Asian-Aust. J. Anim. Sci.
Vol. 20, No. 8 : 1258 - 1265
August 2007

www.ajas.info

Restriction of Metabolizable Energy in Broiler Growers and Its Impact on Grower and Breeder Performance

G. Shyam Sunder*, **Ch. Vijaya Kumar, A. K. Panda, M. V. L. N. Raju, S. V. Rama Rao N. C. S. Gopinath and M. R. Reddy**
Project Directorate on Poultry, Rajendranagar, Hyderabad, 500 030 India

ABSTRACT : Metabolizable energy (ME) required for basal metabolism, activity and growth was considered as the criterion for targeting specific increases in body weight (100 g/week) of broiler chicks during the grower phase (5-20 weeks) and its impact was evaluated on breeder performance. Broiler female chicks (460) from a synthetic dam line were randomly distributed to 4 test groups with 23 replicates of 5 birds each and housed in cages. The first group (ME-100) was offered a calculated amount of ME by providing a measured quantity of grower diet (160 g protein and 2,600 kcal ME/kg) which increased with age and weight gain (133-294 kcal/bird/day). The other three groups were offered 10 or 20% less ME (ME-90 and ME-80, respectively) and 10% excess ME (ME-110) over the control group (ME-100). From 21 weeks of age, a single breeder diet (170 g protein and 2,600 kcal ME/kg) was uniformly fed to all groups and the impact of grower ME restriction on breeder performance evaluated up to 58 weeks. The targeted body weight gain of 1,600 g in a 16-week period was achieved by pullets of the ME-100 group almost one week earlier by gaining 8.7 g more weight per week. However, pullets in the ME-90 group gained 1,571 g during the same period, which was closer to the targeted weight. At 20 weeks of age, the conversion efficiency of feed (5.21-5.37), ME (13.9-14.1 kcal/g weight gain) and protein (0.847-0.871 g/g weight gain), eviscerated meat yield, giblet and tibia weights were not influenced by ME restriction, but the weights of abdominal fat and liver were higher with increased ME intake. Reduction of ME by 10% in the grower period significantly delayed sexual maturity (169.3 d), but increased egg production (152.5 /bird) with better persistency. Improved conversion efficiency of feed, ME and protein per g egg content were also observed in this group up to 56 weeks. The fertility and hatchability at 58 weeks of age were higher in the ME-90 group compared to the control and 10% excess ME feeding. In conclusion, the present study revealed the possibility of achieving targeted weight gain in broiler growers by feeding measured quantities of ME during the rearing period with consequential benefits in breeder performance. (**Key Words :** Metabolizable Energy, Restriction, Broiler Growers, Breeder Performance)

INTRODUCTION

Genetic selection of broiler breeders for increased growth has resulted in a change in the appetite levels of birds through their central and peripheral hunger mechanism (Denbow, 1994). These stocks do not adequately regulate energy balances leading to long-term storage of adipose tissue (Richards, 2003). Examination of broiler eating behavior revealed that it is controlled more by satiety mechanisms than the hunger mechanisms (Bokkers and Koene, 2003). *Ad libitum* or excess feeding results in obese birds with general loss of vigor, early maturity, high incidences of defective eggs, lowered duration of fertility (Katanbaf et al., 1989a), reduced livability and increased leg problems (Whitehead, 2000). Maintenance of body weight at 40% of the *ad libitum* fed birds up to sexual maturity was found to be ideal for regulating ovulation rates of breeders (Hocking et al., 1989; Hocking and Whitehead, 1990). The reduction in live weight at the point of lay is related to the calorie intake in grower phase (Pinchasov and Galili, 1990). However, there is considerable diversity of opinion on the optimum level of feed restriction and the duration of restriction, due to strain differences and continuous changes in the genetic composition of the stocks. Therefore, feed allocation to broilers should be made conservatively, as they are very sensitive to energy surpluses, which may limit their egg and chick production potential (Robinson et al., 1995). In the current study, an attempt was made to provide measured quantity of energy to broiler growers by calculating the ME required for basal metabolism, activity and weight gain targeting 2,200-2,300

* Corresponding Author: G. Shyam Sunder. Tel: +91-40-2401 3779, Fax: +91-40-24017002, E-mail: ssgajula@rediffmail.com
Received November 1, 2006; Accepted April 3, 2007

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	4.00
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 aminoacids [2]	6.5
Calcium[3]	12.5
Avail. phosphoorus[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 pantothenate 12 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.

g body weight at 20 weeks of age, and examine its impact on breeder performance.

MATERIALS AND METHODS

Stock and management

Six hundred day-old female broiler chicks were procured from a female parent line with genetic background involving White Plymouth Rock, Cornish and commercial broiler breeds, selected for high egg production for 10 generations. They were wing banded and housed in raised wire floor cages (60 cm×75 cm×45 cm for 5 chicks) in open sided houses and reared under standard managemental conditions. All chicks were offered a single starter diet (215 g protein and 2,850 kcal ME/kg diet) at *ad libitum* up to 4 weeks of age. The birds were vaccinated against MD, ND and IBD, as per the standard vaccination schedule. The brooder temperature was maintained at 34±1°C up to 7 days and gradually reduced to 26±1°C by 21 days of age after which, no supportive heat was provided. The chicks were individually weighed to select 460 chicks of relatively closer body weight (560-745 g), and randomly distributed to 4 test groups with 23 replicates of 5 chicks each and retained in the same cages as mentioned above. From the start of 5th week, measured quantity of feed was offered to each of the test groups. After 8 weeks of age, the birds were shifted to individual California cages (37.5 cm×30 cm×30 cm) located in an open sided poultry house up to 58 weeks for recording the performance of growers and breeders. Mortality was recorded replicate and group wise to relate the trend with the feeding regime.

Feeding regimen

Energy required for maintenance (m), activity (a) and weight gain (wg) was calculated targeting an increase of 100 g body weight per week, using a model based on metabolic body weight described by Scott et al. (1982). The approach was as follows

$$ME_m = 83\times\frac{(\text{Body wt})^{0.75}}{0.82}$$

$$ME_a = ME_m\times 0.5$$

$$ME_{wg}\text{ required} = (\text{Targeted wg}\times 0.18\times 4.0) + (\text{Targeted wg}\times 0.15\times 9.0)$$

ME (kcal) required for targeted body weight

$$= ME_m+ME_a+ME_{wg}$$

The factor, 0.18 is related to 180 g-protein/kg bird multiplied by its calorific value. Similarly, for the carcass fat content, 0.15 was multiplied by 9.0. Accordingly, the control group (ME-100) was offered measured quantity of grower diet (160 g protein and 2,600 kcal ME/kg, Table 1) to ensure allocation of calculated ME on weekly basis. Feed was prepared at the processing unit of our breeding farm and provided in the mash form. As the birds advanced in age from 5 to 20 weeks, the ME allocation increased from 133 to 294 kcal/day, which was provided by raising the feed allowance from 51 to 113 g/day for ME-100 group. In the second (ME-90) and third (ME-80) test groups, ME allocation was quantitatively reduced by 10 and 20%, respectively and in the fourth group (ME-110) increased by 10%, over the control group (ME-100). The quantity of protein and amino acids received by the four test groups decreased or increased with the ME input to the respective groups. However, the mineral and vitamin levels were maintained uniformly in all the four groups. From 21 weeks of age, a single breeder diet (170 g protein and 2,600 kcal ME/kg) was offered to all breeders at 130, 140 and 150 g/day, respectively up to 25, 35 and 58 weeks of age. Although the pullets were housed in individual cages, linear feeders were used to space 3 birds per feeder. The photoperiod in grower phase was regulated at 10 L: 14 D from 5 to16 weeks and gradually increased by one h/week to stabilize at 14 L: 10 D by 20 weeks of age, using incandescent bulbs. The growth and production traits were

Table 2. Allocation of different quantities of ME to broiler growers (5-20 wks) and its influence on body weight, weight gain, cumulative intake of ME and protein, and their conversion efficiency in the test groups at 20 weeks of age

Parameter	Age (wk)	Dietary groups with varied ME allocation (%)				SEM	p value
		80	90	100	110		
Body weight (g)	5	659	659	658	657	2.1	0.988
	20	2,085^{d}	2,229^{c}	2,397^{b}	2,589^{a}	13.3	0.0001
Weight gain (g)	5-20	1,427^{d}	1,571^{c}	1,739^{b}	1,932^{a}	13.3	0.0001
Feed intake/wt. gain	5-20	5.21	5.35	5.37	5.25	0.03	0.191
ME intake (kcal)	5-20	19,419^{d}	21,876^{c}	24,279^{b}	26,699^{a}	0.23	0.0001
ME intake/wt. gain	5-20	13.9	14.1	14.1	14.0	0.08	0.540
Protein intake (g)	5-20	1,195^{d}	1,346^{c}	1,494^{b}	1,643^{a}	8.691	0.0001
Protein intake/wt. gain	5-20	0.847	0.870	0.871	0.856	0.0049	0.226

$^{a, b, c, d}$ Means with different superscripts in the same row differ significantly (p≤0.05).

recorded up to 56 weeks of age, while fertility and hatchability parameters were studied between 57 and 58 weeks. It is important to note that the energy needs of birds calculated for caged birds and those reared in barns may differ to the extent of energy balances for activity, which is markedly higher for the later method of rearing.

Body weight and carcass traits

Individual birds were weighed at 5 and 20 weeks of age. The overall feed, ME and protein consumed up to 20 weeks of age along with the corresponding weight gains were considered for calculating the conversion efficiency of these factors. Body weights were also recorded at 40 weeks of age to examine the influence of grower energy restriction and subsequent uniform feeding on breeder weight gain between 21 and 40 weeks. At the end of 20 weeks, 8 pullets from each dietary group were starved over night, weighed and sacrificed by cervical dislocation. The weights of eviscerated meat yield, giblet, liver, abdominal fat pad and oviduct of breeders in the four dietary groups were recorded and converted per kg live weight. The tibiae were separated and boiled to clear the soft tissue and diaphysis. The bones were dried at 100°C/12 h and defatted by soaking in petroleum ether for 48 h. They were then weighed and ashed at 600±20°C for 5 h to determine the percent total ash (AOAC, 1995).

Production traits

The first egg laid by individual pullet was considered as the age of sexual maturity and egg production was recorded up to 56 weeks of age. Egg production over 28 days was considered as a single period and nine such periods were covered to assess the influence of grower ME restriction on subsequent breeder performance. The egg content produced by individual bird per day was calculated by subtracting the shell weight from egg weight and multiplying with per cent egg production. The quantity of feed required for producing kg egg mass and that of ME and protein per g egg content were calculated. The shell thickness of eggs that were collected during the afternoons (3 pm) of the last 3 days of each period was measured using a micrometer gauge (Mitutoyo code 7027, Japan). At the end of 56 weeks of age, the breeders were inseminated with 0.1ml of pooled semen collected from the cocks of same hatch. The semen was introduced at the utero-vaginal junction, at 5 day intervals. The fertile eggs were collected from the second day of post-insemination for 11 days and stored at 15°C (RH -90%). All eggs were numbered, set in pedigree boxes and placed in automated incubators (VJ Equipments, Pune, India) for 18 days. Eggs were candled on the 3rd day for screening the infertiles and, again on the 18th day for dead embryos. The percent hatchability was calculated on total eggs set and the fertile eggs transferred.

Statistical analysis

The data were analyzed using General Linear Model Procedures of SAS Institute (1994). One-way analysis of variance was carried out and the group means were compared using Duncan multiple range test (Duncan, 1955) with significance at 5% level.

RESULTS

Growth and performance of broiler growers

Body weight gain showed progressive increase with age in all test groups, but with a significant (p≤0.05) difference in the rate of growth among the groups (Table 2). The targeted weight gain of 100 g/week was achieved by the pullets of ME-100 group and with an additional increase of 8.7 g/week. However, the breeders in ME-90 group recorded an average growth of 98.2 g/week, which was closer to the targeted weight, while those maintained on 10% excess ME (ME-110) gained 120.8 g/week. Compared to ME-100, there was a decrease in weight gain by 9.7 and 17.9%, respectively in ME-90 and ME-80 groups and an increase of 11% in ME-110 group. There was no mortality in any group during rearing period, except one bird in ME-100 group.

The average feed consumption in ME-100 group during grower period was 9338g/bird, which decreased (p≤0.05) to

Table 3. Feeding measured quantities of ME to broiler growers (5-20 wks) and its influence on carcass attributes, weight of tibia and oviduct, and percent tibia ash at 20 weeks of age

Parameter	Dietary groups with varied ME allocation (%)				SEM	p value
	80	90	100	110		
Pre-slaughter weight (g)	2,069[c]	2,232[bc]	2,346[ab]	2,563[a]	48.5	0.001
Eviscerated weight[1]	763	753	760	758	2.16	0.443
Abdominal fat[1]	5.5[c]	9.6[bc]	12.7[b]	21.3[a]	1.18	0.0001
Liver weight[1]	13.6[b]	15.8[a]	17.2[a]	16.2[a]	0.48	0.043
Giblet weight[1]	38.0	41.4	40.4	38.2	0.68	0.238
Tibia weight[1]	3.35	3.37	3.45	3.2	0.057	0.536
Tibia ash (%)	47.31	46.08	45.98	45.90	0.26	0.189
Oviduct weight[1]	1.04[b]	1.42[b]	3.25[a]	3.78[a]	0.263	0.0001

[a, b, c] Means with different superscripts in the same row differ significantly (p≤0.05).[1] Weight of organs g/kg live weight.

Table 4. Influence of controlled ME feeding of broiler growers (5-20 wks) on sexual maturity, egg production, average egg weight, egg content, conversion efficiency of feed, ME and protein in the four test groups

Parameter	Dietary groups with varied ME allocation (%)				SEM	p value
	80	90	100	110		
Age of maturity (d)	172.0[a]	169.3[ab]	165.6[bc]	162.2[c]	0.84	0.0001
Egg production (no)	147.9[ab]	152.5[a]	140.9[b]	138.4[b]	1.76	0.019
Avg. egg weight (g)	59.43[a]	59.27[a]	58.41[b]	58.48[b]	0.088	0.0001
Feed intake (kg)/egg mass (kg)	4.240[bc]	4.100[c]	4.550[ab]	4.730[a]	0.065	0.0018
Egg content (g/d)	31.9[ab]	32.8[a]	29.8[bc]	29.4[c]	0.37	0.003
ME (kcal)/egg content (g)	12.09[bc]	11.70[c]	12.97[ab]	13.49[a]	0.185	0.0017
Protein (g)/egg content (g)	0.767[bc]	0.744[c]	0.822[ab]	0.855[a]	0.011	0.0017

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

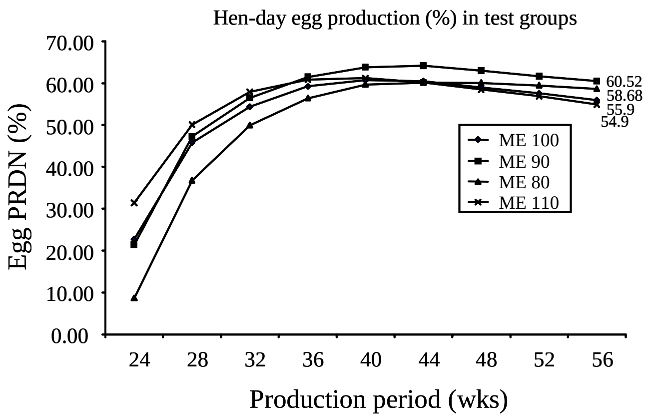

Figure 1. Effect of measured ME feeding in grower phase (5-20 wks) on subsequent egg production (%) in breeders up to 56 weeks of age.

8,414 and 7,469 g in ME-90 and ME-80 groups, respectively and increased to 10,269 g in ME-110 group. However, the feed required per unit weight gain among the four test groups ranged between 5.21 and 5.37 without any statistical difference. Similarly, the cumulative ME consumption over 16 week period varied significantly (p≤0.05) from 19,419 to 26,699 kcal/bird, but the ME conversion efficiency remained non-significant. The overall protein intake also ranged significantly (p≤0.05) between 1,195 and 1,643 g/bird among the test groups, but its conversion efficiency did not vary statistically (p≥0.05).

Carcass parameters

The pre-slaughter live weight at 20 weeks of age varied significantly (p≤0.05) with the level of ME consumed, but the eviscerated yield per kg live weight did not differ with the variations in live weight (Table 3). Higher energy consumption by the breeders of ME-110 group influenced abdominal fat deposition. In contrast, those in ME-80 group had significantly (p≤0.05) less abdominal fat and liver weight, but heavier giblets. Also, the body weight at 20 weeks of age significantly (p≤0.05) influenced oviduct development. The breeders under severe to moderate restriction of energy (ME-80 and ME-90) had minimum oviduct growth compared to the other two groups. The relative weights of tibia were not affected by the reduction of ME and protein intake, suggesting that the weight of tibia was proportionate to body weight in the respective groups. Bone mineralization was uniform in all groups.

Production traits

Broiler breeders raised on 10% energy reduction in grower phase matured late (p≤0.05) compared to ME-110 group, but not different from ME-100 or ME-80 groups (Table 4). However, the overall egg number up to 56 weeks of age was significantly (p≤0.05) high in this group compared to ME-100 and ME-110 groups, due to better persistency of production (Figure 1). Though the birds of ME-80 group had higher egg number than ME-100 or ME-110, the differences were not significant. The feed required for producing kg egg mass and the quantity of ME and

Table 5. Effect of measured ME feeding of broiler growers (5-20 wks) on 40 week body weight of breeders following uniform feeding from 21-40 weeks of age

Parameter	Age (wk)	Dietary groups with varied ME allocation (%)				SEM	p value
		80	90	100	110		
Body weight (g)	20	2,085[d]	2,229[c]	2,397[b]	2,589[a]	17.60	0.0001
Body weight (g)	40	3,281[b]	3,321[b]	3,306[b]	3,470[a]	17.37	0.0004
Weight gain (g)	21-40	1,196[a]	1,092[b]	910[c]	881[c]	18.64	0.0001
Relative weight gain (g)		131	120	100	97		

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

Table 6. Influence of grower ME restriction on egg weight, shell thickness, fertility and hatchability of breeders at 58 weeks of age

Parameter	Dietary groups with varied ME allocation (%)				SEM	p value
	80	90	100	110		
Egg weight (g)	65.49[b]	66.99[a]	65.49[b]	66.10[ab]	0.201	0.020
Shell thickness (mm)	0.419	0.421	0.415	0.413	0.001	0.106
Fertility (%)	89.79[a]	91.34[a]	84.10[b]	87.17[ab]	0.947	0.032
Hatchability on total egg set (%)	79.81[a]	79.39[a]	66.69[b]	70.73[b]	1.473	0.001
Dead embryos and weaklings (%)	11.22[b]	13.03[b]	20.51[a]	19.25[a]	1.176	0.006

[a, b] Means with different superscripts in the same row differ significantly (p≤0.05).

protein utilized per g egg content were significantly (p≤0.05) less in ME-90 group. Since, the average egg weight and egg number in ME-90 group were higher, the egg content per day was significantly (p≤0.05) more than ME-100 and ME-110 groups, resulting in improved nutrient conversion efficiency per g egg content. Mortality from 21 to 56 weeks was between 8 and 11 birds in the four test groups (11.4-15.71%) and was not related to the nature of dietary regimes employed in the experiment.

Body weight at 40 weeks of age

Uniform feeding of breeder ration from 21 weeks of age benefited the breeders of ME-90 and ME-80 groups by achieving body weights equivalent to ME-100, at 40 weeks of age. The breeders of ME-110 group however, remained heavier (p≤0.05) than the other three groups (Table 5). The relative weight gain between 21 and 40 weeks was significantly (p≤0.05) more in ME-90 and ME-80 groups compared to ME-100 or ME-110 for the same period. For every 100 g increase in ME-100 group, the birds of ME-90 and ME-80 groups gained 120 and 131g, respectively for similar level of feeding, which was significantly(p≤0.05) high. The breeders in ME-110 group gained 97 g during the same period.

Fertility and hatchability

The results on egg weight, shell weight, fertility, hatching losses and hatchability of eggs collected from each dietary group in the 57th and 58th week are presented in Table 6. The average egg weight was higher in ME-90 group compared to ME-100, but not different from and ME-80 or ME-110 groups. Though the shell thickness of eggs was better in ME-90 group compared to other groups, the difference was not significant. The fertility in ME-90 group was higher over the controls and numerically better than the other two groups. Restriction of ME by 10 or 20% in grower phase significantly (p≤0.05) improved the percent hatchability compared to controls or those fed 10% excess energy, as hatching losses were high in the later groups.

DISCUSSION

The results have clearly established the relationship between ME restriction during grower period and the subsequent production performance of broiler breeders. In grower phase, the birds that belonged to ME-100 group achieved the targeted weight of 1,600 g almost one week earlier. In contrast, the breeders in ME-90 group gained 1,571 g during the same period at an average growth of 98.2 g/week, which was closer to the targeted weight of 100 g/week. The difference in weight gain between the extreme levels of feeding (ME-80 and ME-110) was 505 g, which can be attributed to variation in energy consumption (7,280 kcal ME/bird) between them. Also, the weight of abdominal fat pad was significantly (p≤0.05) more (54.6 g/kg live weight) in ME-110 compared to ME-80 group (11.0 g/kg live weight), which partly contributed to the difference in weight gain. In a study conducted by Robinson et al. (1991), much of the body weight difference between *ad libitum* and restricted fed hens (68% of 700 g body weight) was due to fat. Similar magnitude of fat deposition was however, not witnessed in our study because the breeders were maintained on measured ME feeding, and not on *ad libitum*. Nevertheless, a large difference existed in the relative weight of abdominal fat pad between the groups due to variation in the quantity of energy consumed.

In the current study, protein consumption increased concomitant to the energy intake and varied significantly (p≤0.05) from 1,195 to 1,643 g due to the difference in quantity of feed consumed during the 16 week grower period. However, the minimum protein required for broiler growers was not more than 10 g/bird/day (Bowmaker et al., 1989), which was provided in our trial to the breeders maintained even on the lowest energy inputs (ME-80). Several workers suggested that the low protein intake did not alter the percentage body protein in broiler growers (Bennet and Leeson, 1990; Lilburn and Myers-Millers, 1990; Yu et al., 1992a) and that protein as low as 10-12% with uniform lysine (0.8%) and total sulphur amino acids (0.6%) was adequate, and helped in low nitrogen excretion (Lopez and Leeson, 1995). It is in this context that our study focused discussion primarily on the consequences of energy variations in broiler growers rather than the protein level.

During the grower period, despite wide variation in energy consumption between the breeders of ME-110 (26,699 kcal/bird) and ME-80 (19,419 kcal/bird) groups, neither the feed intake per unit weight gain (5.21-5.37) nor kcal ME required per g weight gain (13.9-14.1) was affected ($p\geq 0.05$) by the feeding regimes (Table 2). It is possible that feed restriction increased the relative weights and lengths of various segments of gastrointestinal tract for retention of feed for longer duration and slower evacuation, which facilitated better nutrient utilization by the birds (Nir et al., 1996). The energy needs of such birds could also be low due to decreased heat loss, as a consequence of deprived feed supply (Katanbaf et al., 1989a). These observations support our findings, as the breeders maintained under ME restriction achieved parity in feed and energy efficiencies with those in ME-100 or ME-110 groups, possibly through better nutrient utilization..

Allocation of varied levels of ME and protein to the four test groups during grower period did not affect the weight of eviscerated meat yield, gizzard or giblets per kg live weight, at 20 weeks of age. However, the abdominal fat in breeders fed 10% excess ME was significantly ($p\leq 0.05$) more by 2.22 and 3.87 times than ME-90 and ME-80 groups, respectively. This can be related primarily to the wide variation in ME intake among the groups. The relationship between higher ME intake and abdominal fat deposition was clearly evident. In the trial conducted by Yu et al. (1992a), the increase in carcass fat of *ad libitum* fed birds was four times that of the restricted birds at 18 weeks of age. It was clear that broiler breeders do not adequately regulate feed intake to achieve energy balances, resulting in long term maintenance of fat stores (Richards, 2003). Similar trend in abdominal fat deposition was also noticed in our study due to substantial difference in ME intake (30%) between the two extreme levels of feeding. At 20 weeks of age, the liver weight in ME-80 group was less than ME-100 group by 21%, probably due to severe ME restriction imposed in the former. Mobilization of liver lipids was perhaps more pronounced in heavier birds at this age, for creating suitable situation for early formation of ovarian follicles compared to the restricted birds (Katanbaf et al., 1989c). Increased liver weight may be an indicator of lipid and yolk precursor synthesis (Renema et al., 1999a). The development of oviduct was also apparently dependent upon body weight and the level of feeding. In ME-90 and ME-80 groups, the oviducts were lighter at 20 weeks of age, indicating the influence of body weight on oviduct development. Obviously, feed restriction in growers significantly ($p\leq 0.05$) delayed oviduct development (Yu et al., 1992b). However, the weight of tibia at 20 weeks of age was not affected by energy restriction. Feed restriction significantly influenced the body weight gain, carcass fat and other related traits, but not the growth of bone, which was least affected (Yu et al., 1992a). In broiler breeders with limited access to feed or skip-a-day restriction, Hudson et al. (1999) observed no difference in the properties of cortex of femur. This concept supported our findings on bone mineralization, which was not influenced by the extent of energy restriction in grower phase.

The breeders maintained on 10% excess ME in grower phase, matured earlier ($p\leq 0.05$) than those in ME-90 and ME-80 groups, which can be chronologically attributed to 20 week body weight. In different studies, the advancement of sexual maturity has been reported to range from 1.0 to 8.1 weeks, depending up on the degree of feed restriction, genetic strain and age of photo stimulation (Renema and Robinson, 2004). Since, the latter two factors were common for all the four test groups in our trial, the difference in sexual maturity could be due to variations in ME intake during rearing period. However, uniform feeding of breeder diet from 21 weeks of age appeared to minimize the differences in age of maturity between ME-100 and ME-90; ME-90 and ME-80; and ME-100 and ME-110 groups. It seems that sexual maturity in birds fed more than their actual needs depended heavily on hypothalamic maturity, which is related to age. In contrast, the sexual maturity was regulated by the body weight and carcass composition in breeders maintained on feed restriction (Katanbaf et al., 1989b). Both, the body weight and age act as indicators of energy balance and responsiveness to hypothalamic-pitutary-gonadal axis (Renema et al., 1999a), which influenced the time of sexual maturity. The difference in age of maturity in our study may be due to variable levels of ME consumed by the four test groups.

Breeders fed 10% excess ME in grower period produced more eggs during the first 4 weeks of lay due to early sexual maturity (Figure 1). The rapid onset of egg production in ME-110 group compared to the restricted groups suggested that the internal signal for reproductive development was possibly a metabolic one (Renema et al., 1999b). However, there was uniformity in egg production amongst the four test groups from 25 to 32 weeks of age, and from 37 weeks the breeders of ME-90 group produced consistently higher ($p\leq0.05$) egg number than ME-110 up to 56 weeks of age. A reduction of 10% ME over controls in grower period, supported higher egg production with better persistency, indicating the possibility of a regulated ovulation rate compared to 10% excess feeding. The overall egg number was also better in this group compared to ME-100 or ME-80 groups. In his study, Hocking (1993) noticed similar trend in egg production between the restricted and *ad libitum* fed pullets. With the degree of reduction in body weight at the onset of lay there was a proportionate decrease in multiple ovulations, resulting in improved egg production (Hocking and Whitehead, 1990). In contrast, the pullets fed 10% excess ME during grower period laid fewer eggs than the other groups, despite coming into production earlier. This may be due to shorter primary egg sequences, which were in turn related to body weight at the point of lay and early sexual maturity (Robinson et al., 1993). Further more, the breeders of ME-110 group made an early decline in egg production from 40 weeks of age. In general, broiler breeders are very sensitive to over feeding during pre-laying period and susceptible to obesity and even small quantities of over feeding have impact on egg production (Robinson et al., 1995).

The feed allocation in four test groups was although maintained at uniform level from 21 weeks of age, higher egg production in ME-90 group facilitated better conversion efficiency of feed per kg egg mass and ME per g egg content, compared to ME-100 or ME-110 groups. The superior energy conversion efficiency in this group was supported by higher egg number and better egg weight. The breeders in ME-90 group consumed on an average 376 kcal/day and utilized 11.7 kcal to produce g egg content. Similar ME conversion efficiency (11.0 kcal/g egg content) was also observed by Neuman et al. (1998) in breeders fed 376 kcal/day. When they increased ME allowances to 477 and 492 kcal/day, the ME conversion ratios widened respectively to 14.8 and 15.3 kcal/g egg content, suggesting the possibility of diversion of surplus energy to body mass than to egg output. The decline in feed conversion efficiency in ME-110 group in the current study could also be due to similar reasons.

In grower phase, the ME regimes influenced 20 week body weight of pullets, but uniform feeding from 21 weeks of age resulted in rapid weight gain in the two restricted groups. At 20 weeks of age, pullets of ME-90 and ME-80 groups received 263 and 234 kcal/day, respectively compared to 294 and 322 kcal/day by ME-100 and ME-110 groups. On changing over to uniform feeding from 21 weeks, the difference in nutrient availability was higher in ME-90 and ME-80 groups than the other two groups, which perhaps triggered rapid weight gain in them up to 40 weeks of age. These findings are in line with the concept of “compensatory” or “catch-up” growth in broilers (Nir et al., 1996).

The percent fertility and hatchability at 58 weeks of age seemed to favor energy restriction in grower period, as reflected by the number of chicks produced by the breeders of ME-90 and ME-80 groups. Fertility was maximum in ME-90 group. Goerzen et al. (1996) indicated that the body weight of breeders was strongly correlated with the rate of lay and duration of fertility. Significantly higher body weight in ME-100 and ME-110 groups was probably responsible for poor fertility and hatchability compared to ME-90 or ME-80 groups. The heavy breeders might have suffered from reproductive insufficiency, as observed by Brake et al. (1985). The viability of embryos was markedly high in ME-90 and ME-80 groups despite uniform feeding in breeder phase, indicating that embryonic mortality was related to body weight prior to sexual maturity (Robinson et al., 1993). Poor hatchability in heavier breeders was attributed to late embryonic mortality by Hocking et al. (2002), which was also noticed in our study. The overall chick production was similar in ME-80 and ME-90 groups indicating the significance of grower restriction on hatchability.

In conclusion, our study reiterated the importance of controlled weight gain in broiler pullets for optimizing breeder production, which was effectively regulated by feeding measured quantity of energy considering the ME needed for basal metabolism, activity and weight gain, and was specific to caged birds. The same concept would be applicable to the barn reared breeders, but with higher ME requirement for activity. Nevertheless, ME was found to be useful in regulating weight gain in breeder pullets during grower phase with consequential benefits of improved egg and chick production, and better conversion efficiency of feed and energy. The synthetic dam line used in this trial needed 10% less ME than the calculated energy for achieving the targeted weight gain of 100 g/week in grower phase, further strengthening the premise that feeding measured quantities of ME could be useful in regulating weight gain in breeders during pre-laying period.

REFERENCES

Association of Official Analytical Chemist. 1995. Official Methods of Analysis, 16th ed. (Washington, DC, AOAC).

Bokkers, E. A. M. and P. Koene. 2003. Eating behavior, and pre-prandial and postprandial correlation in male broilers and layer chickens. Br. Poult. Sci. 44:538-544.

Bennett, C. D. and S. Lesson. 1990. Body composition of the broiler-breeder pullet. Poult. Sci. 69:715-720.

Brake, J., J. D. Garlich and E. D. Peebles. 1985. Effect of protein and energy intake by broiler breeders during the pre-breeder transition period on subsequent reproductive performance. Poult. Sci. 64:2335-2340.

Bowmaker, J. E. E. and R. M. Gous. 1989. Quantification of reproductive changes and nutrient requirements of broiler breeder pullets at sexual maturity. Br. Poult. Sci. 30:663-675.

Denbow, D. M. 1994. Appetite and its control. Poult. Sci. Rev. 5:209-229.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics, 11:1-42.

Goerzen, P. R., W. L. Julsrud and F. E. Robinson. 1996. Duration of fertility in *ad libitum* and feed- restricted caged broiler breeders. Poult. Sci. 75:962-965.

Hocking, P. M. 1993. Welfare of broiler breeder and layer females subjected to food and water control during rearing: Quantifying the degree of restriction. Br. Poult. Sci. 34:53-64.

Hocking, P. M. and C. C. Whitehead. 1990. Relationships between body composition, ovarian structure and reproduction in nature females of genetically lean or fat broilers given different food allowances. Br. Poult. Sci. 31:319-330.

Hocking, P. M., R. Bernard and G. W. Robertson. 2002. Effects of low dietary protein and different allocations of food during rearing and restricted feeding after peak rate of lay on egg production, fertility and hatchability in female broiler breeders. Br. Poult. Sci. 43:94-103.

Hocking, P. M., D. Waddington, M. A. Walker and A. B. Gilbert. 1989. Control of the development of the ovarian follicular hierarchy in broiler breeder pullets by food restriction during rearing. Br. Poult. Sci. 30:161-174.

Hudson, H. A., J. L. Wilson, G. N. Rowland, R. J. Buhr and W. M. Britton. 1999. Feed restriction affects bone properties of the broiler breeder pullet femur. J. Appl. Poult. Res. 8:400-407.

Katanbaf, M. N., E. A. Dunnington and P. B. Siegel. 1989a. Restricted feeding in early and late-feeding chickens. 1. Growth and physiological responses. Poult. Sci. 68:344-351.

Katanbaf, M. N., E. A. Dunnington and P. B. Siegel. 1989b. Restricted feeding in early and Late-Feathering Chickens. 2. Reproductive Response. Poult. Sci. 68:352-358.

Katanbaf, M. N., E. A. Dunnington and P. B. Siegel. 1989c. Restricted feeding in early and late-feathering chickens.3.Organ size and carcass composition. Poult. Sci. 68:359-368.

Lopez, G. and S. Lesson. 1995. Response of broiler breeders to low-protein diets. Adult breeder performance. Poult. Sci. 74:685-695.

Lilburn, M. S. and D. J. Myers-Miller. 1990. Dietary effects on body composition and subsequent production characteristics in broiler breeder hens. Poult. Sci. 69:1126-1132.

Neuman, S. L., R. H. Harms and G. B. Russell. 1998. An innovative change in energy restriction for broiler breeder hens. J. Appl. Poult. Res. 7:328-335.

Nir, I., Z. Nitsan, E. A. Dunnington and P. B. Siegel. 1996. Aspects of food intake restriction in young domestic fowl: metabolic and genetic considerations. World's Poult. Sci. J. 52:251-266.

Pinchasov, Y. and D. Galili. 1990. Energy requirement of feed-restricted broiler breeder pullets. Poult. Sci. 69:1792-1795.

Renema, R. A. and F. E. Robinson. 2004. Defining normal: comparison of feed restriction and full feeding of female broiler breeders. World's Poult. Sci. J. 60:508-522.

Renema, R. A., F. E. Robinson, M. Newcomb and R. I. Mckay. 1999a. Effects of body weight and feed allocation during sexual maturation in broiler breeder hens, 1. Growth and carcass characteristics. Poult. Sci. 78:619-628.

Renema, R. A., F. E. Robinson, J. A. Proudman, M. Newcomb and R. I. Mckay. 1999b. Effects of body weight and feed allocation during sexual maturation in broiler breeder hens. 2. Ovarian morphology and plasma hormone profiles. Poult. Sci. 78:629-639.

Richards, M. P. 2003. Genetic regulation of feed intake and energy balance in poultry. Poult. Sci. 82:907-916.

Robinson, F. E., N. A. Robinson and T. A. Scott. 1991. Reproductive performance, growth and body composition of full-fed versus feed restricted broiler breeder hens. Can. J. Anim. Sci. 71:549-556.

Robinson, F. E., N. A. Robinson and R. T. Hardin. 1995. The effects of 20-week body weight and feed allocation during early lay on female broiler breeders. J. Appl. Poult. Res. 4:203-210.

Robinson, F. E., J. L. Wilson, M. W. Yu, G. M. Fasenko and T. Hardin 1993. The relationship between body weight and reproductive efficiency in meat-type chickens. Poult. Sci. 72:912-922.

SAS Institute. 1994. SAS User's Guide, Version 6.12 SAS Institute Inc., Cary, NC.

Scott, M. L., M. C. Nesheim and R. J. Young. 1982. Energy chapter II. Nutrition of the chicken. pp. 7-57. (M. L. Scott and Associates, Publishers Ithaca, New York).

Whitehead, C. C. 2000. Nutrition: the integrative science. Br. Poult. Sci. 41:5-15.

Yu, M. W., F. E. Robinson and A. R. Rubble. 1992a. Effect of feed allowance during rearing and breeding of female broiler breeders. 1.Growth and carcass characteristics. Poult. Sci. 71:1739-1749.

Yu, M. W., F. E. Robinson and R. J. Etches. 1992b. Effect of feed allowance during rearing and breeding on female broiler breeders.3.Ovarian steroid genesis. Poult. Sci. 71:1762-1767.