Animal (2008), **2:9**, pp 1324–1330 © The Animal Consortium 2008
doi:10.1017/S1751731108002437

animal

Effects of meal-time feeding and protein restriction on walking ability and some bone and carcass properties in broilers

Y. Konca[1†], E. Yaylak[1] and A. Önenç[2]

[1]*Ödemis Vocational Training School, Ege University, Turkey;* [2]*Agricultural Faculty, Ege University, Izmir 35750, Turkey*

(Received 4 May 2007; Accepted 8 April 2008; First published online 8 July 2008)

This experiment was designed to investigate the effects of meal-time feeding and protein restriction on performance, gait score (GS) and carcass and bone traits in broilers. A total of 420 1-day-old chicks were wing banded and randomly distributed into 21 pens with 20 chicks each. At 7 days of age, chicks were weighed and randomly assigned to one of the three treatments: (1) control (C) feed (23.02% crude protein (CP)) was available ad libitum*; (2) meal-time feeding (MF); control feed was available from 0100 to 0900 h and from 1500 to 2300 h. Food was withdrawn from 0900 to 1500 h and whole wheat (10 g/bird per day) was dispersed on the floor from 7 to 21 days; and (3) low-protein (LP) diet (19.71% CP) was fed to the chicks from 7 to 21 days. All of the groups were fed* ad libitum *from 1 to 7 days of age and from 21 to 45 days of age with a standard commercial diet. Individual body weight was measured on days 7, 21 and 45. Feed consumption was measured from 7 to 21 days and from 21 to 45 days. Forty-two chicks were humanly slaughtered and eviscerated for bone evaluation, on days 21 and 45. Also carcass characteristics were determined on day 45. Control group body weight was significantly higher ($P < 0.05$) at 21 and 45 days of age than the MF and LP groups, which did not differ. Feed intake was reduced by meal-time feeding and LP diet ($P < 0.01$). Feed efficiency was the best in the MF group during the period of 21 to 45 days of age ($P < 0.01$). In the control group, shank was significantly longer than that of the LP group and tibia breaking strength was higher than that of the MF group at 21 days ($P < 0.05$). However, shank width, tibia wet weight and tibia mid-diaphysis ash percentage of the MF group were significantly lower than those of the C and LP groups at 21 days of age ($P < 0.05$). GS, shank and carcass and tibia bone traits on day 45 were not significant among groups. No compensatory growth and walking ability improvement were observed at 45 days of age for broilers fed with MF and LP between 7 and 21 days of age.*

Keywords: broiler, carcass, gait score, meal feeding, protein

Introduction

Leg weakness is a major economic and welfare problem in the broiler industry (Sorensen *et al*., 1999; Weeks *et al*., 2000; Venäläinen *et al*., 2006). It can increase mortality, downgrades and number of culls (Morris, 1993). Since modern broilers are too heavy for normal locomotion, they tend to spend 76% to 86% of the day lying, and the proportion of broilers lying increased with age and lameness (Weeks *et al*., 2000). Thus, sitting behavior is strongly associated with poor walking ability and is of serious welfare consequence as birds suffer pain (Julian, 1998), have difficulty reaching for food and water and may lose weight (Yalçın *et al*., 1998). In a survey in Denmark, impaired walking ability was found in 75% of the chicks (Sanotra *et al*., 2001).

Several management techniques have been used to improve walking ability and bone growth (Yalçın *et al*., 1998; Su *et al*., 1999; Bizeray *et al*., 2002a). Protein restriction may affect bone growth and gait score (GS). Feeding diets containing 30% or 40% less protein from 1 to 6 weeks of age reduced growth and incidence of leg disorders of turkey toms (Ferket and Sell, 1989). Yalçın *et al*. (1998) reported that the diets contained 20.5% and 21.9% protein from 0 to 4 and 4 to 7 weeks, respectively, resulting in fewer birds with poor walking quality. However, diet containing low protein (LP) and amino acid levels may enhance general activity in chickens (Rovee-Collier *et al*., 1993).

Previous studies demonstrated that exercise can improve bone strength and decrease leg disorders (Balog *et al*., 1997; Falcone *et al*., 2004). However, it was found that dispersing whole wheat on the floor from 8 to 17 days of age impaired the walking ability of broilers (Bizeray *et al*., 2002a). It was also reported that feed-restricted broilers appeared more active during the feed-restricted period by scratching and searching the litter for food (Nielsen *et al*., 2003; de Jong *et al*., 2005). However, Lippens *et al*. (2002)

† E-mail: yusuf.konca@ege.edu.tr

found a trend towards reduced mortality by 80% of *ad libitum* intake from 4 to 7 days but no clear effect on leg problems. On the contrary, Su *et al*. (1999) reported that birds fed fewer meals per day had better walking ability. Bruno *et al*. (2000) noted that bone length and width reduced when feed was restricted to 40% of *ad libitum* intake in broiler from 7 to 14 days.

The aim of the present experiment was to determine the effect of meal-feeding regimes with wheat feeding during feed withdrawal and protein restriction on performance, walking ability and some bone and carcass characteristics of broilers.

Material and methods

Animals and diets

A total of 420 mixed-sex 1-day-old Ross-308 chicks were obtained from a breeder flock 34 weeks of age. All chicks were wing banded on the day of hatching, weighed and randomly assigned into 21 pens with 20 chicks per pen (15 birds/m^2). The floor was covered with wood-shaving litter. The experimental house was artificially heated to provide standard brooding temperatures (28°C to 34°C) from hatch to 3 weeks and the growing period temperature remained 23°C. The lighting schedule was 24L : 0D from 0 to 7 days and 22L : 2D (darkness from 2300 to 0100 h) from 7 to 45 days.

All chicks were fed on starter diet (control diet, 13.39 MJ ME and 230 g crude protein (CP) per kg, Table 1) from 0 to 7 days. On day 7, these chicks were subjected to three treatment groups from 7 to 21 days. Treatments were as follows: (1) control (C): chicks were fed on the starter diet containing 13.39 MJ ME and 230 g CP per kg; (2) meal feeding (MF): chicks were maintained fed on starter diet from 0100 to 0900 h and from 1500 to 2300 h. Feeders were lifted from 0900 to 1500 h and daily 10 g whole wheat per bird was dispersed onto the litter; and (3) LP diet: chicks were fed a LP diet (13.39 MJ ME 197 g CP per kg). From days 21 to 45, all chicks were fed with a grower diet (13.39 MJ ME and 204 g CP per kg) *ad libitum*. Water was provided *ad libitum*. The compositions of experimental diets are shown in Table 1.

Measurements

Individual body weight (BW) was measured on days 7, 21 and 45. Body weight gain (BWG) from 7 to 21 and from 21

Table 1 *Composition of the diets (g/kg)*

Diet composition	Starter diet, 0 to 21 days		Grower diet, 21 to 45 days
	Control and meal feeding*	Low protein	
Yellow corn	450.0	450.0	500.0
Wheat	60.62	173.3	84.99
Soybean meal	221.90	122.98	241.8
Full-fat Soy	150.0	150.0	100.0
Soy oil	40.0	29.41	41.12
Fish meal	48.31	40.0	–
Limestone	12.25	12.57	14.53
Dicalcium phosphate	10.29	12.0	11.31
Salt	2.0	2.0	2.0
Lysine	0.09	2.63	-
Methionine	1.04	1.61	0.75
Clinacox (anticoccidial)	1.0	1.0	1.0
Vitamin and mineral premix[1]	2.5	2.5	2.5
Chemical analysis			
Dry matter (%)	90.71	90.94	90.12
Crude protein (%)	23.02	19.71	20.40
Crude ash (%)	6.45	6.27	5.82
Crude cellulose (%)	4.27	3.79	5.10
Calcium (%)	1.09	1.20	1.28
Phosphorus (%)	0.68	0.69	0.44
Calculated analyses			
Lysine (%)	1.30	1.30	1.03
Methionine (%)	0.50	0.50	0.38
Available phosphorus (%)	0.45	0.45	0.35
Metabolizable energy (MJ/kg)	13.39	13.39	13.39

[1]Vitamin–mineral premix provided per kg of diet; vitamin A, 12 000 IU; vitamin D_3, 3000 IU; vitamin E, 50 mg; vitamin K_3, 5 mg; vitamin B_1 (thiamin), 3 mg; vitamin B_2 (riboflavin) 6 mg; vitamin B_6, 5 mg; vitamin B_{12}, 0.03 mg; niacin, 30 mg; biotin, 0.10 mg; calcium D-pantothenate, 10 mg; folic acid, 1 mg; choline chloride, 400 mg; manganese, 100 mg; iron, 60 mg; zinc, 60 mg; copper, 5 mg; iodine, 1 mg; cobalt, 0.2 mg; selenium, 0.2 mg.

*Meal feeding: chicks were fed on starter diet from 0100 to 0900 h and from 1500 to 2100 h. Feeders were lifted from 0900 to 1500 h and daily 10 g whole wheat per bird was dispersed onto the litter.

to 45 days was calculated for each chick. Feed consumption (FC) was measured on pen bases on the same days and corrected for mortality. Feed efficiency was calculated as the ratio between total BWG to total FC of all birds in each pen. Dispersed whole wheat was not included as feed consumed in the MF treatment because the amount of unconsumed wheat remaining in the litter of pen could not be determined (Bizeray *et al*., 2002a). Broilers were observed individually and classified into four different categories by two observers consulting together at 45 days of age: 0, the bird walked normally; 1, the bird able to walk but had an obvious gait defect; 2, the bird walked only when driven; 3, the bird could not walk (Yalçın *et al*., 1998).

All chicks' pen shank length and width were measured on days 21 and 45. Following the measuring of shank length and width of all chicks, 42 live male birds (two male chicks from each subgroup) were weighed, humanely slaughtered and eviscerated at 21 to 45 days of age. Carcass, breast with backbone and thigh with hip, neck and wing weights were taken from all eviscerated chicks. Percentage of carcass yield (carcass weight : live weight) and part weight : carcass weight ratio (breast, thigh, neck wing weights relative to carcass weight) were determined. The left tibia was removed; muscle and connective tissues were cleaned and immediately weighed. Bones were frozen and stored at −20°C until analyzed. Breaking strength was determined on thawed whole tibia. The tests were performed on 3-point bending using an Instron Universal Machine (Norgaard-Nielsen, 1990). The center of each bone was broken with a probe (10 mm diameter) at 30 mm/min speed. The supports for each bone were 30 mm apart. The breaking strength was determined from the failure point (peak) of each loading curve. The bone samples were cut at points 20 (proximal) and 50% (mid-diaphysis) along their length and were ashed at 550°C for 16 h to determine tibia ash content and were expressed as percentage of ash.

The pH value of the samples was measured with a pH meter (Hanna Instruments-8413), using an FC-200 probe by thrusting the probe into the breast and thigh meat. Cooking loss was determined in 1.5-cm-thick meat samples of similar geometry, individually placed inside polyethylene bags in a water bath at 75°C for 20 min until the temperature of 70°C was achieved and then cooled for 30 min. The samples were removed from the bags, dried with paper and weighed (Önenç and Kaya, 2004). The weight loss, expressed as a percentage of initial weight, was the cooking loss.

Statistical analyses

The distribution of GSs within control; MF and LP were analyzed using the χ^2-test. There were no birds with a GS of 3, χ^2 analyses were performed over three GSs (0, 1 and 2). The current data were analyzed using the General Linear Models procedure of the Statistical Analysis System (SAS, 1996). The models included control, MF and LP. Effects of feeding methods and sex and interactions were included in the model for BW and BWG. Means were separated using Duncan's multiple range tests. The results of statistical analysis were shown as mean values and standard error of the mean ± s.e. in tables.

Results

Growth performance

Average livability value was 97.4 ± 1.35 (%) for experiment and significant differences were not found among treatments. The BW and weight gain of the chicks are presented in Table 2. There were no BW differences at 7 days among treatment groups. Control birds had significantly ($P < 0.05$) heavier BW at 21 and 45 days compared to MF and LP groups. However, there were no significant differences between MF and LP groups. BW gain followed the same pattern from 7 to 21 and from 7 to 45 days. Weight gain in

Table 2 *Effects of feeding regime and sex on body weight (g), and body weight gain (g/bird per day) of broilers*

	Body weight (g/bird)			Daily body weight gain (g/bird per day)		
	Day 7	Day 21	Day 45	7 to 21 days	21 to 45 days	7 to 45 days
Feeding						
Control	116	645[a]	2395[a]	37.8[a]	73.0	60.1[a]
Meal feeding	117	620[b]	2323[b]	36.0[b]	70.8	57.6[b]
Low protein	116	621[b]	2315[b]	36.1[b]	70.5	57.6[b]
s.e.	1.3	8.3	25.0	0.5	0.8	0.7
Sex						
Male	117	644[a]	2471[a]	37.6[a]	76.1[a]	62.0[a]
Female	116	613[b]	2217[b]	35.6[b]	66.7[b]	55.2[b]
s.e.	1.1	7.0	20.4	0.4	0.7	0.9
Statistical analysis (*P* values)						
Feeding regime	ns	*	*	*	ns	*
Sex	ns	**	**	**	**	**
Feeding regime × Sex	ns	ns	ns	ns	ns	ns

[a,b]Means within a column with different superscripts are significant (*$P < 0.05$; **$P < 0.01$).
s.e. = standard error of the means (pooled); P = probability; ns = non-significant ($P > 0.05$).

the control group was higher than the MF and LP groups, but weight gain did not differ in the MF and LP groups. BW gain did not differ among the groups at 21 to 45 days. BW and weight gain of males were significantly higher than females throughout the experiment ($P < 0.01$). From restriction period to slaughter age, both BW and BWG of the MF and LP groups were lower compared to control birds. Interactions between treatment and sex had no effect on examined parameters (not shown in table).

The feed intake and feed conversion ratio (FCR) of the chicks are presented in Table 3. Although control birds consumed more feed from 7 to 21 days than restricted broilers, feed intake was similar among groups ($P > 0.05$). At the period of 21 to 45 days lower feed intake was observed in the MF group than others ($P < 0.01$). Also, feed intake in the MF group was the lowest than that of the control and LP groups and feed intake in the LP group was lower than that in the control group at 7 to 45 days ($P < 0.01$). Feed efficiency was the best in the MF group compared with other groups at the periods of 21 to 45 days ($P < 0.01$). On the other hand, FCR was not statistically influenced by the treatments at the periods of 7 to 21 and 7 to 45 days ($P > 0.05$). Whole wheat consumption dispersed onto the litter was not included in feed intake of the MF group. However, we could not measure the unconsumed amount of it.

Gait score and bone traits

The distribution of birds in each GS categories is presented in Table 4. As shown in Table 4, meal-time feeding and dietary LP had no effect but sex had significant effect on GS of broilers at 45 days. There were no broilers with score 3 in the treatment groups. However, the percentages of birds with poor walking ability (namely, scores 1 and 2) were high in males ($P < 0.01$). The overall number of birds with leg disorders (1 + 2, male and female) were 50.8% and 28.3%; 40.0% and 29.0%; and 40.0% and 27.2% for the control, the MF and the LP groups, respectively (Table 4).

Effects of treatments on bone traits of the groups are given in Table 5. The shank width, tibia wet weight and tibia mid-diaphysis ash percentage of the MF group were significantly lower than that of the control and the LP groups at 21 days ($P < 0.05$). Significant differences were not found on bone traits at 45 days ($P > 0.05$). Effects of treatments on carcass and meat characteristics of the groups are given in Table 6. Carcass and breast yield, thigh, neck, wing and meat pH and cooking loss were not different among groups ($P > 0.05$).

Discussion

The aim of this research was to investigate meal feeding and dispersing onto the floor whole wheat and a LP diet in

Table 3 *Effects of feeding regime on daily feed intake and feed efficiency of broilers*

	Daily feed intake (g/bird per day)			Feed conversion ratio (g feed/g gain)		
Feeding	7 to 21	21 to 45	7 to 45	7 to 21	21 to 45	7 to 45
Control	50.0	152.4[a]	114.7[a]	1.29	2.10[a]	1.91
Meal feeding	47.8	140.0[b]	106.0[c]	1.32	1.95[b]	1.84
Low protein	48.8	147.7[a]	111.2[b]	1.33	2.14[a]	1.95
s.e.	0.85	1.53	1.05	0.02	0.03	0.23
P value	ns	**	**	ns	**	ns

[a,b]Means within a column with different superscripts are significant (**$P < 0.01$).
s.e. = standard error of the means (pooled); P = probability; ns = non-significant ($P > 0.05$).

Table 4 *Distribution of male and female broilers with each gait score (0, 1 and 2)* at 45 days according to feeding treatment*

		Males				Females			
Feeding		0	1	2	1 + 2	0	1	2	1 + 2
Control	%	49.2	44.4	6.4	50.8	71.7	28.3	0	28.3
	n	31	28	4	32	43	17	0	17
Meal feeding	%	60.0	32.7	7.3	40.0	71.0	24.6	4.4	29.0
	n	33	18	4	22	49	17	3	20
Low protein	%	60.0	29.1	10.9	40.0	72.9	22.9	4.3	27.2
	n	33	16	6	22	51	16	3	19
Treatment	$\chi^2 = 6.085$ (ns)								
Sex	$\chi^2 = 12.738$**								

*Gait scores: 0 = the bird walked normally; 1 = the bird able to walk but had an obvious gait defect; 2 = the bird walked only when driven.
P = probability; ns = non-significant ($P > 0.05$).
**$P < 0.01$.

Table 5 *Effects of feeding regime on bone traits of male broilers*

Age	Control	Meal feeding	Low protein	s.e.	*P* value
21 days					
Shank length (mm)	43.61	43.00	42.79	0.26	ns
Shank width (mm)	9.16[a]	8.60[b]	9.05[a]	0.09	**
Tibia wet weight (g)	5.53[a]	4.79[b]	5.29[a]	0.17	*
Tibia breaking strength (kg)	23.3	19.0	21.7	1.26	ns
Tibia proximal epiphysis ash (%)	38.02	36.52	37.61	0.60	ns
Tibia mid-diaphysis ash (%)	54.61[a]	52.54[b]	54.91[a]	0.60	*
45 days					
Shank length (mm)	68.23	67.44	67.72	0.44	ns
Shank width (mm)	13.45	13.04	13.32	0.12	ns
Tibia wet weight (g)	24.79	23.63	23.50	0.76	ns
Tibia breaking strength (kg)	43.10	36.70	40.20	2.44	ns
Tibia proximal epiphysis ash (%)	30.89	30.72	30.42	0.83	ns
Tibia mid-diaphysis ash (%)	45.63	46.15	44.92	0.74	ns

[a,b]Means within the same row with different superscripts are significant (*$P < 0.05$; **$P < 0.01$).
s.e. = standard error of the means (pooled); P = probability; ns = non-significant ($P > 0.05$).

Table 6 *Effects of feeding regime on carcass characteristics of broilers*

Traits	Control	Meal feeding	Low protein	s.e.	*P* value
Carcass yield (%)	69.88	69.12	70.59	0.70	ns
Breast (%)	29.71	29.35	30.54	0.57	ns
Thigh (%)	31.28	31.12	31.91	0.35	ns
Neck (%)	2.85	2.96	3.18	0.18	ns
Wing (%)	8.88	8.64	8.13	0.36	ns
Meat characteristics of thigh					ns
pH	5.95	5.93	5.97	0.02	ns
Cooking loses (%)	30.71	30.77	29.54	0.92	ns

s.e. = standard error of the means (pooled); P = probability; ns = non-significant ($P > 0.05$).

the early life of chicks' performance, GS, carcass and bone traits. Because the majority of bone consolidation occurs during the first 3 weeks of age (Rose *et al*., 1996), modifying growth rate and increasing activity during this early period may be the most appropriate age to improve bone quality (Bizeray *et al*., 2002a). The reduction in leg problems may also be related to changes in muscle tissue because of slowing down of the growth rate (Tesseraud *et al*., 1992).

The current study showed that the meal-time feeding birds had a poor live BW and FC but better feed efficiency compared with the control birds. These findings were supported by Ballay *et al*. (1992), Su *et al*. (1999), Lee and Leeson (2001) and Bizeray *et al*. (2002a). They reported that the birds fed fewer meals had lower BW and also had better feed efficiency than those fed more meals. Cristofri *et al*. (1997) and Faria Filho *et al*. (2005) also reported that restricted birds utilized feed more efficiently during the restriction period and compensatory growth period. The birds fed meal-time feeding regimen were unable to adapt to feed intake and also they did not compensate BW losses until slaughter age. In the meal-time feeding group, the majority of whole wheat dispersed onto the litter was unconsumed until the end of the experiment. We observed that chicks were sighted on the floor during dispersion of whole wheat but interestingly lasted for a very short time and chicks only packed them. We used a mash starter and grower feed in the experiment. Hence, whole wheat possibly was a novel feed for chicks, perhaps making it difficult for the birds to recognize it as feed. We agree with the results of Bizeray *et al*. (2002a) who observed similar behavior in broiler chicks. Researchers reported the whole wheat was a novel feed for 1-week-old birds, when it was supplied on the floor rather than at the feeder. In the current study, meal feeding with whole wheat dispersion onto the floor affected BW and feed efficiency in broiler. However, these results were inconsistent with the results of Bizeray *et al*. (2002a). This difference may be caused by the dispersing manner of whole wheat. Likewise, we dispersed whole wheat onto the litter when feeder was lifted. But the researches dispersed whole wheat onto the floor when feeders exist. If it is dispersed, chicks may consume enough feed in case of whole wheat.

We observed that MF chicks were apparently more active and standing than that of the control group (personal observation by Y. Konca and E. Yaylak). Similarly, Nielsen *et al*. (2003) reported that meal-fed groups were more

active than the *ad libitum* groups. Therefore, we expected that in the meal-feeding group GS may enhance via increased locomotor activity but it was not improved. However, the percentages of birds with poor walking ability (namely, score 1 and 2) were higher in the control group but it was statistically insignificant. Our results are contrary to the results of Su *et al*. (1999), who found that the meal-feeding group had significantly better walking ability in the four levels of meal feeding. On the other hand, Bizeray *et al*. (2002a) found that alternating complete diet and whole wheat onto the litter reduced GS in broilers. In their study, complete diet offered with whole wheat and birds' BW were slightly higher than control birds at slaughter age. It is reported that there is a relationship between high BW and intensity of leg disorders in broilers (Su *et al*., 1999). In the current study, the MF birds had lower BW than control birds, and also GS was not affected at 45 days. This is an agreement with the results of de Jong *et al*. (2005) who suggested that limited improvement in GS could be achieved by feed restriction.

Shank width, tibia weight, breaking strength and tibia proximal epiphysis ash in the meal-feeding group was lower compared to the control group on day 21. The effect of restriction on linear bone growth seems to be associated with chondrocyte activity (Bruno *et al*., 2000), as Heinrichs *et al*. (1997) determined that a rapid depletion of growth plate chondrocytes and inhibition of longitudinal bone growth occur in food-restricted rabbits. Also our findings (at 21 days) are in agreement with earlier studies, which showed that food restriction could adversely affect bone formation in chicks (Bruno *et al*., 2000) and rats (Fetoui *et al*., 2006). These findings suggest that growth of bones seems to be negatively influenced at the early restriction period. Bone is a metabolically highly active tissue at early ages. Various factors are necessary to ensure normal skeletal development (Fetoui *et al*., 2006). Our findings showed that in the MF group, tibia mid-diaphysis ash was lower than in others ($P < 0.05$) but tibia proximal epiphysis ash did not differ at 21 days. On the other hand, regional variations in the ash content of broiler bones were reported (Bonser and Casinos, 2003).

In the present study, LP diet decreased BW, BWG and FC but feed efficiency did not differ significantly. Similarly, it is reported that the LP diets resulted in a decrease in the BW of the birds (Hurwitz *et al*., 1998; Yalçın *et al*., 1998; Faria Filho *et al*., 2005). Dietary protein level had no significant effect on GS as Summers *et al*. (1984) found. Likewise, Hester *et al*. (1985) showed that lowering the amino acid such as the lysine and methionine + cystine content of diets to 90% from NRC recommendation did not cause a significant reduction in the incidence of leg abnormalities. In contrast to Hulan *et al*. (1980) and Yalçın *et al*. (1998), in our study reported that a lower incidence of leg abnormalities was found in birds given LP diets. In our research, GS was affected by sex ($P < 0.05$). This finding is in agreement with the results of Yalçın *et al*. (1998) who reported that percentage of birds with poor walking ability was higher in males than in females.

In the current study, LP diet did not affect bone parameters except shank length. Shank length was decreased by the LP diet. Yalçın *et al*. (1998) observed that bone parameters such as shank length, width, tibia bone weight, breaking strength, and bone length and width were not affected by dietary protein. Similar results were published by Bahtiyarca and Konca (1996), who reported that LP and amino acid (methionine and lysine) did not affect bone dry weight, length, diameter and ash but decreased bone-breaking strength in quails. On the other hand, Bizeray *et al*. (2002b) stated that sequential feeding with lysine decreased tibia length and weight and but also had no effect on bone proximal-diaphysis and distal-end ash.

No effects of meal feeding and LP were observed on percentage yields of carcass, breast, thigh, wing, neck and pH and cooking loss of breast muscle. These observations support the findings of Palo *et al*. (1995) who reported that carcass and breast yields were not affected in two early feed-restriction programs. Similarly, Dozier *et al*. (2003) confirmed these findings.

To conclude, our findings suggest that both meal feeding and LP diet reduced BW and FC but increased feed efficiency overall period. However, these methods decreased bone traits at 21 days and did not affect GS, carcass and bone traits at 45 days. The different results in the literature are due to a number of factors that can influence the responses of broilers to feed restriction. These factors are the nature, timing, severity and duration at under-nutrition and also genetic factors such as strain and sex (Lippens *et al*., 2000). Leg problems are important for sustainability poultry production; hence, other methods should be investigated to help solve this problem.

Acknowledgments

We would like to thank S. Yalçın (Ege University, Agricultural Faculty, Department of Animal Science) who reviewed the original manuscript and made several helpful suggestions.

References

Bahtiyarca Y and Konca Y 1996. The effect of dietary calcium protein, lysine and methionine levels on the performance carcass weight and bone development in young Japanese quail (Rasyon kalsiyum, protein, lisin ve metiyonin seviyelerinin genç japon bıldırcınlarında performans, karkas ağırlığı ve kemik gelişimine etkisi). Selçuk Universitesi, Ziraat Fakultesi Dergisi 10, 87–99.

Ballay M, Dunnington EA, Gross WB and Siegel PB 1992. Restricted feeding and broiler performance: age at initiation and length of restriction. Poultry Science 71, 440–447.

Balog JM, Bayyari GR, Rath NC, Huff WE and Anthony NB 1997. Effect of intermittent activity on broiler production parameters. Poultry Science 76, 6–12.

Bizeray D, Estevez I, Leterrier C and Faure JM 2002a. Influence of increased environmental complexity on leg condition, performance, and level of fearfulness in broilers. Poultry Science 81, 767–773.

Bizeray D, Leterrier C, Constantin P, Picard M and Faure JM 2002b. Sequential feeding can increase activity and improve gait score in meat-type chickens. Poultry Science 81, 1798–1806.

Bonser RHC and Casinos A 2003. Regional variation in cortical bone properties from broiler fowl- a first look. British Poultry Science 44, 350–354.

Bruno LDG, Furlan RL, Malheiros EB and Macari M 2000. Influence of early quantitative food restriction at different environmental temperatures in broiler chickens. British Poultry Science 41, 389–394.

Cristofri C, Melluzzi A, Giordani G and Sirri F 1997. Early and late quantitative feed restriction of broilers. Effects on productive traits and carcass fatness. Archive für Geflügelkunde 61, 162–166.

de Jong IC, Fillerup M and Blokhuis HJ 2005. Effect of scattered feeding and feeding twice a day during rearing on indicators of hunger and frustration in broiler breeders. Applied Animal Behaviour Science 92, 61–76.

Dozier WA, Liens RJ, Hess JB, Bilgili SF, Gordon RW, Lasten CP and Vieira SL 2003. Effect of early skip a day feed removal on broiler live performance and carcass yield. Journal of Applied Poultry Research 11, 297–303.

Falcone C, Mench JA and Wakenell P 2004. Can perches and platforms act the incidence of gait abnormalities in broiler chickens? Journal of Animal Science 82 (Suppl. 1), 362.

Faria Filho DE, Rosa PS, Vieira BS, Macari M and Furlan RL 2005. Protein levels and environmental temperature effects on carcass characteristics, performance, and nitrogen excretion of broiler chickens from 7 to 21 days of age. Revista Brasileira de Cincia Avcola 7, 247–253.

Ferket PR and Sell JL 1989. Effect of severity of early protein restriction on large turkey toms. 1. Performance characteristics and leg weakness. Poultry Science 68, 676–686.

Fetoui H, Mahjoubi-Samet A, Jammousi K, Ellouze F, Guermazi F and Zeghal N 2006. Energy restriction in pregnant and lactating rats lowers bone mass of their progeny. Nutrition Research 26, 421–426.

Heinrichs C, Colli M, Yanovski JA, Laue L, Gerstl NA, Kramer AD, Uyeda JA and Baron J 1997. Effects of fasting on the growth plate: systemic and local mechanisms. Endocrinology 138, 5359–5365.

Hester PY, Suttan A, Elkin RG and Klingensmith PM 1985. The effect of lighting, dietary aminoacids and litter on the incidence of leg abnormalities and performance of turkey toms. Poultry Science 64, 2062–2075.

Hulan HW, Proudfoot FG, Ramey D and Mcrae KB 1980. Influence of genotype and diet on general performance and incidence of leg abnormalities of commercial broilers reared to roaster weight. Poultry Science 59, 748–757.

Hurwitz S, Sklan D, Talpaz H and Plavnik I 1998. The effect of dietary protein level on the lysine and arginine requirements of growing chickens. Poultry Science 77, 689–696.

Julian RJ 1998. Rapid growth problems: ascites and skeletal deformities in broilers. Poultry Science 77, 1773–1780.

Lee KH and Leeson S 2001. Performance of broilers fed limited quantities of feed or nutrients during seven to fourteen days of age. Poultry Science 80, 446–454.

Lippens M, Room G, De Groote G and Decuypere E 2000. Early and temporary quantitative food restriction of broiler chickens. 1. Effects on performance characteristics, mortality and meat quality. British Poultry Science 41, 343–354.

Lippens M, Huyghebaert H and De Groote G 2002. The efficiency of nitrogen retention during compensatory growth of food-restricted broilers. British Poultry Science 43 (Suppl.), 669–676.

Morris MP 1993. National survey of leg problems. Broiler Industry. May 20–24.

Nielsen BL, Litherland M and Nøddegaard F 2003. Effects of qualitative and quantitative feed restriction on the activity of broiler chickens. Applied Animal Behaviour Science 83, 309–323.

Norgaard-Nielsen G 1990. Bone strength of laying hens kept in an alternative system, compared with hens in cages and on deep-litter. British Poultry Science 31, 81–89.

Önenç A and Kaya A 2004. The effects of electrical stunning and percussive captive bolt stunning on meat quality of cattle processed by Turkish slaughter procedures. Meat Science 66, 809–815.

Palo PE, Sell JL, Piquer FJ, Vilaseca L and Soto-Salanova MF 1995. Effect of early nutrient restriction on broiler chickens. 2. Performance and digestive enzyme activities. British Poultry Science 74, 1470–1483.

Rose N, Constantin P and Letterier C 1996. Sex differences in bone growth of broiler chickens. Growth Development Aging 60, 49–59.

Rovee-Collier C, Collier G, Egert K and Jackson D 1993. Developmental consequences of diet and activity. Physiology and Behavior 53, 353–359.

Sanotra GS, Lund JD, Ersboll AK, Petersen JS and Vestergaard KS 2001. Monitoring leg problems in broilers: a survey of commercial broiler production in Denmark. World's Poultry Science Journal 57, 55–69.

SAS 1996. Statistical Analyses System, SAS User's Guide: Statistics. 1996 ed. SAS Institute, Inc., Carry, NC.

Sorensen P, Su G and Kestin SC 1999. The effect of photoperiod:scotoperiod on leg weakness in broiler chickens. Poultry Science 78, 336–342.

Su G, Sorensen P and Kestin SC 1999. Meal feeding is more effective than early feed restriction at reducing the prevalence of leg weakness in broiler chickens. Poultry Science 78, 949–955.

Summers JD, Shen H, Leeson S and Julian RJ 1984. Influence of vitamin deficiency and level of dietary protein on the incidence of leg problems in broiler chicks. Poultry Science 63, 1115–1121.

Tesseraud S, Larbier M, Chagneau AM and Geraert PA 1992. Effect of dietary lysine on muscle protein turnover in growing chickens. Reproduction Nutrition Development 32, 163–171.

Venäläinen E, Valaja J and Jalava T 2006. Effects of dietary metabolisable energy, calcium and phosphorus on bone mineralisation, leg weakness and performance of broiler chickens. British Poultry Science 47, 301–310.

Weeks CA, Danbury TD, Davies HC, Hunt P and Kestin SC 2000. The behaviour of broiler chickens and its modification by lameness. Applied Animal Behaviour Science 67, 111–125.

Yalçın S, Settar P and Dicle O 1998. Influence of dietary protein and sex on walking ability and bone parameters of broilers. British Poultry Science 39, 251–256.