breeders, but it is difficult to define the optimum level of energy restriction due to continued changes in the genetic composition of stocks. Nevertheless, if the BW for a given age is defined, the intensity of energy restriction can be accordingly scheduled. Regulation of energy allowances during rearing period could be instrumental in achieving the targeted WG with desirable carcass composition. Age could also be an important factor in optimizing the performance of breeders in grower phase. Therefore, metabolizable energy (ME) was utilized as the primary nutrient in the present experiment targeting fixed increases in WG in broiler breeders and examine its influence on growth, nutrient digestibility, carcass attributes, bone and muscle parameters and stress at different age intervals during rearing period from 5 to 20 wk of age.

MATERIALS AND METHODS

Stock and management

Day-old female broiler chicks (600) from a synthetic female parent line were procured, wing banded and randomly distributed in battery cages (60 cm×75 cm×45 cm-for 5 chicks) with raised wire floor and kept in open sided house. They were brooded at 34±1°C for 7 d, which was gradually reduced to 26±1°C by 21 d of age. The supportive heat was withdrawn thereafter. The chicks were fed *ad libitum* on a starter diet (215 g protein and 2,850 kcal ME/kg) up to 4 wk of age, weighed individually to select 460 chicks within the weight range of 560 and 745 g. They were equally distributed to 4 test groups with 23 replicates of 5 chicks each, and reared under uniform managemental conditions. They were protected against Newcastle disease, Marek's disease and infectious bursal disease following the prescribed vaccination schedule. At the start of 5th wk measured quantity of grower diet (160 g protein and 2,600 kcal ME/kg; Table 1) was offered to each of the four groups following energy schedule on weekly basis. In the 8th wk, birds were shifted to individual cages (37.5 cm×30 cm×30 cm) up to 20 wk of age.

Experimental groups and dietary regimes

During grower period, a model suggested by Scott et al. (1982) was used to calculate the ME required for maintenance (m), activity (a) and growth (wg) targeting 100 g increase in BW/wk. Detailed description of this model has been presented elsewhere (Shyam Sunder et al., 2007). Briefly, by multiplying the metabolic body weight with 83 and dividing the product by 0.82, the ME needed for maintenance (MEm) was derived. The ME for activity was obtained by multiplying ME_m with 0.5. The ME required for wg was calculated using the factors 0.18×4.0 and 0.15×9.0 respectively, representing the protein and fat contents per gram increase in weight. The summation of ME_m, ME_a and ME_{wg} was considered as the energy required for achieving the targeted increase in BW. Accordingly, the ME required for 100g increases in BW/wk was calculated, and measured quantity of grower diet (Table 2) was offered to the control group (ME-100). Additionally, three separate groups were considered by quantitatively reducing ME by either 10% (ME-90) or 20% (ME-80) and increasing by 10% (ME-110) over the control. The grower diet was formulated using maize, soybean meal and de-oiled rice bran considering the ME values determined at this Directorate (Rama Rao et al., 2006). The quantity of protein and amino acids offered to the four test groups varied with the amount of diet offered to each of them. However, uniform intake of minerals and vitamins was ensured by adjusting their inclusion levels in the four test diets.

Body weight and carcass traits

Individual body weights and replicate feed consumption were recorded at the end of each week to calculate the conversion efficiency of feed, protein and ME up to 20 wk of age. At the end of 8th, 16th and 20th wk, 8 birds from each dietary group were starved over night, weighed and

Table 2. Schedule of energy and feed offered to broiler growers in the four test groups, during each of the 4-wk periods up to 20 wk of age

Age intervals (wks)	Energy allowances (kcal/b/d) offered to different dietary groups			
	ME-80	ME-90	ME-100	ME-110
5-8	107-135	120-153	133-169	146-185
	(41-52)	(46-59)	(51-65)	(56-71)
9-12	146-172	164-192	182-213	200-234
	(56-66)	(63-74)	(70-82)	(77-90)
13-16	179-203	200-231	224-255	247-281
	(69-78)	(77-89)	(86-98)	(95-108)
17-20	213-234	239-265	265-294	291-322
	(82-90)	(92-102)	(102-113)	(112-124)

Values within the parenthesis represent the range of feed offered (g/b/d) during 4-wk intervals to different test groups during grower phase.

Table 3. Effect of ME restriction on body weight and conversion efficiency of feed, protein and ME in broiler breeders at different age intervals during rearing period

Parameters	Age (wks)	Energy restriction regimes				SEM	p value
		ME-80	ME-90	ME-100	ME-110		
Body weight (g)	5	659	659	658	657	2.1	0.988
	8	905^{d}	959^{c}	$1,022^{b}$	$1,066^{a}$	4.8	0.001
	12	$1,312^{d}$	$1,409^{c}$	$1,514^{b}$	$1,591^{a}$	8.4	0.001
	16	$1,702^{d}$	$1,815^{c}$	$1,946^{b}$	$2,104^{a}$	11.1	0.001
	20	$2,085^{d}$	$2,229^{c}$	$2,397^{b}$	$2,589^{a}$	13.3	0.001
Feed intake (g/b)	5-8	$1,302^{d}$	$1,463^{c}$	$1,624^{b}$	$1,785^{a}$	9.38	0.0001
	9-12	$1,701^{d}$	$1,918^{c}$	$2,128^{b}$	$2,338^{a}$	12.36	0.0001
	13-16	$2,058^{d}$	$2,324^{c}$	$2,576^{b}$	$2,835^{a}$	15.04	0.0001
	17-20	$2,408^{d}$	$2,709^{c}$	$3,010^{b}$	$3,311^{a}$	17.53	0.0001
Feed intake /wt. gain	5-8	5.54^{a}	5.09^{b}	4.68^{c}	4.47^{c}	0.06	0.001
	9-12	4.29	4.40	4.45	4.54	0.04	0.232
	13-16	5.53^{c}	5.89^{ab}	6.21^{a}	5.73^{bc}	0.06	0.007
	17-20	6.40^{b}	6.70^{ab}	6.85^{a}	6.93^{a}	0.05	0.003
ME intake (kcal)/wt. gain	5-8	14.75^{a}	13.70^{b}	12.28^{c}	11.77^{c}	0.16	0.001
	9-12	11.31	11.86	11.65	11.91	0.123	0.293
	13-16	15.08^{b}	15.65^{ab}	16.28^{a}	15.15^{b}	0.17	0.050
	17-20	17.69	17.66	17.90	18.23	0.207	0.752
Protein intake (g)/wt. gain	5-8	0.887^{a}	0.816^{b}	0.748^{c}	0.715^{c}	0.009	0.001
	9-12	0.687	0.704	0.712	0.726	0.006	0.226
	13-16	0.885^{c}	0.944^{ab}	0.993^{a}	0.916^{bc}	0.009	0.001
	17-20	1.02^{b}	1.07^{ab}	1.09^{a}	1.10^{a}	0.008	0.003

[a, b, c, d] Means with different superscripts in the same row differ significantly ($p \leq 0.05$).

sacrificed by cervical dislocation to record the carcass parameters. The weights of eviscerated meat yield, gizzard, liver, giblet and abdominal fat pad were calculated per kilogram pre-slaughter weight. Tibiae were collected and pressure-cooked to remove the attached muscle and soft tissues including diaphysis. The bones were dried at 100°C /12 h, defatted in petroleum ether for 48 h, weighed and ashed at 600±20°C for 5 h and the percent total ash was determined (AOAC, 1995). Samples of breast muscle were collected from each bird and oven dried at 80°C for 24 h to estimate the percent water and protein contents.

Apparent digestibility of nutrients

A balance study was conducted in cages to determine the apparent digestibility of nutrients in the 8^{th}, 16^{th} and 20^{th} wk. Measured quantity of each experimental diet was offered to 4 replicates of 2 birds each, as per the predetermined schedule of experimental groups for 3 consecutive days and total excreta was collected on the following days. Dry matter (DM), protein (CP) and calcium (Ca) contents in diets and excreta were estimated as per AOAC (1995), and the phosphorus (P) content following the method of Fiske and Subbarow (1925). The difference between input and output of nutrients was calculated on dry matter basis to determine the percent apparent digestibility.

H:L ratios

Blood smears from 8 birds/group were collected in the 8^{th}, 16^{th} and 20^{th} wk. They were processed with May-Greenwald-Giemsa stain and viewed under oil immersion lens to count the number of heterophils and lymphocytes spread over 60 cells to determine their ratios (Gross and

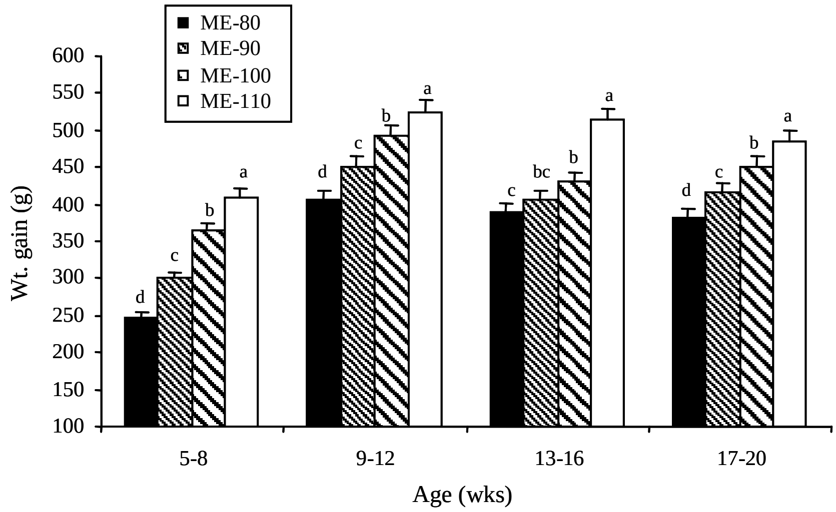

Figure 1. Variations in weight gain of broiler breeders due to energy regimes during each of the 4-week periods during rearing period.

Siegel, 1983). The weights of bursa and spleen were recorded during the same age intervals and calculated per kilogram pre-slaughter weight.

Statistical analysis

Data were analyzed using General Linear Model Procedures of SAS Institute (1994). Two-way analysis of variance was conducted considering the four energy regimes and age intervals as the two factors. The interaction between them was also determined. The mean values for main and interaction effects were tested for statistical significance ($p\leq 0.05$) using Duncan multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

Analyzed results of BW pooled over 4-wk intervals showed steady increase in WG with age in all dietary groups, but with a significant ($p\leq 0.05$) difference in the rate of growth during rearing period (Table 3). Breeders offered measured quantity of energy (ME-100) or 10% excess (ME-110) achieved the targeted WG (1,600 g) earlier by 9 and 20 days, respectively. In contrast, the breeders in ME-90 group gained 1,571 g at 20 wk of age, which was closer to the targeted weight despite 10% decrease in energy allowances compared to the control group. It is possible that the energy requirements of birds under restriction were considerably lower than those maintained on higher plain of feeding. Perhaps, need utilization improved under need restriction regime (Pinchasov and Galili, 1990).

Although the breeders in control group were offered calculated energy allowances anticipating uniform increase in WG by 400 g during each of the 4-wk periods, the realized growth lacked uniformity and varied considerably between different age intervals (Figure 1). In control group, the lowest WG of 364 g was recorded during 5-8 wk of age compared to other age intervals. This may be due to the shift in feeding pattern from *ad libitum* (244 kcal/d) in the 4^{th} wk to grower restriction (152 kcal/d) in the 5^{th} wk leading to quantitative reduction of energy by 38% between the two periods, which decreased WG much below the anticipated level. However, maximum WG of 492 g was recorded between 9-12 wk of age, which can be attributed to quick adaptation of the breeders to energy restriction. The same trend was also noticed in other feeding regimes. Nir et al. (1996) observed that broilers under feed restriction make physiological alterations in the gastrointestinal tract by increasing its capacity to facilitate slower evacuation of intestinal contents and improve nutrient availability. Quick adaptation to energy restriction, particularly from 9 wk of age in our study may be due to the same phenomenon. Further, our results showed that breeders maintained under severe or moderate ME restriction (ME-80 and ME-90) had relatively higher intensity of WG between 9-12 wk of age than the control or 10% excess energy fed birds, suggesting significant compensatory growth in the former groups (Prader et al., 1963). The phenomenon of compensatory growth was perhaps more closely related to the degree of restriction, as seen in ME-80 and ME-90 groups.

The conversion efficiency of feed, protein and energy was poor in ME-80 and ME-90 groups during 5-8 wk of age and improved either significantly ($p\leq 0.05$) or remained at par with the control and ME-110 group during 13-16 and 17-20 wk of age (Table 3). Among the age intervals, the period between 9-12 wk showed better conversion efficiency of feed, protein and energy, possibly due to higher growth rate during that period. Some studies have identified certain critical periods within the rearing period when restriction imparted its effect more intensely than others (Bruggeman et al., 1999). Our results showed maximum effect of restriction during 9-12 wk of age, which was stabilized thereafter.

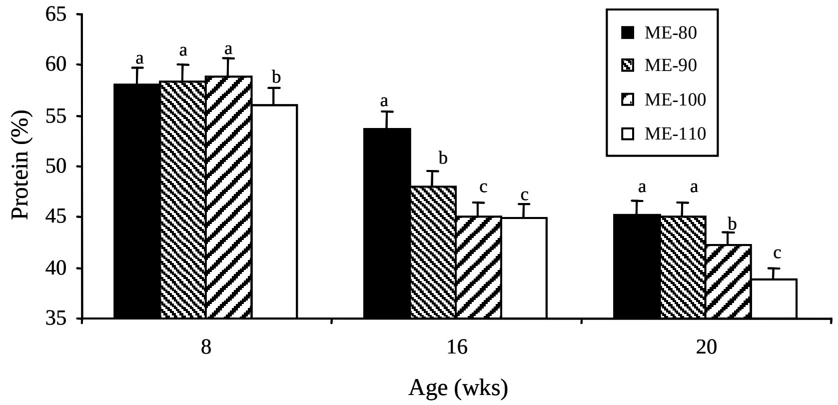

Figure 2. Effect of energy regimes on apparent digestibility of protein (%) in broiler breeders at different age intervals during rearing period.

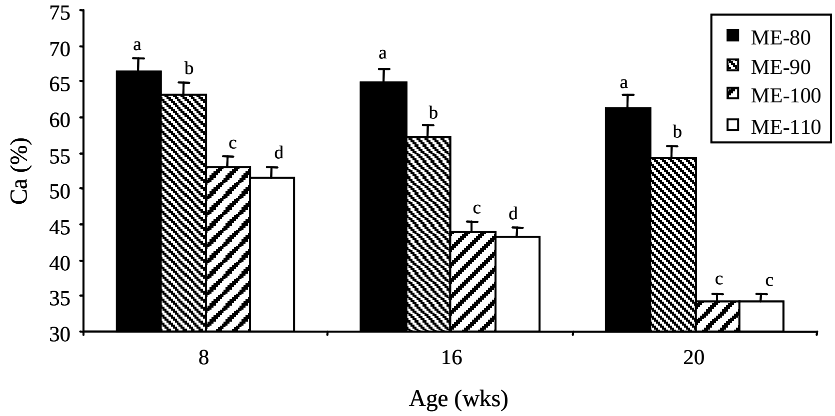

Figure 3. Influence of energy regimes on apparent digestibility of Ca (%) in broiler breeders at different age intervals during grower phase.

In our study, the discussion was focused mainly on the effects of energy regimes, although there was a significant difference in the total protein intake between ME-80 and ME-110 groups (1,195 to 1,643 g/b) up to 20 wk of age. The average protein received by both groups was 10.7 and 14.7 g/d, respectively. Bowmaker et al. (1989) indicated that the broiler growers needed protein at 10.0 g/d and it did not alter the percent body protein, particularly when lysine (0.80%) and methionine+cystine (0.60%) were maintained at optimum levels (Bennet and Leeson, 1990; Lilburn and Myers Millers, 1990; Yu et al., 1992). Among our experimental groups, even the breeders maintained on severe energy restriction (20%) received more than 10.0 g protein/d and hence, the emphasis was primarily on energy regimes and not on protein.

The apparent digestibility of protein (CP), calcium (Ca) and phosphorus (P) was influenced by the quantity of energy consumed by the four dietary groups in the 8th, 16th and 20th wk (Figures 2, 3 and 4). The digestibility of CP was significantly ($p<0.05$) high in the two ME restricted groups in the 16th and 20th wk (Figure 2), while that of Ca in all the three age intervals compared to ME-100 or ME-110 groups (Figure 3). Retention of P was also better in ME-80 group at 16 and 20 wk of age compared to ME-100 and ME-110 groups (Figure 4). However, the DM digestibility of diets showed no variation among themselves up to 20 wk of age. Improved digestibility of protein was perhaps responsible for restricting the weight loss in ME-90 and ME-80 groups to 7 and 17%, respectively at 20 wk of age compared to controls, although the energy offered to these groups was reduced by 10 and 20% (Figure 2). Pinchasov and Galili (1990) observed that the energy requirement of the birds under feed restriction was considerably low, which was perhaps responsible for better energy conversion efficiency in the restricted groups in our study. Improved energy retention was concomitant to protein retention, suggesting the possibility of decreased diversion of dietary protein to energy, resulting in better protein conversion efficiency in ME-80 and ME-90 birds (Nir et al., 1996).

Irrespective of the restriction levels, age significantly ($p\leq0.05$) influenced apparent digestibility of CP, Ca and P in breeders by being significantly ($p\leq0.05$) better at 8 wk than at 16 or 20 wk of age (Table 6). Metabolic activity being high during early age, the demand for nutrients was

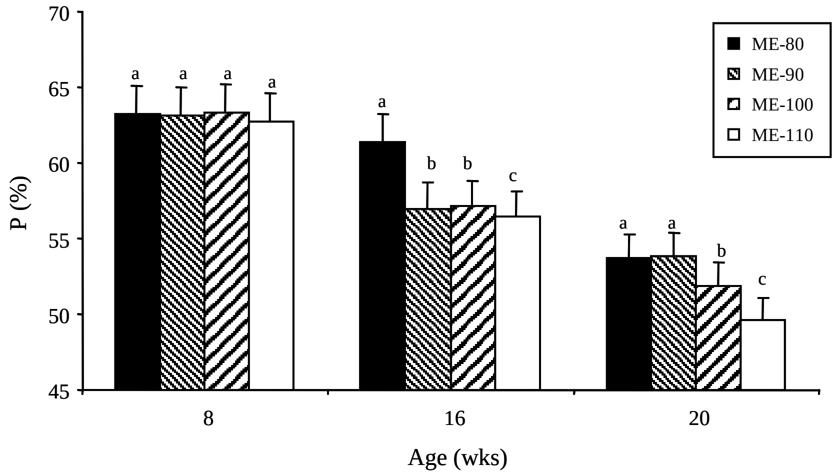

Figure 4. Influence of energy regimes on apparent digestibility of P (%) in broiler breeders at different age intervals during grower phase.

more intense, which was facilitated by higher nutrient retention**.** In feed restricted breeders, the hepatic lipogenesis and glycogen synthesis increased during the period of feeding, while heat loss was reduced during feed deprivation facilitating them to make some important physiological adjustments for better nutrient utilization (Nir et al., 1996).

Results on carcass constituents showed no significant effect of dietary regimes on eviscerated meat yield in the 8^{th}, 16^{th} and 20^{th} wk (Table 4), but the weight of abdominal fat pad in ME-90 group was less by 2.74-3.52 times compared to ME-110, during different age intervals. This variation was related to the difference in energy consumption (4,823 kcal/b) between the two groups up to 20 wk of age. Further decline in abdominal fat was noticed in ME-80, although it was not different from ME-90. Our findings are in agreement with the results reported by Robinson et al. (1991) and Katanbaf et al. (1989b), who observed reduction

Table 4. Influence of energy regimes on carcass traits, bone parameters and composition of breast muscle in broiler breeders at different age intervals

Parameters	Age (wk)	Energy restriction regimes				SEM	p value
		ME-80	ME-90	ME-100	ME-110		
Eviscerated yield[1]	8	681	689	694	699	3.81	0.404
	16	754	750	751	740	2.27	0.130
	20	763	753	760	758	2.15	0.403
Abdominal[1] fat weight	8	1.38[b]	2.07[b]	2.02[b]	5.73[a]	0.34	0.001
	16	2.72[b]	3.13[b]	9.92[a]	11.01[a]	0.76	0.001
	20	4.97[c]	8.13[c]	13.15[b]	22.28[a]	1.17	0.001
Liver weight[1]	8	17.95[b]	20.86[a]	20.42[a]	20.34[a]	0.41	0.049
	16	15.17	15.33	16.05	15.15	0.24	0.543
	20	13.89[b]	15.22[ab]	16.71[a]	16.23[a]	0.30	0.002
Gizzard[1] weight	8	30.60	30.42	28.40	29.55	0.51	0.428
	16	23.92[a]	22.93[a]	23.59[a]	20.14[b]	0.38	0.001
	20	20.58	20.40	18.80	18.42	0.38	0.102
Tibia weight[1]	8	3.34	3.07	3.22	2.95	0.06	0.182
	16	3.63	3.63	3.43	3.10	0.09	0.152
	20	3.35	3.37	3.46	3.21	0.05	0.509
Tibia ash (%)	8	54.50[a]	49.89[b]	49.71[b]	49.42[b]	0.412	0.001
	16	48.32[a]	46.97[b]	46.53[b]	46.42[b]	0.217	0.003
	20	47.31	46.08	45.96	45.90	0.253	0.158
Water in muscle (%)	8	74.74[ab]	74.04[b]	74.61[ab]	75.53[a]	0.178	0.030
	16	73.18	73.17	74.03	73.39	0.157	0.170
	20	73.17	73.29	73.92	73.57	0.141	0.240
Protein in muscle (%)	8	87.00[a]	86.40[a]	85.05[b]	85.28[b]	0.147	0.001
	16	89.52[a]	89.77[a]	88.73[b]	86.90[c]	0.166	0.001
	20	89.84[a]	89.17[a]	86.76[b]	85.91[c]	0.226	0.001

[1] g per kilogram live weight. [a, b, c] Means within a row having different superscripts vary significantly ($p\leq0.05$).

Table 5. Changes in H:L ratios and weight of bursa and spleen due to different energy regimes in broiler breeders during rearing period

Parameters	Age (wk)	Energy restriction regimes				SEM	p value
		ME-80	ME-90	ME-100	ME-110		
H:L ratios	8	0.46[a]	0.42[b]	0.38[c]	0.39[bc]	0.007	0.001
	16	0.45[a]	0.40[b]	0.34[c]	0.35[c]	0.007	0.001
	20	0.40[a]	0.33[b]	0.23[c]	0.25[c]	0.011	0.001
Bursa weight[1]	8	1.15[a]	1.17[a]	0.85[b]	0.75[b]	0.05	0.002
	16	0.79	0.81	0.90	0.87	0.04	0.838
	20	0.63	0.50	0.59	0.61	0.02	0.314
Spleen weight[1]	8	2.03	2.07	2.03	1.90	0.05	0.721
	16	1.19	1.26	1.42	1.33	0.04	0.300
	20	1.34	1.35	1.37	1.36	0.03	0.987

[1] g per kilogram live weight, H:L - heterophils:lymphocytes. [a, b, c, d] Means with different superscripts in a row vary significantly (p≤0.05).

Table 6. Effect of different age intervals on performance, apparent digestibility of nutrients, carcass, bone and muscle parameters, and H:L ratios in broiler breeders during rearing period

Parameters	Age in weeks			SEM	p value
	8	16	20		
Weight gain (g)	330[b]	436[a]	432[a]	2.73	0.001
Feed (g)/wt. gain (g)	4.95[c]	5.84[b]	6.78[a]	0.03	0.001
Protein (g)/ wt. gain (g)	0.792[c]	0.933[b]	1.08[a]	0.006	0.001
Energy (kcal)/ wt. gain (g)	13.14[c]	15.52[b]	17.87[a]	0.104	0.001
Apparent digestibility of protein (%)	58.11[a]	47.92[b]	42.28[c]	0.65	0.001
Apparent digestibility of Ca (%)	58.46[a]	52.31[b]	45.76[c]	0.91	0.001
Apparent digestibility of P (%)	63.12[a]	58.00[b]	52.17[c]	0.40	0.001
Eviscerated wt[1].	691[c]	749[b]	759[a]	3.18	0.001
Abd. fat wt.[1]	2.72[c]	6.70[b]	12.29[a]	0.589	0.001
Liver weight[1]	20.15[a]	15.42[b]	15.72[b]	0.30	0.001
Giblet weight[1]	53.98[a]	41.92[b]	39.50[c]	0.69	0.001
Gizzard weight[1]	29.71[a]	22.64[b]	19.55[c]	0.46	0.001
Tibia weight[1]	3.15[b]	3.45[a]	3.35[ab]	0.04	0.010
Tibia ash (%)	50.85[a]	47.09[b]	46.31[c]	0.254	0.001
Water in muscle (%)	74.73[a]	73.44[b]	73.49[b]	0.09	0.001
Protein in muscle (%)	85.93[c]	88.73[a]	87.89[b]	0.129	0.001
H:L ratios	0.41[a]	0.39[b]	0.30[c]	0.006	0.001
Bursa wt.[1]	0.98[a]	0.85[b]	0.58[c]	0.02	0.001
Spleen wt.[1]	2.00[a]	1.30[b]	1.35[b]	0.03	0.001

[a, b, c] Means with different superscripts in a row vary significantly (p≤0.01). [1] g per kilogram live weight.

in abdominal fat pad and carcass fat due to feed restriction, which was directly related to the severity of restriction imposed in their studies. The relative weight of liver in breeders that received 20% less energy was significantly (p≤0.05) low, particularly in the 8th and 20th wk**.** Lipogenic activity is related to energy intake and liver being the primary site of this activity; changes in its weight were attributed to lipid deposition particularly in groups that received higher quantity of energy (Renema et al., 1999). In contrast, gizzards were lighter in ME-110 group.

The energy regimes had no effect on tibia weight, but bone mineralization was significantly (p≤0.05) better in ME-80 group over others up to 16 wk of age, but not thereafter. It has been reported that the physical properties of dynamic bone were not affected by limiting the access to feed in broiler breeders (Hudson et al., 1999). Compared to adipose and muscle tissues, feed restriction had limited influence on bone weight (Yu et al., 1992). However, the percent bone ash, which reflected bone mineralization was significantly (p≤0.05) high in the 8th and 16th wk in birds maintained on 20% energy restriction. No difference could be seen at 20 wk of age. Similar effect of increased percent body ash was also observed by other workers in the breeders under feed restriction (Yu et al., 1992; Renema et al., 1999). The balance trial conducted in our study showed improved apparent digestibility of Ca and P (Figures 3 and 4) in energy-restricted groups, which perhaps supported better bone mineralization than ME-100 or ME-110 groups.

No significant (p≥0.05) influence of energy regimes on water content of muscle was noticed in the 16th and 20th wk, but it was low in ME-90 group at 8 wk of age (Table 4). However, the muscle protein was significantly (p≤0.05) higher in birds of ME-90 group than ME-110, and it increased with age from 1.12 to 3.26%. The relative increase of muscle protein and decrease in abdominal fat deposition in ME-90 group and the vice versa in ME-100

Table 7. Interaction between energy regimes and age intervals on the performance, nutrient digestibility, carcass traits, bone parameters and H:L ratios in broiler breeders during rearing period

Parameters	Energy regimes ×age intervals (p values)	SEM
Body weight (g)	0.0001	14.44
Weight gain (g)	0.0001	2.73
Feed conversion efficiency	0.0001	0.03
Protein conversion efficiency	0.0001	0.006
Energy conversion efficiency	0.0001	0.104
Protein digestibility[1]	0.0001	0.65
Ca digestibility[1]	0.0001	0.91
P digestibility[1]	0.0001	0.40
Tibia ash[1]	0.001	0.254
Muscle protein[1]	0.0001	0.129
H:L ratios	0.002	0.006
Bursa (g/kg)	0.004	0.02

[1] g per kilogram live weight.

and ME-110 groups was related to the quantity of energy consumed by both groups. These results are consistent with those reported by Sun et al. (2006) and Renema et al. (1999), who reported increased carcass protein and decreased absolute abdominal fat pad weight and percent carcass fat in broiler breeders that were under feed restriction.

Age intervals influenced carcass attributes significantly ($p\leq0.05$), as the weight of eviscerated meat yield and abdominal fat pad per kilogram pre-slaughter weight increased with the advancement of age, while that of gizzard, giblet and liver decreased (Table 6). Also the age of bird influenced tibia weight, though relatively less at 8 wk than at 16 wk of age. In contrast, bone mineralization was maximum at 8 wk suggesting that the dynamic activity of bone was more intense during early period of growth than the subsequent ages. Further, our data showed that protein accretion in muscle increased significantly ($p\leq0.05$) with advancement of age. During early age (8 wk), the breast muscle had higher water and lower protein contents and the vice-versa in the 16^{th} and 20^{th} wk (Table 6). These results suggest that independently age of the bird exhibited definite effects on carcass parameters, bone traits and muscle composition.

The stress caused due to controlled energy feeding was relatively less in breeders of ME-100 and ME-110 groups compared to the two energy restricted groups up to 20 wk of age, as reflected by higher H:L ratios (Table 5). Our findings confirmed the earlier evidence that feed restriction is a physiological stressor and elicited alterations in lymphocyte counts, resulting in higher H:L ratios (Katanbaf et al., 1989a; de Jong et al., 2005). However, the ratios recorded in ME-80 and ME-90 groups at different age intervals were moderate, as per the characteristic scale suggested by Gross and Siegel (1993). They considered the ratios below 0.5 as optimum, and our restriction schedule showed values within the limits of comfort zone. Bursa weight increased due to energy restriction, particularly in ME-80 group, but age appeared to normalize this change. Spleen did not record any such variation in weight due to energy restriction. However, breeders adapted well to feeding regimes with age and the increases in feed allowances further helped in reducing stress (Table 6).

Interaction between dietary regimes and age of breeders

The interaction between age and energy restriction was noticeably significant ($p\leq0.05$) between 9-12 wk in all groups recording maximum WG compared to other age intervals. In contrast, minimum WG was observed between 5-8 wk indicating the influence of both factors on WG. In broiler growers, the time and duration of feed restriction were considered important for sexual maturity in breeder pullets. Yu et al. (1992) indicated that controlled feed intake was essential from 4 to 18 wk of age, while Bruggeman et al. (1999) observed that feed restriction period between 7-15 wk of age was critical for breeder performance. From our results, it was obvious that the best responses in growth and conversion efficiencies of feed, protein and energy were between 9-12 wk of age and to a lesser extent during 5-8 wk, while other parameters were supported by the later age intervals up to 20 wk of age. The age dependent advantage was evident more in energy-restricted groups than the control or 10% excess ME fed groups, particularly when the restriction regimes were continued up to 20 wk of age.

The apparent digestibility of CP, Ca and P was significantly ($p\leq0.05$) better at 8 wk compared to 16 or 20 wk of age, indicating better nutrient utilization during early ages. Energy restriction by 10 or 20% levels complimented this effect over controlled energy or 10% excess energy feeding. It was possible that the requirements of these three nutrients were higher during early period of growth, particularly when energy restriction was severe, than during the later ages. Bone mineralization as reflected by percent bone ash was better due to energy restriction because of improved retention of Ca and P compared to ME-100 or ME-110 groups (Yu et al., 1992). The intensity of mineralization was more during early age (5-8 wk), especially in the feed restricted groups, indicating an age related relationship with energy restriction, which was stabilized after 16 wk of age in all groups.

Energy regimes did not influence eviscerated meat yield, but it increased with age in all dietary groups. However, both factors significantly ($p\leq0.05$) affected the weight of abdominal fat pad. The weight of abdominal fat pad at 8 wk of age in the breeders of ME-110 group was equivalent to that in ME-80 group at 20 wk of age. Similarly, the weight of abdominal fat pad in ME-100 group at 16 wk was at par with ME-90 at 20 wk of age, indicating the significance of energy restriction on fat accumulation. Broiler pullets do not adequately regulate energy balance, which was evident in ME-110 group resulting in cumulative effect on fat stores as the age advanced (Richards, 2003). The protein content of breast meat considered as an indicator of protein accretion was influenced both by energy regimes and age. The muscle protein in the breeders of ME-80 and ME-90 groups at 8 wk of age was equivalent to that in ME-100 or ME-110 groups at 20 wk of age, indicating an inverse relationship between protein and fat deposition in energy restricted birds.

Breeders that received low energy inputs (ME-80 and ME-90) exhibited more stress as indicated by higher H: L ratios compared to ME-100 and ME-110 at all age intervals. The interaction between energy regimes and age showed a decline in H:L ratios with age, but restriction of energy continued to exert relatively more stress in ME-80 and ME-90 groups than ME-100 and ME-110. Energy restriction was stressful particularly in young broilers, as they were in a rapid phase of growth and with high metabolic activity (Mench, 2002). However, the range of H: L ratios observed in our study due to feed restriction regimes was moderate even in groups under feed restriction and it did not offset the advantages of controlled ME feeding.

This study clearly established that feeding measured energy allowances was an effective means to regulate WG in broiler breeders during rearing period to achieve the targeted BW at 20 wk of age. However, the synthetic parent line tested in our experiment needed 10% less energy (119-265 kcal/b/d) to reach the targeted weight compared to the control group (133-294 kcal/d), which considered the energy needed for maintenance, activity and growth targeting 100 g increase in BW/wk. Reduction of ME by 10% provided the distinct advantage of better nutrient utilization, carcass composition and bone mineralization. Age was also a critical factor for optimizing nutrient utilization and bone mineralization during early period, and the carcass composition and bone weight in the later ages. Although, energy restriction induced stress, the energy allowances scheduled in our program were not too severe to affect performance. In conclusion our results suggest that the targeted WG in broiler breeders can be achieved through measured ME feeding, while not ignoring the impact of age on the performance of pullets up to 20 wk of age.

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