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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 12 (8): 631-636, 2009
ISSN 1028-8880

Effects of Housing Systems on Growth Performance, Blood Plasma Constituents and Meat Fatty Acids in Broiler Chickens

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Abstract: A research was conducted to determine the influence of the conventional and the free-range broiler housing systems using female broiler chicks had low hatching weight on growth performance, breast meat characteristics and some blood plasma parameters. In the conventional (totally confined) housing system sixty one-day-old female Ross broiler chicks were placed in indoor floor pens with three replicates of 20 chicks. In the free-range (partly-confined) housing system, sixty one-day-old Ross broiler chicks were placed in indoor floor pens and also accessed to a grass paddock during 44 day experimental period after 7 days old. Birds of both systems were fed the same commercial broiler diet. The free-range housing system significantly decreased the total feed intake and body weight of broilers ($p<0.05$). The redness (a* color) and yellowness (b* color) in breast meat were affected by the housing systems ($p<0.05$). The housing systems had no affect on fatty acids composition of breast meat ($p>0.05$). The plasma triglyceride and VLDL levels of the conventional reared birds were significantly higher than those reared the free-range ($p<0.05$). In conclusion, longer growth period was necessary to the free-range reared broilers.

Key words: Housing systems, broilers, fatty acids, plasma components

INTRODUCTION

In recent years, demands of consumers to organically produced foods have progressively increased. Consumers are willing to pay higher prices for organically grown animal products in Europe (Bennet, 1996). Demands to organic and free-range reared broiler meat have also become increasingly available to consumers (Fanatico *et al*., 2005; Husak *et al*., 2008). The matter of animal welfare has led to studies in order to evaluate alternative housing systems to improve well-being (Barbosa Filho *et al*., 2005). The free-range broiler housing system has increased substantially as a result of the greater demand to natural broiler meat production (Dawkins *et al*., 2003). Totally confined housing systems lead to poultry stress and cause poor performance (Mendl, 1999). The semi-intensive system is an alternative method of housing broilers in which the birds are kept in a poultry house and have free access to a pasture area during the day (Barbosa Filho *et al*., 2005; Lima and Nääs, 2005). The system has been used in last years, mainly due to aspects related to the greater concern with food quality by consumers. The semi-intensive systems minimize the effects of stressing factors and contribute to bird welfare (Sundrum, 2001). Birds can stay longer in the pasture area. They have greater mobility and bird welfare will be improved. Therefore, productivity and profits might be improved in alternative poultry production if strains adapted to this system (Barbosa *et al*., 2005). However, the avian influenza is the biggest disadvantages of free-range housing system. Fast-growing animals are not adapted to the organic system and health and welfare problems are recurrent (Castellini, 2005). Ward *et al*. (2001) compared Ross chickens reared under conventional and free-range conditions to see whether there was a difference in thermal resistance of the plumage and found that the free-range birds had a thicker plumage and a higher total resistance to heat transfer in the pectoral region. Farmer *et al*. (1997) found a faster body weight gain and a more efficient feed conversion ratio in Ross chickens compared to ISA chickens. Meat color was a prominent preference factor for consumers.

Le Bihan-Duval *et al*. (1999), Bianchi and Fletcher (2002) and Santos *et al*. (2005) have indicated the significant correlations between breast meat color and meat quality. Relationships were also indicated between color and composition (Qiao *et al*., 2002). The housing systems might affect breast meat color and fatty acid contents (Husak *et al*., 2008).

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There has been little research on the effects of the free-range housing systems using fast growing broiler strains on the performance and the qualitative characteristics of products. The aim of this research was to compare the growth performance, breast meat color and fatty acids composition and some blood plasma parameters of the broilers reared under conventional and the free-range housing systems.

MATERIALS AND METHODS

In this experiment, the conventional broiler housing system was compared to the free-range broiler housing system using female Ross broiler chicks had low hatching weight (approximately 31 g). From June to July 2005, one-day-old chicks, were randomly assigned to one of two housing conditions. The procedures in experiment were approved by the University Animal Care and Use Committee. The experiment was arranged to completely randomized design. In designing the experiment, it was decided to slaughter birds at the similar age (44 days). The conventional housing system was represented in three replicate indoor pens (each 0.270 m^2 $bird^{-1}$) containing 20 chicks each (60 birds per treatment). The free-range housing system was represented in three replicate indoor pens (each 0.270 m^2 $bird^{-1}$) with three grass paddocks.

Broilers in the free-range group were allowed to grass paddocks after 7 day old using a short tunnel under the wall from indoor pens to grass paddocks between 9:00 h and 18:00 h. Feed and water were provided only in indoor pens to the free-range broilers. The outdoor grass paddock covered with forage each measured 2×1.85 m. The indoor floor pens contained wood shavings and a continued photoperiod was provided. Feeders and drinkers were available indoors. The indoor temperature was 32°C at 1st week and then gradually decreased to 23°C at fourth week of age. The maximum and minimum environmental temperature in grass paddock area between 9:00 h and 18:00 h ranged from 27.98 to 23.8°C and the relative humidity ranged from 65 to 75% during the 44 days experimental period.

Birds were fed the same commercial starter (1-14 days), grower (14-35 days) and finisher (35 to 44 days) diets (Table 1). Birds received feed and water *ad libitum* throughout the experimental period. The animal by products and antibiotics were not included in diets.

Birds and feed were weight weekly for determination of body weight, feed gain and feed efficiency (feed-to-gain ratio). Mortality rate was calculated taking into account the dead birds from the 1st day of housing.

Table 1: The ingredients and the composition of the diet (as fed basis)

	Composition of diet (g kg^{-1})		
Ingredients	Starter (1 to 14 days)	Grower (14 to 35 days)	Finisher (35 to 44 days)
Corn	400.0	400.0	452.8
Soybean meal	383.6	303.2	271.4
Wheat	99.4	156.3	170.1
Fullfat soybean	8.5	36.2	-
Soybean oil	70.0	70.0	70.0
Limestone	14.4	13.2	14.1
Dicalcium phosphate	15.0	13.1	14.3
NaCl	3.5	3.5	3.5
DL-Methionine	2.1	1.0	0.3
Vitamin premix*	2.5	2.5	2.5
Trace mineral premix**	1.0	1.0	1.0
Total	1000	1000	1000
Calculated composition			
Metabolizable energy (MJ kg^{-1})	13.0	13.4	13.4
Crude protein	220	200	180
Lysine	12.5	11.5	9.5
Methionine	5.0	4.0	3.2
Methionine+cysteine	9.0	7.5	6.0
Calcium	10.0	9.0	9.0
Available phosphorus	4.5	4.0	3.5

*Vitamin premix kg^{-1} diet: Vitamin A; 12 000 IU; Vitamin D_3; 1 500 IU; Vitamin E; 50 mg; Vitamin K_3: 5 mg; Vitamin B_1: 3 mg; Vitamin B_2: 6 mg; Vitamin B_6: 5 mg; Vitamin B_{12}; 0.03 mg; Niacin: 25 mg; Ca-D-pantothenate: 12 mg; Folic acid: 1 mg; D-biotin: 0.05 mg; Apo-carotenoic acid ester: 2.5 mg; Choline chloride: 400 mg, **Trace mineral premix kg^{-1} diet: Mn: 80 mg; Fe: 60 mg; Zn: 60 mg; Cu: 5 mg; Co: 0.20 mg; I: 1 mg; Se: 0.15 mg

Feed was withdrawn 12 h prior to slaughter and then six birds from each replicate pen were killed by manual exsanguination at slaughtering plant. Automated equipment was used for scalding and picking. Blood samples were taken from baranchial vein in test tubes for analysis and centrifuged at 1800x g for 15 min. The blood plasma was obtained and analyzed as earlier described by Demir *et al*. (2008). The abdominal fat, heart, liver and spleen were evaluated as a percentage of carcass weight (Demir *et al*., 2004).

Six carcasses of each replicate were chilled and packed in polyethylene bags and stored in a refrigerator at -2°C to determine breast meat color and faty acids composition. At the time of the fatty acids analysis and color measurement, the individual carcasses from each housing system was trimmed to obtain breast (*pectoralis major*) muscles. The breast meat color were measured on the raw muscles. Readings were made on the right breast with skin. The breast meat was sliced at 1 cm thickness and submitted for analysis prior to determine meat color. The color of the breast meat was determined by the (CIELAB) method colorimeter.

According to this method, higher L* values are light, higher a* values are red and higher b* values are yellow (Miltenburg *et al*., 1992). Fatty acid changes were made on the left breast with skin. For determination of the fatty

acids of the breast meat, lipids were extracted according to the method of Folch *et al*. (1957). Fatty acids methyl esters were determined at the Laboratory of the Marmara Research Center Linked to the Scientific and Research Council of Turkey by using Perking Elmer autosystem XL gas chromatography (IUPAC, 1987).

Statistical analysis carried out by using the Generalized Linear Model Procedure of SPSS (Version 11.0). Before the analyses, data distribution was tested for normality by Probit analysis and variance homogeneity by Bartlett test. The significant differences among the mean values of treatment determined by Duncan test (Ozdamar, 1999).

RESULTS AND DISCUSSION

Performance data: The housing systems differed ($p<0.05$) 44 day body weight and feed intake. Housing systems did not influence feed conversion ratio, liveability and the relative weights of abdominal fat, heart, liver and spleen. The conventionally reared broilers consumed ($p<0.05$) more feed and gained more body weight than the free-range reared broilers. Body weights were significantly depressed by the free-range treatment. (Table 2).

Meat color and fatty acids composition: There were significant differences between the conventional and the free-range reared birds for color of breast with skin except L* color (Table 3). The housing systems had an effect ($p < 0.05$) on a* color and b* color values (Table 3). The L* color value was not affected by the housing systems. The a* color in breast meat of conventionally reared broilers was higher ($p<0.05$) than that of the free-range reared broilers. However, the b* color in breast meat of the free-range reared broilers was higher ($p<0.05$) than the conventionally reared broilers.

The fatty acids composition of breast meat were not differed ($p<0.05$) between the housing systems. In the present study, oleic acid (C18:1) was the main fatty acid in skinned breast meat fat, fallowed by linoleic (C18:2) and palmitic (C16:0).

Blood plasma and constituents: The housing systems had no effect on total cholesterol, leukocytes (WBC), erythrocytes (RBC), hemoglobin (Hb), hematocrit (Ht), Na, K and Cl levels in blood plasm, (Table 4). The plasma triglyceride and Very Low Density Lipoprotein (VLDL) levels in conventionally reared broilers were ($p<0.05$) higher than those in the free-range reared birds.

Table 2: The effects of housing systems on growth performance, liveability, relative organs and abdominal fat weight

	Housing systems		
Variables	Conventional	Free-range	Significance
Initial body weight (g)	31.160±0.21	31.210±0.21	NS
Body weight (44 days) (g)	1831.800±52.57	1639.900±63.40	*
Total feed intake (1 to 44 days) (g)	3655.300±80.25	3351.900±72.48	*
Feed conversion ratio (1 to 44 days) (kg:kg)	2.060±0.02	2.090±0.11	NS
Liveability (%)	91.670±0.85	90.000±0.82	NS
Heart (g/100 g b.wt.)	0.550±0.03	0.560±0.03	NS
Liver (g/100 g b.wt.)	1.850±0.09	1.870±0.09	NS
Spleen (g/100 g b.wt.)	0.097±0.007	0.118±0.001	NS
Abdominal fat (g/100 g b.wt.)	2.170±0.30	2.460±0.37	NS

*p<0.05; NS: Not Significant; **Data are expressed as Mean±SE

Table 3: The effects of housing systems on color and fatty acids composition (g 100 g^{-1} of total fatty acids) of breast meat

	Housing systems		
Variables	Conventional	Free-range	Significance
Breast with skin			
L color (lightness)	71.62±0.83	70.27±1.02	NS
a color (redness)	5.51±0.35	3.92±0.39	*
b color (yellowness)	4.91±0.67	5.41±1.68	*
Breast with skin			
∑ saturated fatty acids	25.66±1.04	26.22±1.05	NS
Palmitic	20.32±0.93	20.68±1.18	NS
Stearic	5.03±0.17	5.17±0.29	NS
∑ unsaturated fatty acids	74.40±4.02	73.78±3.98	NS
Palmitoleic	3.53±0.5	3.56±0.5	NS
Oleic	34.81±1.59	34.96±1.59	NS
Linoleic	33.04±2.72	32.12±2.49	NS
Eicosapentaenoic	2.05±0.21	2.10±0.16	NS

*p<0.05; NS: Not Significant; **Date are expressed as Mean±SE

Table 4: The effects of housing systems on some blood plasma constituents

	Housing systems		
Variables	Conventional	Free-range	Significance
Total cholesterol (mg dL^{-1})	118.33±13.27	125.00±6.71	NS
Triglycerides (mg dL^{-1})	61.67±3.02	41.67±2.12	*
VLDL (mg dL^{-1})	12.13±0.60	10.00±0.47	*
WBC (10^3 μL^{-1})	196.72±15.91	211.60±7.50	NS
RBC (10^6 mm^{-3})	2.44±0.19	2.60±0.07	NS
Hb (g dL^{-1})	11.30±1.48	12.28±0.37	NS
Ht (%)	31.05±2.53	32.70±0.97	NS
Na (mmol L^{-1})	236.00±6.78	243.33±4.94	NS
K (mmol L^{-1})	3.67±0.20	4.00±0.26	NS
Cl (mmol L^{-1})	52.00±6.63	56.67±4.22	NS

*p<0.05; NS: Not Significant; **Data are expressed as Mean±SE

Results of the present study have indicated that the free-range housing system had a detrimental effect on body weight and feed intake of female Ross broilers at a standard slaughter age (44 days old) compared to the conventional housing system. Results are in agreement with observations of Castellini *et al.* (2002a), who reported that outdoor organic treatments reduced growth rate compared to conventional. Confirming previous findings showed that fast growing birds do not grow well under poor environmental conditions (Reiter, 2004). Castellini *et al.* (2002b) indicated that fast growing strains do not adapt well to organic broiler meat production. The stress such as temperature, relative humidity and sun radiation in indoor and grass paddock are important indexes of environment quality to the animal (Bockisch *et al.*, 1999). Gordon and Charles (2002) reported that temperature and photoperiod have the potential to influence growth mainly by affecting feed intake.

In the present study, no shaded grass paddocks didn't contribute a significant nutrient to broilers. The greater motion, a short growth period (44 days old) for the free-range birds and the high environmental temperature during the trial might primary factors reduced slaughter weight and feed intake.

Some researchers have indicated lightness values to be an useful indicator of breast meat quality for further processing (McCurdy *et al.*, 1996; Owens *et al.*, 2000). It was generally accepted that the color values of meat are closely related to the pH values. The structure of meat myofibrils, water holding capacity and meat color was also related to pH value of meat. Castellini *et al.* (2002a) found lower pH value and water holding capacity in breast meat of the organically reared Ross male broilers compared to the conventionally reared. They assumed that the lower pH of the organically reared broilers was due to the better welfare conditions that reduced the stress pre-slaughter and thus consumption of glycogen. The low pH value reduces the importance of myoglobin in selectively absorbing green light, resulting in meat that appears less red and more yellow. Castellini *et al.* (2002a) determined higher b* color and L* color values in organic breast meat compared to the conventionally produced. They also found that the a*color value tended to decrease in organic broiler meat. The a* color value in present study is in agreement with observations of Castellini *et al.* (2002a). The shorter duration of growth period (44 days vs 56 days or 81 days) had probably effect on the breast meat color. Petracci and Fletcher (2002) indicated that the color measurement of broiler skin and breast meat are greatly affected by early aging times during processing and post-mortem aging.

Castellini *et al.* (2002a) have indicated that the breast meat of muscles of organic reared Ross broilers showed a higher fraction of saturated fatty acids and lower one of monounsaturated with respect to the conventionally reared broilers. The percentage of polyunsaturated fatty acids were higher, particularly the levels of eicosapentaenoic acid (EPA) and total n-3 fatty acids. They reported that this trend could be partly due to the different compositions of the ingested foods, caused by grass intake. Husak *et al.* (2008) reported that organic breasts contained less saturated and monounsaturated fatty acids and more polyunsaturated, omega-3 and omega-6 fatty acids when compared to the free-range and conventionally reared chickens.

The fatty acid pattern in present study (oleic-linoleic-palmitic) was inconsistent with that reported by Sheu and Chen (2002) and De Marchi *et al.* (2005). They found different fatty acid pattern (oleic-palmitic-linoleic) in breast meat. The differences in findings could be explained by the differences of the diet composition (oil supplements), grass and sex.

There are limited reports on the effects of conventional and the free-range broiler housing systems on blood constituents of broiler chickens. Birds in two housing systems were fed the same diet. The differences in plasma triglyceride and very low density lipoprotein levels might due to intake of grass in paddocks contained high levels of polyunsaturated fatty acids and improved welfare conditions of free-range birds.

From these results, it is concluded that housing broiler chickens by the free-range housing system caused a decrease in body weigh gain and feed efficiency during a conventional growth period. There was a decrease in redness and an increase in yellowness of breast meat color in free-range reared birds. The fatty acids composition of breast meat was not affected by the housing systems. The plasma triglyceride and VLDL levels was lowered by the free-range treatment. In hot climates, shaded pasture area will contribute to improve performance.

The longer growth period is necessary for the fast growing broiler strains in free-range conditions. Further research must be conducted to evaluate growth characteristics, meat quality, blood plasma costituents and birds' immune response the free-range system.

ACKNOWLEDGMENT

The authors are grateful for the financial support of the Unit of the Scientific Research Projects of Gaziosmanpasa University.

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