Indian Journal of Animal Sciences **86** (11): 1311–1317, November 2016/Article
https://doi.org/10.56093/ijans.v86i11.63424

Effects of lighting programme and early feed restriction on performance, some stress parameters and quality characteristics of breast meat in broilers

H DEGER ORAL TOPLU[1], AHMET NAZLIGUL[2], SERAP UNUBOL AYPAK[3], SOLMAZ KARAARSLAN[4] and MEHMET KAYA[5]

Faculty of Veterinary Medicine, Adnan Menderes University, 09016 Isikli, Aydin Turkey

Received: 2 March 2016; Accepted: 12 May 2016

ABSTRACT

This study was conducted to determine effects of lighting program and early feed restriction on performance, stress and meat quality characteristics in broilers. Broilers (320) were randomly assigned to 4 groups based on lighting program (23 h lighting, 1 h dark or 16 h light, 8 h dark/day) and feeding program (*ad lib.* or feed restriction) with 4 replicates. Broilers in feed restricted group received feed as 50% of daily *ad lib.* consumption recommendations from 8 to 14 days of age. Final body weight, heterophil-lymphocyte ratio (H/L), tonic immobility (TI) duration and the percentages of total SFA of breast meat were lower, whereas the percentages of PUFA and PUFA/SFA were higher for broilers in feed restricted group than those fed *ad lib.* H-L ratio and TI duration of broilers exposed to 16L:8D were lower than those exposed to continuous lighting. In conclusion, early feed restriction negatively affected growth performance of broilers. However, broilers subjected to early feed restriction had less fat deposition and healthier fatty acid profile in breast meat and also they had less stress level, compared to *ad lib.* fed broilers. Lighting program of 16L:8D decreased the stress situation of broilers without any negative effect on production performance and meat quality characteristics.

Key words: Broiler, Early feed restriction, Lighting program, Meat quality, Stress

Growth performance of broiler chickens increased over the last 30 years mainly due to the genetic progress, improvements of nutrition and controlled environment so that it takes only 33 days to reach finishing body weight of about 2 kg (Sahraei 2012). This increase in growth rate is associated with high body fat deposition, high mortality and high incidence metabolic disease and skeletal disorders (Tùmová and Teimouri 2010). Recently, consumer preference for leaner meat has increased due to the relationship between human consumption of certain fats and cardiovascular diseases. This stimulated interest in reducing abdominal fat deposition in broiler chickens and trend towards leaner carcasses (Jalal and Zakaria 2012). Feed restriction programs applied early in the lifecycle of broilers are one of the alternatives to reduce problems related to the high growth rates of modern strains. Omosebi *et al.* (2014) showed that restricted feeding of broilers reduced carcass fatness and increased protein deposition, thus improving carcass composition. However, some reported that early feed restriction in broilers may lead to increasing fat deposition later in the rearing period (Zhan *et el.* 2007, Velleman *et al.* 2014, Poltowicz *et al.* 2015).

Present address: [1]Principal Scientist (doral@adu.edu.tr), [2]Professor (anazligul@adu.edu.tr), [4,5]Research Scientist (solmazkaraarslan@adu.edu.tr, mehmet.kaya@adu.edu.tr), Animal Breeding and Husbandry. [3]Assistant Professor (sunubol@adu.edu.tr), Biochemistry.

Broilers are usually kept on a continuous or nearly continuous lighting schedule to maximize growth rate. Continuous lighting programs lead to problems like locomotory problems, decrease in feed conversion rate and immunosuppression and thus, have a negative impact on animal welfare (Campo *et al.* 2007, Schwean-Lardner *et al.* 2013, Çoban *et al.* 2014). Darkness is important for growth and health of broilers as light and short photoperiods early in life reduce feed intake and limit growth (Olanrewaju *et al.* 2006). However, there is limited information related to the effects of lighting program and early feed restriction on meat quality characteristics of broilers. The aim of this study was to investigate the effects lighting program and early feed restriction on performance, some stress parameters and meat quality characteristics in broilers.

MATERIALS AND METHODS

Animals and management: This study was approved by local ethic committee of Adnan Menderes University. Male broilers, Ross 308 (320) with initial body weights of 47.9 ± 0.22g were obtained from a commercial hatchery. Broilers were housed in floor pens covered with wood shavings in windowed poultry house. A 2 × 2 factorial design was used, with 2 levels of lighting program and 2 levels of feeding programs and 4 replicates for each lighting-feeding program combination. All birds in the experiment received continuous light 24 h from the hatching day- to 3-day-old age. From 4-day-old age to 42-day-old age, in one room, lighting period remained at near continuous lighting (23L: 1D), while in the other room the photoperiod was 16 h light and 8 h dark/day. Each lighting groups were divided into 2 groups according to feeding program as *ad lib.* feeding and feed restriction. Feed restriction was applied as 50% daily *ad lib.* consumption from 8 to 14 days of age (Anonymous 2012**)**. After the restriction period, birds were fed *ad lib.* until 42 days of age. Broilers were fed with a starter diet from 0 to 21 days of age (3,060 kcal ME/kg, 23% crude protein) and grower diet from 22 to 42 days of age (3,200 kcal ME/kg, 21.5% crude protein) as recommended by North *et al.* (1990).

Determination of performance parameters: Daily mortality was recorded. Body weight and feed intake were measured on a weekly basis. At d 42, 5 broilers from each pen, a total of 80 broilers, were slaughtered to determine carcass characteristics. Cold carcass weights were recorded after the carcasses were stored at 4°C for 24 h. Hot and cold carcass dressing percentages were expressed as percentages of body weight at slaughter. Each carcass was cut into 5 parts as breast, thigh, wing, neck and back according to the chicken cut technique of TSE (Turkish Standards Institution) (Anonymous 1989). Carcass cuts were expressed as percentage of cold carcass weight.

Sampling and blood analysis: At 40 days of age, blood samples were collected from wing vein of 5 broilers from each pen. The bleeding procedure was limited to 1 min or less to minimize the influence of handling stress. Serum glucose, cholesterol, triglyceride and total protein levels were measured with an automatic analyzer using commercial test kits. To obtain the H/L ratio, blood samples were smeared on a glass slide. After the smears were stained with May-Grünwald-Giemsa stain, 100 leucocytes were counted on each slide, using a light microscope at × 1,000 magnification. The H/L ratio was calculated by dividing the number of heterophils by the number of lymphocytes (Gross and Siegel 1983).

Tonic immobility duration measurement: At 41 days of age, TI duration of 5 broilers from each pen of which blood sample was not collected was recorded. Placing a bird on its back induced tonic immobility. The bird was restrained for 10 sec by maintaining a light pressure on its sternum. A stopwatch was started to record latencies until the bird righted itself. If the bird righted itself in less than 10 sec, the restraining procedure was repeated. If the bird did not show a righting response over the 10 min test period, a maximum score of 600 sec was given (Campo and Rodendo 1997).

Meat quality measurements: In the study, pH of breast meat was measured at 15 min postmortem (pH_{15min}) and 24 h after slaughter (pH_{24h}) using a digital pH meter (Testo 205) equipped with a penetrating electrode. Muscle colour was measured on the surface on left breast muscle 24 h after slaughter. Colour measurement was performed using a chroma-meter in the CIELAB colour space using a D65 illuminant, in which L^* indicates relative lightness, a^* indicates relative redness and b^* represents relative yellowness. Cooking loss was determined in meat samples of breast muscle (Honikel 1998). Chemical characteristics of breast muscle samples (moisture, crude fat, protein and ash) were analyzed using standard analytical methods (AOAC 1990).

Fatty acid analysis: Lipid from 2 g breast meat samples was extracted using chloroform:methanol (2:1) according to Folch *et al.* (1957). Fatty acid methyl esters were prepared according to TS 4504 EN ISO 5509 (2002) and measured with a gas chromatography equipped with a split-splitless injector and a flame ionization detector using a silica capillary column (Supelco, 60 m, 0.25 mm i.d., 0.2 µm film thickness). Results were expressed as a percentage of total fatty acids identified. The percentage of total saturated fatty acids (SFA), unsaturated fatty acids (UFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), n-3 and n-6 fatty acids were calculated from individual fatty acids. The ratios of PUFA/SFA and n-6/n-3 were calculated.

Statistical analysis: Analysis of variance was performed using the GLM procedure of SPSS 13.0 package program to test the effects of lighting program and feed restriction and their interaction on the studied traits (SPSS 2004). Least squares method was used to determine effects of lighting program and early feed restriction on investigated traits (Harvey 1987). The mathematical model used in the analyses of investigated traits was.

$$Y_{ijk} = \bar{\mu} + a_i + b_j + ab_{ij} + e_{ijk}$$

where Y_{ijk} is any investigated trait, $\bar{\mu}$ is the overall mean, a_i is the effect of lighting program (23L:1D, and 16L: 8 D), b_j is the effect of feeding program (j: *ad lib.* feeding throughout the experimental period and feed restriction as 50% daily *ad lib.* consumption defined in Ross 308 guidelines from 8 to 14 days of age), ab_{ij} is the effect of lighting program and feeding program interaction, e_{ijk} is the residual random error.

RESULTS AND DISCUSSION

Broilers in 16 h lighting treatment had similar feed intake and body weight gain from 1 to 42 days of age and had similar final body weight at 42 days of age compared with broilers reared in 23 h lighting treatment (Table 1). In the present study, no compensation in live weight was observed within growth period of 42 days and thus broilers fed restricted diet had significantly lower final body weight at 42 days of age than those fed *ad lib.* This result could be explained by the similarities in feed intake and body weight gain between early feed restricted broilers and those fed *ad lib.* in the period from 15 to 42 days of age. Similar to the current study, Jalal and Zakaria (2012) also reported that broilers subjected to similar degree of feed restriction during starter period were not able to show compensatory growth by the age of 42 days.

Stressed birds show an increase in heterophils and a decrease in lymphocytes and thus an increase in the H/L ratio (Gross and Siegel 1983). In this study, H/L ratio for the broilers reared in the group of 16 h lighting was

Table 1. Effects of lighting program and early feed restriction on growth performance of broilers[1]

Trait	Lighting program		Feeding program		Significance		
	23 L: 1 D	16 L: 8 D	*Ad libitum*	Restricted	Lighting program	Feeding program	Lighting program 'X' Feeding program
Body weight (g)							
1 d	48.3 ± 0.31	47.5 ± 0.31	47.6 ± 0.31	48.1 ± 0.31	ns	ns	ns
14 d	336 ± 3.01	324 ± 2.99	392 ± 2.99	268 ± 3.01	**	***	ns
42 d	2482 ± 21.74	2449 ± 21.53	2518 ± 21.81	2413 ± 21.46	ns	**	ns
Body weight gain (g/bird)							
8-14 d	169 ± 3.59	165 ± 3.59	231 ± 3.59	104 ± 3.59	ns	***	ns
1-14 d	287 ± 3.03	277 ± 3.01	344 ± 3.01	220 ± 3.03	*	***	ns
15- 42 d	2147 ± 31.06	2123 ± 31.06	2125 ± 31.06	2145 ± 31.06	ns	ns	ns
1- 42 d	2434 ± 32.44	2400 ± 32.44	2469 ± 32.44	2365 ± 32.44	ns	*	ns
Feed intake (g/bird)							
8-14 d	262 ± 2.56	250 ± 2.56	329 ± 2.56	183 ± 2.56	**	***	ns
1-14 d	413 ± 3.41	385 ± 3.41	471 ± 3.41	327 ± 3.41	***	***	ns
15- 42 d	3871 ± 59.69	3818 ± 59.69	3824 ± 59.69	3865 ± 59.69	ns	ns	ns
1- 42 d	4283 ± 61.84	4203 ± 61.84	4294 ± 61.84	4192 ± 61.84	ns	ns	ns
FCR (g feed/g gain)							
8- 14 d	1.64 ± 0.04	1.57 ± 0.04	1.43 ± 0.04	1.78 ± 0.04	ns	***	ns
1-14 d	1.45 ± 0.02	1.41 ± 0.02	1.37 ± 0.02	1.49 ± 0.02	ns	***	ns
15- 42 d	1.80 ± 0.03	1.80 ± 0.03	1.80 ± 0.03	1.80 ± 0.03	ns	ns	ns
1-42 d	1.76 ± 0.02	1.75 ± 0.02	1.74 ± 0.02	1.77 ± 0.02	ns	ns	ns

[1]Data presented as least square means ± standart error. FCR, Feed conversion ratio; ns, P>0.05; *, P<0.05; **, P<0.01; ***, P<0.001.

Table 2. Effects of lighting program and early feed restriction on heterophil-lymphocyte (H-L) ratio, tonic immobility (TI) duration and the serum concentrations of glucose, cholesterol, triglyceride, total protein[1]

Trait	Lighting program		Feeding program		Significance		
	23L:1D (n = 40)	16L:8D (n = 40)	*Ad libitum* (n = 40)	Restricted (n = 40)	Lighting program	Feeding program	Lighting program 'X' feeding program
H-L ratio	1.04 ± 0.08	0.809 ± 0.08	1.10 ± 0.08	0.743 ± 0.08	*	**	ns
TI duration	277 ± 18.66	209 ± 18.66	301 ± 18.66	185 ± 18.66	*	***	ns
Glucose (mg/dl)	245 ± 15.67	236 ± 15.67	254 ± 15.67	227 ± 15.67	ns	ns	ns
Cholesterol (mg/dl)	127 ± 5.88	120 ± 5.88	131 ± 5.88	116 ± 5.88	ns	ns	ns
Triglyceride (mg/dl)	80.6 ± 6.62	66.1 ± 6.62	89.4 ± 6.62	57.4 ± 6.62	ns	**	ns
Total protein (g/dl)	3.31 ± 0.20	2.80 ± 0.20	3.15 ± 0.20	2.97 ± 0.20	ns	ns	ns

[1]Data presented as least square means ± standart error. ns, P>0.05; *, P<0.05; **, P<0.01; ***, P<0.001.

significantly lower than those reared in the group of 23 h lighting (P<0.05). Feed restricted broilers also had lower H/L ratio than broilers fed *ad lib.* (P<0.01) (Table 2), suggesting that 23 h lighting and *ad lib.* feeding caused the more stress situation in broilers compared with 16 h lighting and early feed restriction. Similar to the present study, Zülkifli *et al.* (2003) reported that broilers exposed to 60% feed restriction on 4, 5 and 6 days of ages had lower H/L ratio than those fed *ad lib.* in heat stress conditions. Khajavi *et al.* (2003) also determined that the H/L ratio was higher for broilers in *ad lib.* fed group than the group fed every other day from d 11 to d 20 but, the difference between groups was not significant. TI duration was significantly longer for broilers in the group of 23 h lighting than those in the group of 16 h lighting (P<0.05). Broilers fed *ad lib.* displayed longer TI duration and than those fed restricted diet (P<0.001). Based on these results, it can be said that nearly continuous lighting and *ad lib.* feeding caused greater fearfulness in broilers compared to 16 h lighting and early feed restriction. These results agree with that of Campo *et al.* (2007), who reported that TI duration was longer for broilers in continuous lighting group than those in 14L:10D lighting group.

In this study, lighting program had no significant effect on serum glucose, cholesterol, triglyceride and total protein levels. Early feed restriction significantly reduced serum triglyceride level (P<0.01). This reduction in serum triglyceride level by early feed restriction could be related

Table 3. Effects of lighting program and early feed restriction on carcass and quality characteristics of breast meat in broilers[1]

Trait	Lighting program		Feeding program		Significance		
	23L:1D (n = 40)	16L:8D (n = 40)	*Ad libitum* (n = 40)	Restricted (n = 40)	Lighting program	Feeding program	Lighting program × feeding program
Hot carcass yield (%)	75.1 ± 0.30	74.5 ± 0.30	75.2 ± 0.30	74.4 ± 0.30	ns	ns	ns
Cold carcass yield (%)	73.4 ± 1.47	72.8 ± 1.47	73.2 ± 1.47	72.9 ± 1.47	ns	ns	ns
Breast [2]	37.8 ± 1.04	38.6 ± 1.04	39.5 ± 1.04	36.9 ± 1.04	ns	ns	ns
Breast meat[2]	20.1 ± 0.70	20.0 ± 0.70	20.8 ± 0.70	19.3 ± 0.70	ns	ns	ns
Thigh[2]	31.4 ± 0.88	30.3 ± 0.88	29.9 ± 0.88	31.7 ± 0.88	ns	ns	ns
Wings[2]	11.9 ± 0.28	11.5 ± 0.28	11.4 ± 0.28	12.0 ± 0.28	ns	ns	ns
Neck and back[2]	17.1 ± 0.52	17.8 ± 0.52	17.3 ± 0.52	17.6 ± 0.52	ns	ns	ns
Abdominal fat[2]	1.82 ± 0.10	1.74 ± 0.10	1.87 ± 0.10	1.68 ± 0.10	ns	ns	ns
pH_{15min}	6.42 ± 0.04	6.46 ± 0.04	6.48 ± 0.04	6.40 ± 0.04	ns	ns	ns
pH_{24h}	5.89 ± 0.03	5.87 ± 0.03	5.90 ± 0.03	5.86 ± 0.03	ns	ns	ns
L^*	51.8 ± 0.59	52.0 ± 0.59	52.3 ± 0.59	51.5 ± 0.59	ns	ns	ns
a^*	5.28 ± 0.13	4.94 ± 0.13	5.03 ± 0.13	5.19 ± 0.13	ns	ns	ns
b^*	4.03 ± 0.15	3.89 ± 0.15	4.14 ± 0.15	3.77 ± 0.15	ns	ns	ns
Cooking loss (%)	24.2 ± 0.49	22.8 ± 0.49	23.8 ± 0.49	23.2 ± 0.49	ns	ns	ns
Protein (%)	21.5 ± 0.22	21.6 ± 0.22	21.5 ± 0.22	21.5 ± 0.22	ns	ns	ns
Fat (%)	2.14 ± 0.11	2.04 ± 0.11	2.33 ± 0.11	1.85 ± 0.11	ns	**	ns
Moisture (%)	75.2 ± 0.31	75.0 ± 0.31	74.9 ± 0.31	75.3 ± 0.31	ns	ns	ns
Ash (%)	1.14 ± 0.04	1.15 ± 0.04	1.18 ± 0.04	1.11 ± 0.04	ns	ns	ns

[1]Data presented as least square means ± standart error; [2]percentage of carcass cuts weights to cold carcass weight; ns, P>0.05; *, P<0.05.

to retarded synthesis, reduced hepatic output, enhanced clearance or a combination of these factors (Santoso 2001). Unlike the present study, Zhan *et al.* (2007) reported that at 63 d of age, serum glucose and triglyceride levels significantly increased in broilers exposed to early feed restriction. They stated that this increase in serum glucose and triglyceride levels might be due to the enhanced insulin resistance and reduced glucose tolerance caused by the metabolic programming for early malnutrition. The difference between the studies might be due to feed restriction level and duration of the studies. In their study, early feed restriction was applied by removing feed 4 h/ day from 1 to 21 days of age. The first week of life in broilers is the critical stage and so initial day, long period and lower intensity of feed restriction might induce metabolism programming, thus contributing to excessive fat deposition in adult life of broilers (Zhan *et al.* 2007).

Lighting program and early feed restriction had no significant effect on carcass and physical meat quality characteristics measured on breast meat in broilers (Table 3). There is little information about the effects of lighting program and early feed restriction on physico-chemical meat quality characteristics in broilers. Lippens *et al.* (2000) reported that feed restriction to 80 or 90% of *ad lib.* from 4 to 7 days of age, or feed restriction to 80% of *ad lib.* from 4 to 11 days of age had no significant effect on pH, colour and cooking loss of breast muscle. Butzen *et al.* (2013) also showed that cooking loss and shear force value of breast fillet were not significantly affected by feed restriction to 80% of *ad lib.* from 8 to 16 days of age. Poltowicz *et al.* (2015) reported that feed restricted broilers showed a tendency for higher final pH, despite the lack of statistical significance and breast muscles of these birds were characterized by significantly lower cooking loss and thus breast muscles of restricted chickens had better parameters of water holding capacity compared to the muscle of chickens fed *ad lib.* However, in their studies feed restriction was applied as 6 h daily from 3 to 4 weeks of age or from 4 to 5 weeks of age.

Improved meat quality attracts more and more attention from consumers, and excessive fat deposition is one of the important factors of poor meat quality of broilers (Sahraei 2012). Some studies showed that feed restriction decreased fat content and increased protein content of breast muscle of broilers (Zhan *et al.* 2007, Omosebi *et al.* 2014). In the current study, it was determined that early feed restriction decreased fat content of breast meat of broilers at 42 days of age, whereas protein, moisture and ash content were not affected by early feed restriction. Decreased fat content of breast meat with early feed restriction could be due to the reduction of lipogenesis in the liver (Santoso 2002). The lower serum triglyceride concentration in restricted fed broilers as compared with those fed *ad lib.* supported this assumption (Table 2). Unlike this study, Poltowicz *et al.* (2015) reported that there were no significant difference between *ad lib.* fed group and feed restricted groups in terms of fat and protein content of breast muscles in broilers. The discrepancies might be due to the higher intensity of feed

Table 4. Effects of lighting program and early feed restriction on fatty acid composition of breast meat in broilers[1]

Fatty acids (%)	Lighting program		Feeding program		Significance		
	23L:1D (n = 32)	16L:8D (n = 32)	*Ad libitum* (n = 32)	Restricted	Lighting program (n = 32)	Feeding program	Lighting program× feeding program
C14:0	0.389 ± 0.04	0.349 ± 0.04	0.425 ± 0.04	0.314 ± 0.04	ns	ns	ns
C15:0	0.146 ± 0.01	0.162 ± 0.01	0.154 ± 0.01	0.152 ± 0.01	ns	ns	ns
C16:0	21.79 ± 1.05	19.99 ± 1.05	23.56 ± 1.05	18.22 ± 1.05	ns	**	ns
C16:1	3.22 ± 0.29	3.95 ± 0.28	3.31 ± 0.29	3.87 ± 0.28	ns	ns	ns
C17:1	0.063 ± 0.01	0.056 ± 0.01	0.064 ± 0.01	0.054 ± 0.01	ns	ns	ns
C18:0	6.05 ± 0.59	4.82 ± 0.59	6.15 ± 0.59	4.72 ± 0.59	ns	ns	ns
C18:1	28.60 ± 0.98	28.96 ± 0.98	27.49 ± 0.98	30.07 ± 0.98	ns	ns	ns
C18.2 n-6	26.04 ± 0.89	28.17 ± 0.89	25.56 ± 0.89	28.65 ± 0.89	ns	*	ns
C18:3n-3	0.675 ± 0.09	0.798 ± 0.09	0.475 ± 0.09	0,997 ± 0.08	ns	***	ns
C20:0	0.129 ± 0.01	0.099 ± 0.01	0.116 ± 0.01	0.112 ± 0.01	ns	ns	ns
C20:1	0.405 ± 0.03	0.433 ± 0.03	0.386 ± 0.03	0.452 ± 0.03	ns	ns	ns
C20:2 n-6	0.851 ± 0.05	0.755 ± 0.05	0.841 ± 0.05	0.765 ± 0.05	ns	ns	ns
C20:3 n-6	0.905 ± 0.05	0.805 ± 0.05	0.903 ± 0.05	0.820 ± 0.05	ns	ns	ns
C20:4 n-6	6.77 ± 0.05	6.76 ± 0.05	6.82 ± 0.05	6.71 ± 0.05	ns	ns	ns
C20:5 n-3	0.155 ± 0.03	0.184 ± 0.03	0.138 ± 0.03	0.201 ± 0.03	ns	ns	ns
C22:4 n-6	2.47 ± 0.04	2.45 ± 0.04	2.52 ± 0.04	2.40 ± 0.04	ns	ns	ns
C22:5 n-3	0.733 ± 0.03	0.701 ± 0.03	0.493± 0.03	0.942 ± 0.03	ns	***	ns
C22:6 n-3	0.363 ± 0.03	0.381 ± 0.03	0.347 ± 0.03	0.403 ± 0.03	ns	ns	ns
SFA	28.69 ± 1.55	25.58 ± 1.55	30.60 ± 1.55	23.69 ± 1.55	ns	**	ns
MUFA	32.34 ± 1.12	33.40 ± 1.12	31.30 ± 1.12	34.44 ± 1.12	ns	ns	ns
PUFA	38.97 ± 0,89	41.00 ± 0.89	38.10 ± 0.89	41.87 ± 0.89	ns	*	ns
UFA	71.30 ± 1.76	74.40 ± 1.76	69.39 ± 1.76	76.31 ± 1.76	ns	**	ns
n-3	1.93 ± 0.08	2.06 ± 0.08	1.46 ± 0.08	2.54 ± 0.08	ns	***	ns
n-6	37.04 ± 0.09	38.94 ± 0.09	36.64 ± 0.09	39.33 ± 0.09	ns	*	ns
n-6/n-3	20.11 ± 0.47	19.75 ± 0.47	24.87 ± 0.47	14.99 ± 0.47	ns	***	ns
PUFA/SFA	1.38 ± 0.13	1.63 ± 0.13	1.24 ± 0.13	1.77 ± 0.13	ns	**	ns

[1]Data presented as least square means ± standart error; ns, P>0.05; *, P<0.05; **, P<0.01;***, P<0.001.

restriction applied to birds in our experiment.

It is well accepted that dietary intake of UFA reduces the risk of cardiovascular diseases and the incidence of some cancers, asthma and diabetes. At the same time, it is recommended that PUFA to SFA ratio should be 0.4, with the normal PUFA/SFA ratio of meat at around 0.1 (Wood *et al.* 2003). In this study, no significant differences were found between lighting programs in terms of fatty acid composition of breast meat (Table 4). Early feed restriction decreased the percentage of total SFA (P<0.01) and caused significant increase in PUFA (P<0.05), UFA and PUFA/SFA ratio (P<0.01). The decrease in the percentage of total SFA in restricted fed group could be attributed to the lower fat content of breast meat in this group. Several researchers have previously reported that fatness has an effect on fatty acid composition of meat and the percentage of SFA increased with increasing fatness (De Smet *et al.* 2004, Simsek *et al.* 2009). De Smet *et al.* (2004) reported that the content of SFA and MUFA increases faster with increasing fatness than does the content of PUFA, leading to a decrease in the relative proportion of PUFA and consequently in PUFA/SFA ratio. Similar results were obtained by Wiecek *et al.* (2011) in pigs. However, Sugiharto *et al.* (2015) determined that feed deprivation over the first 48 h post-hatching had no significant effect on fatty acid composition of breast meat in broilers. These differences between the studies most probably relate to use of different feed restriction program in the studies.

The n-3 and n-6 fatty acids play an important role in human nutrition, both being precursors of eicosanoids, prostaglandins, leucotriens, and thromboxanes that regulate the cardiovascular system and immunological process (Grashorn 2007). It is recommended that the ratio of n-6/n-3 should be less than 4 (Wood *et al*. 2001). In the current study, the ratio of n-6/n-3 was higher than 4. This result could be attributed to the diets consumed by broilers. It is known that in poultry, fatty acid composition of tissue lipids depends on the lipids in the diets (Skrivan *et al.* 2000). In this study, diets consumed by broilers contained high level of n-6 fatty acids, which resulted in high ratio of n-6/n-3 in breast meat of broilers consuming these diets. In the present study, early feed restriction increased deposition of desirable n-3 fatty acids in breast meat and thus resulted in decrease in the ratio of n-6/n-3 (P<0.001). These results indicated that breast meat of broilers subjected to feed restriction from 8 to 14 days of age had the healthier fatty acid profile than those fed *ad lib.* throughout the experimental period.

Our results showed that early feed restriction during 8 to 14 days of age negatively affected growth performance of broilers. Broilers subjected to feed restriction 50% of *ad lib.* were not able to attain live weight compensation by 42 days of age. However, broilers subjected to early feed restriction had less fat deposition and healthier fatty acid profile in breast meat and also they had less stress level, compared to *ad lib.* fed broilers. Lighting program of 16L: 8D decreased the stress situation of broilers without any negative effect on production performance and meat quality characteristics.

ACKNOWLEDGMENT

This study was supported by the Research Fund of Adnan Menderes University (Project no: VTF–12004).

REFERENCES

Anonymous. 1989. *Turkish Standards of Poultry Carcass-Rules for Carcass Dissecting*.

AOAC. 1990. *Official Methods of Analysis*.15th edn. Arlington, VA, USA: Association of Official Analytical Chemists.

Anonymous. 2012. *Ross 308 Broiler Performance Objectives*. Page 4. http://www.poultryhub.org

Butzen F M, Riberio A M L, Vieira M M, Kessler A M, Dadalt J C and Della M P. 2013. Early feed restriction in broilers. I-Performance, body fraction weights, and meat quality. *Journal of Applied Poultry Research* **22**: 251–59.

Campo J L and Rodendo A. 1997. Negative association between heterophil to lymphocyte ratio and tonic immobility reaction in hens. *Proceedings of 5th European Symposium Animal Welfare*. Wageningen, The Netherlands, pp. 163–64.

Campo J L, Gil M G, Davila S G and Munoz I. 2007. Effect of lighting stress on fluctuating asymmetry, heterophil to lymphocyte ratio and tonic immobility duration in eleven breeds of chickens. *Poultry Science* **86**: 37–45.

Coban O, Lacin E and Genc M. 2014. The effect of photoperiod length on performance parameters, carcass characteristics and heterophil/lymphocyte ratio in broilers. *Journal of the Faculty of Veterinary Medicine, Kafkas University* **20**: 863–70.

De Smet S, Raes K and Demeyer D. 2004. Meat fatty acid composition as affected by fatness and genetic factors: A review. *Animal Research* **53**: 81–98.

Folch J, Lees M and Stanley G H. 1957. A simple method for the isolation and purification of total lipids from animal tissues. *Journal of Biological Chemistry* **226**: 497–509.

Grashorn M A. 2007. Functionality of poultry meat. *Journal of Applied Poultry Research* **16**: 99–106.

Gross W B and Siegel H S. 1983. Evaluation of the heterophil/lymphpcyte ratio as a measure of stress in chickens. *Avian Diseases* **27**: 972–79.

Harvey W R. 1987. User's guide for LSMLMWPC-I version mixed model least squares and maximum likelihood computer program. Ohio University, Colombus, Mimeo.

Honikel K O. 1998. Reference methods for the assessment of physical characteristics of meat. *Meat Science* **49**: 447–57.

Jalal M A R and Zakaria H A. 2012. The effect of quantitative feed restriction during the starter period on compensatory growth and carcass characteristics of broiler chickens. *Pakistan Journal of Nutrition* **11**: 719–24.

Khajavi M, Rahimi S, Hassan Z M, Kamali M A and Mousavi T. 2003. Effect of feed restriction early in life on humoral and cellular immunity of two commercial broiler strains under heat stress conditions. *British Poultry Science* **44**: 490–97.

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**: 343–54.

North M O and Bell D D. 1990. *Commercial Chicken Production Manual*. An Avi Book by Van Nostrand Reinhold, New York.

Olanrewaju H A, Thaxton J P, Dozier III W A, Purswell J, Roush W B and Branton S L. 2006. A review of lighting programs for broiler production. *International Journal of Poultry Science* **5**: 301–08.

Omosebi D J, Adeyemi O A, Sogunle M O, Idowu O M O and Njoku C P. 2014. Effects of duration and level of feed restriction on performance and meat quality of broiler chickens. *Archivos de Zootecnia* **63**: 611–21.

Poltowicz K, Nowak J and Wojtysiak D. 2015. Effect of feed restriction on performance, carcass composition and physicochemical properties of the *M. Pectoralis superficialis* of broiler chickens. *Annals of Animal Science* **15**: 1019–29.

Sahraei M. 2012. Feed restriction in broiler chickens production. *Biotechnology in Animal Husbandry* **28**: 333–52.

Santoso U. 2001. Effects of early feed restriction on growth, fat accumulation and meat composition in unsexed broiler chickens. *Asian Australasian Journal of Animal Science* **14**: 1585–91.

Santoso U. 2002. Effects of early feed restriction on breast and leg meat composition and plasma lipid concentration in unsexed broiler chickens reared in cages. *Asian Australasian Journal of Animal Science* **15**: 1475–81.

Schewean-Lardner K, Fancher B I, Gomis S, Van Kessel A, Dalal S and Classen H L. 2013. Effect of day length on cause of mortality, leg health and ocular health in broilers. *Poultry Science* **92**: 1–11.

Simsek U G, Cerci I H, Dalkilic B, Yilmaz O and Ciftci M. 2009. Impact of stocking density and feeding regimen on broilers: Chicken meat composition, fatty acids, and serum cholesterol levels. *Journal of Applied Poultry Research* **18**: 514–20.

Skrivan M, Skrivanova V, Marounek M, Tümova E and Wolf J. 2000. Influence of dietary fat source and copper supplementation on broiler performance, fatty acid profile of meat and depot fat, and on cholesterol content in meat. *British Poultry Science* **41**: 608–14.

Sonatra G S, Damkjer J, Lund K and Vestergaard S. 2002. Influence of light-dark schedules and stocking density on behavior, risk of leg problems and occurrence of chronic fear in broilers. *British Poultry Science* **43**: 344–54.

SPSS, 2004. *Statistical Package for Social Science for Windows*. Version 13.0 (Chicago, IL, SPSS Inc.).

Sugiharto S, Isroli I, Yudiarti T, Widiastuti E and Kusumanti E. 2015. Effect of post-hatch feed deprivation on fatty acid composition of broiler meat. *Journal of the Indonesian Tropical Animal Agriculture* **40**: 234–37.

TS 4504 EN ISO 5509, 2002: Animal and vegetable fats and oils. Preparation of methyl esters of fatty acids.

Tùmová E and Teimouri A. 2010. Fat deposition in the broiler chicken: A review. *Scientia Agriculturae Bohemica* **41**: 121–

28.

Velleman S G, Coy C S and Emmerson D A. 2014. Effect of the timing of posthatch feed restriction of fat during broiler breast muscle development. *Poultry Science* **93**: 2622–27.

Wiecek J, Rekiel A, Batorska M and Skomia J. 2011. Effect of restricted feeding and realimentation periods on pork quality and fatty acid profile of *M. longissimus thoracis*. *Meat Science* **87**: 244–49.

Wood J, Enser M, Scollan N, Gulati S, Richardson I and Nute G. 2001. The effects of ruminally protected dietary lipid on the lipid composition and quality of beef muscle. *Proceedings of the 47th International Congress of Meat Science and Technology*. Meat and Fat Research Institute, Warszawa, pp.186–87.

Wood J D, Richardson R I, Nute G R, Fisher A V, Campo M M, Kasapidou E, Sheard P R and Enser M. 2003. Effect of fatty acids on meat quality: A Review. *Meat Science* **66**: 21–32.

Zhan X A, Wang M, Ren H, Zhao R Q, Li J X and Tan Z L. 2007. Effect of early feed restriction on metabolic programming and compensatory growth in broiler chickens. *Poultry Science* **86**: 654–60.

Zülkifli I, Liew P K, Israf D A, Omar A R and Hair-Bejo M. 2003. Effects of early age feed restriction and heat conditioning on heterophil/lymphocyte ratios, heat shock protein 70 expression and body temperature of heat-stressed broiler chickens. *Journal of Thermal Biology* **28**: 217–22.