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Effect of Ambient Temperature and Light Intensity on Growth Performance and Carcass Characteristics of Heavy Broiler Chickens at 56 Days of Age

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Abstract: The effects of ambient temperature, light intensity and their interaction on growth performance and carcass characteristics of broilers were investigated in 2 trials. The experiment was consisted of a factorial arrangement of treatments in a randomized complete block design. The 9 treatments consisted of 3 levels (Low = 15.6, Moderate = 21.1, High = 26.7°C) of temperatures from d 21-56 d of age and 3 levels (0.5, 3.0, 20 lx) of light intensities from 8-56 d of age at 50% RH. Five hundred and forty Ross 708 chicks were randomly distributed into 9 environmentally controlled chambers (30 males and 30 females chicks/chamber) at 1 d of age. Feed and water were provided *ad libitum*. Birds were provided a four phase-feeding program (starter: 1 to 14 d, grower: 15-28 d, finisher: 29-42 d and withdrawal: 43-56 d). At 56 d of age, both feed intake and birds' weight were recorded for the growth performance. Also, 20 (10 males and 10 females) birds from each chamber were processed to determine weights and yields. Broilers subjected to high ambient temperature of 26.7°C had significantly ($P \le 0.05$) lower BW, BWG, FI, carcass weight and pectoralis major and minor weights along with a significant ($P \le 0.05$) increased in FCR when compared with low and moderate ambient temperatures broilers. Plasma corticosterone concentrations were not statistically affected by temperature, light intensity or their interaction, suggesting an absence of stress. These results indicate that exposure of modern heavy weight broilers to high ambient temperature of 26.7°C in comparison with low and moderate ambient temperatures has a negative effect on growth performance and carcass characteristics, suggesting that they need to be grown under lower ambient temperature than previously reported.

Key words: Temperature, light-intensity, stress, meat yield, broiler

INTRODUCTION

International animal welfare concerns have included the effects of temperature and lighting programs on broilers (Food Marketing Institute and National Council of Chain Restaurants, 2003; National Chicken Council, 2005). Research development in poultry production has been displayed through the genetic selection of breeds for high productivity. However, this genetic potential will not be fully realized until microenvironmental constraints (temperature, humidity, light intensity, air velocity, etc) have been fully addressed. Exposure of poultry to chronic environmental temperatures (high or low) during the course of poultry production has an adverse impact on production efficiency (BW, BWG, FCR), meat yield, immune response and mortality (Washburn, 1985; Howlider and Rose, 1989). Temperature needs of heavy birds (3.0 kg or greater) were shown to be lower than previously reported (Xin *et al.*, 1994). When ambient temperature is high, chickens have higher energy (feed) needs than when in thermoneutral environments. Major losses result from a less efficient conversion of feed to meat, which detrimentally impacts poultry health and productivity. It is estimated that a 1% improvement in feed conversion would save U.S. poultry producers more than $50 million/year.

Light management is an important component of broiler production. Most modern lighting programs begin with a high light intensity (~20 lx) that is decreased to around 5 lx by 14-21 d of age and is then maintained at 5 lx or less for the remainder of the grow-out period. However, there are currently a wide variety of lighting programs (wavelength, intensity and duration) and devices available to poultry producers, with each possessing its own characteristics and applicability to rearing poultry. Although we have a good understanding of how photoperiod affects poultry production, our knowledge of how light intensity affects poultry production is shallow by comparison. These deficiencies, as well as the associated financial losses, have led to an increased interest in developing management techniques that will maximize broiler productivity while minimizing other associated problems. As such, poultry house ambient conditions along with adequate management strategies impact productivity and livability of poultry. The potential for changing temperature and light intensity to influence broiler productivity and health is receiving considerable investigation. Therefore, it is important to determine what levels of the various ambient factors could be in poultry houses to allow broilers to realize their genetic growth potential (Xin *et al.*, 1994; Gates *et al.*, 1998). Although

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many studies have been conducted to evaluate the effect of the thermal environment on birds growth performance (Leenstra, 1992; Yoon *et al.*, 1995; Abu-Dieyeh, 2006), still more studies are necessary to examine the interrelationship of temperature and light intensity to determine the adequate microenvironments (temperature, light-intensity) that can maximize genetic potential of modern heavy broilers, while reducing production costs. The objective of the present study was to evaluate the specific effects of ambient temperature, light intensity and their interaction on growth performance, processing yield and carcass quality of modern heavy broiler chickens.

MATERIALS AND METHODS

Bird husbandry: In each of 2 trials, with each trial lasting 8 wk, 540 1-d-old Ross 708 (Aviagen Inc., Huntsville, AL) chicks were purchased from a commercial hatchery and upon arrival, the chicks were sexed and then group-weighed. Chicks were randomly distributed into 9 environmentally controlled chambers (30 males and 30 females chicks/chamber). Chambers were switched between experiments to remove chamber effects so that treatments are not confounded. Each environmentally controlled chamber had a floor area of 6 m^2 (2.3 m width x 2.6 m depth) with a chamber volume of 15.3 m^3 (2.5 m height). Chicks were vaccinated for Marek's, Newcastle and infectious bronchitis diseases at the hatchery. At 12 d of age, birds received a Gumboro vaccination via water administration. Each chamber contained 7.62 cm depth of fresh pine shavings, tube feeders and a 7-nipple watering system. Birds were provided a 4-phase feeding program (starter: 1-14 d; grower: 15-28 d; finisher: 29-42 d; withdrawal: 43-56 d). Diets were formulated to meet or exceed NRC (1994) nutrient recommendations. Starter feed was provided as crumbles and subsequent feeds were provided as whole pellets. Feed and water were offered *ad libitum*. Ambient temperature was maintained at 33°C at the start of experimentation and was reduced as the birds progressed in age until d 22 when temperature treatments started.

Experimental treatments: The temperature program treatments in this study were designated "high", "moderate" and "low" temperature to describe their relative differences. The final temperature in the "high" temperature program was 26.7°C (80 F), which would be considered a moderate temperature in the context of commercial poultry production where extreme temperatures in growout facilities with heavy broilers can approach 32.2°C (90 F). The 9 treatments consisted of 3 levels (Low = 15.6, Moderate = 21.1, High = 26.7°C) of temperatures from d 21-56 d of age and 3 levels (0.5, 3.0, 20 lx) of light intensities from 8-56 d of age at 50% RH. The sensitivity and variability of the temperature control were ±0.05°C and ±1.0°C, respectively. Light intensities were verified and adjusted when necessary weekly. Five hundred and forty Ross 708 chicks were randomly distributed into 9 environmentally controlled chambers (30 males and 30 females chicks/chamber) at 1 d of age. Three different temperature step down programs (a high temperature, HT; moderate temperature, MT and lower temperature, LT) were applied along with 3 levels (0.5, 3.0, 20 lx) of light intensities in 3 different chambers per temperature along with light 3 different chambers per intensity group for a total of 9 chambers. Each of the 3 temperature level treatments was paired with one of the three light intensity treatments so that each chamber represented a particular temperature:light-intensity level combination. Ambient temperature treatment step down decreased linearly everyday from 33°C at 1 d of age to reach targeted temperatures of 26.7, 21.1 and 15.6°C, respectively on d 21, to 56 d of age (Fig. 1). The light-intensity from d 1 to d 7 was 20 lx in each chamber. Each chamber was equipped with incandescent lighting, typical of that used in commercial housing. Light intensity settings were verified at bird level (30 cm) using a photometric sensor with NIST-traceable calibration (403125, Extech Instruments, Waltham, Mass) for each intensity adjustment. The light fittings and tubes were cleaned weekly in order to minimize dust build-up, which would otherwise reduce the intensity.

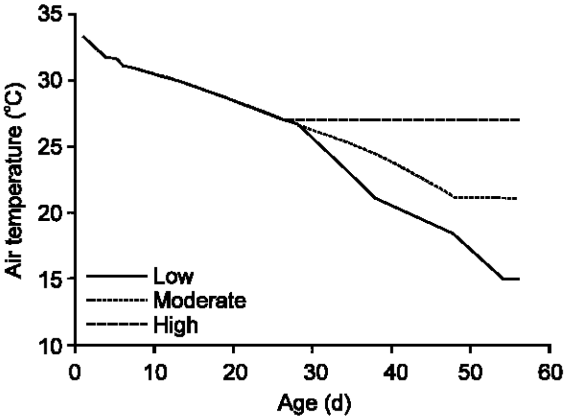

Fig. 1: Ambient temperature treatments step down decreased linearly everyday from 33°C at 1 d of age to reach targeted temperatures of 26.7, 21.1 and 15.6°C, respectively on d 21, to 56 d of age

Measurements: Both feed intake and birds' weight were recorded on d 56 of age for the computation of growth rate, feed consumption and feed conversion. The incidence of mortality was recorded daily and feed conversion was corrected for mortality. Necropsies and cause of death were performed on all birds that died during the trials. Furthermore, on d 56, 20 (10 males/10 females) birds per chamber were randomly selected for processing, weighed and subjected to a 12-h feed withdrawal period. This weight was used to calculate carcass and breast meat yield. Thereafter, the birds were placed in coops and transported to the Mississippi State University Poultry Processing Plant. Birds were electrically stunned, bled, scalded, mechanically picked and mechanically eviscerated. Whole carcass (without neck, giblets, abdominal fat pad) and abdominal fat pad were weighed. Carcasses were split into front and back halves and placed on ice for 4 h after which the front halves were deboned to obtain weights of skinless, boneless, breast fillet (pectorals major muscle) and breast tender (pectorals minor muscle). Carcass yield, abdominal fat pad and total breast meat yields (sum of pectorals major and minor muscles) were determined from live weights (post-feed withdrawal) of the broilers selected for processing at 56 d of age.

Statistical analysis: A 3 x 3 factorial arranged in a randomized complete design was used in this study. Data were replicated over time, with trial being the blocking factor. Chamber was considered the experimental unit. The 9 treatments consisted of 3 levels of temperature x 3 levels of light intensity. The main effects of temperature and light intensity and the interaction of these two factors on live performance, processing yield and carcass quality were tested by using the MIXED procedure of SAS software (SAS Institute, 2004). All mortality data were subjected to arc sine transformation. Means comparisons on d 56 were assessed by least significant differences and statements of significance were based on $P \leq 0.05$.

RESULTS

The influences of ambient temperature exposure, light intensity and their interaction on growth performance of the broilers at d 56 are presented in Table 1. Broilers reared at 26.7°C had a significant ($P \leq 0.05$) reduction in BW, BWG, FI, along with significant ($P \leq 0.05$) increased in FCR when compared with low and moderate ambient temperatures broilers. Mortality was not significantly different between treatments, but rather variable and did not appear to be either temperature, light intensity or their interaction dependent. The main effect of light intensity on the examined variables was not observed in the present study. There was also no significant effect of ambient temperature x light intensity interaction on the examined variables. There were no significant main effects of temperature, light intensity, or their interaction on plasma corticosterone (data not shown). Broilers reared at 26.7°C had a significant ($P \leq 0.05$) reduction in live and carcass weights when compared with broilers reared at 15.6°C and 21.1°C (Table 2). The main effect of ambient temperature on fat yield only approached significance at P = 0.0705. There were no significant main effects of temperature, light intensity, or their interaction on carcass yield and fat weight in the present study. Similar to growth performance data, there was no significant effect of light intensity or temperature x light intensity interaction on all examined variables in the present study.

The influence of ambient temperature, light intensity and their interaction on breast weights and yields of broilers at 56 d of age are presented in Table 3. Broilers reared at 26.7°C ambient temperature had a significant ($P \leq 0.05$) reduction in fillet and tender weights along with fillet yields when compared with 15.6°C and 21.1°C ambient temperatures broilers. The main effect of ambient temperature on tender yields only approached significance at P = 0.0590. There was no significant effect of light intensity or temperature x light intensity interaction on fillet and tender in the present study.

DISCUSSION

When considering the birds' microenvironments, temperature and light are two of the major factors. These factors along with others (RH, air velocity, stocking density) affect the birds' metabolism, which in turn is responsible for maximizing growth performance and body heat to maintain normal physiological processes and functions. The current study clearly demonstrates that high ambient temperatures markedly affect the performance of the bird, as shown by decreased food consumption and growth. Further, the present study supports the general concept that over the growing period, the ambient temperature ranges of 15.6°C and 21.1°C is more suitable for modern heavy broilers, which is similar to that of mature fowls (Charles, 1986). The results of the current study indicated that the increased ambient temperature had a significant impact on the metabolism of modern heavy broiler chickens. These metabolic changes were represented by reduced BW, BWG, FI and increased FCR of chickens during the growth period that had a significant negative impact on the efficiency of production. It has been shown that the chicken is most comfortable, more productive and stress is minimized when the ambient temperature is in the thermoneutral zone (Deaton *et al.*, 1978).

The results obtained in this study, with respect to BW, weight gain, feed intake and feed conversion ratio, are in agreement with the temperature effects reported by others (Deaton *et al.*, 1984; McNaughton and Reece, 1984). Modern fast-growing broilers must consume large quantities of feed in order to attain maximal growth rate. However, the intake and metabolism of feed have a thermogenic effect. At high ambient temperatures, the heat increment aggravates the problem by adding more heat to an already heat stressed system. Unless the basal metabolic rate can be reduced, or the bird's tolerance of hyperthermia increased, feed intakes must decline to allow the maintenance of homeothermy. The bird therefore, reacts by lowering its voluntary feed intake, thereby decreasing the extra heat to be

Table 1: Influence of temperature and light-intensity on growth performance of broilers at 56 d of age[1]

Item	BW (kg)	BW gain (kg)	FI (kg)	FCR	MORT (%)
Temperature treatment (°C)					
Low (15.6)	3.910^{a}	3.867^{a}	7.673^{a}	1.977^{b}	1.45
Moderate (21.1)	3.661^{a}	3.618^{a}	7.302^{a}	2.011^{b}	2.31
High (26.7)	3.075^{b}	2.516^{b}	6.497^{b}	2.598^{a}	2.07
Intensity treatment	3.598	3.445	7.364	1.977	2.64
0.5 lx	3.524	3.336	7.148	2.011	0.86
3.0 lx	3.525	3.221	6.960	2.598	2.31
20 lx					
SEM[2]	0.073	0.089	0.265	0.123	0.953
Temperature-light intensity treatment					
Low-0.5 lx	3.971	3.928	7.813	1.983	2.63
Low-3.0 lx	3.810	3.767	7.473	1.981	0.86
Low-20 lx	3.950	3.907	7.734	1.968	0.85
Moderate-0.5 lx	3.737	3.694	7.432	2.010	1.72
Moderate-3.0 lx	3.606	3.563	6.938	1.936	1.72
Moderate-20 lx	3.641	3.598	7.535	2.088	3.48
High-0.5 lx	3.086	2.712	6.845	2.542	3.57
High-3.0 lx	3.156	2.677	7.032	2.647	0.79
High-20 lx	2.985	2.159	5.613	2.605	2.63
SEM[3]	0.126	0.154	0.823	0.214	1.151
Source of variation	-----------------------------	------------------	P-value	------------------	-----------------------------
Temperature	0.0001	0.0001	0.0251	0.0101	0.8077
Light intensity	0.7223	0.2577	0.8379	0.9694	0.4093
Temperature x light intensity	0.7726	0.2817	0.7721	0.9871	0.7277

[ab]Means within a column and effect that lack common superscripts differ significantly ($P \leq 0.05$)

[1]FI = Feed intake per bird; FCR = Feed conversion ration corrected for mortality

[2]Pooled SEM for main effects (n = 6)

[3]Pooled SEM for interaction effect (n = 2)

dissipated to the environment and limiting the loss for thermolysis. Due to the voluntary decreasing in feed intake, growth rate decrease under high temperature. These energy-consuming responses in a hot environment could reduce retention of metabolizable energy, thus reducing growth rate. A number of previous studies have observed similar detrimental effects of high environmental temperature on BW, BWG in chickens that increased with age especially during the last wk of production at 8 wks of age (Plavnik and Yahav, 1998; Alfataftah and Abu-Dieyeh, 2007). Harris *et al.* (1977) reported that the best environmental temperatures for optimum performance of broilers from 3-8 weeks of age were a constant 24°C or diurnal cyclic from 18-24°C. Deaton *et al.* (1984) reported similar findings that lowering the portion of the temperature cycle from 26.7-21°C during a 24-h period significantly increased broiler body weight at 48 d of age.

In the current study, the depression in the growth rate and body weight gain at high environmental temperatures (26.7°C) might be due to many factors which include decreasing feed consumption (Emmans and Charles, 1989), inefficient digestion (Har *et al.*, 2000), impaired metabolism (Farrell and Swain, 1978), genetic make up of birds (Cahaner *et al.*, 1995) and temperature *per se* (Abu-Dieyeh, 2006). This is confirmed by the results of Leeson *et al.* (1992) wherein the optimum environmental temperature range in which broilers are able to perform to their maximum genetic potential is between 12.7 and 26.7°C from 4-9 weeks of age.

The higher feed conversion ratio observed in broilers under high ambient temperature agreed with report of Leeson *et al.* (1992) who reported that the best values of feed efficiency and feed conversion for broilers are obtained under optimum environmental temperature (12.7-26.7°C). In addition, other investigators (Reece and Lott, 1983; Meltzer, 1986) reported ambient temperature above 28°C had a negative effect on feed to gain ratio of broilers compared with those reared at 21°C. The poor conversion ratio obtained at 26.7°C in this study might be related to decreased feed consumption, decreased feed utilization (insufficient digestion) as reported by previous researchers (Wiernusz and Teeter, 1996; Yahav *et al.*, 1996). Mortality did not appear to be temperature or light intensity dependent. Data for mortality were rather variable and showed no trends that can be attributed to temperature.

In the current study, broilers reared at 26.7°C showed reduction in live weight, carcass weight, fillet weight,

Table 2: Influence of temperature, light-intensity on live weights, carcass weights and yields of broilers at 56 d of age[1,2]

Item	Live weight (kg)	Carcass weight (kg)	Carcass yield (%)	Fat weight (kg)	Fat yield (%)
Temperature treatment (°C)					
Low (15.6)	3.85^a	2.78^a	72.4	0.080	2.92
Moderate (21.1)	3.71^a	2.67^a	72.0	0.073	2.85
High (26.7)	3.13^b	2.31^b	73.5	0.075	3.29
Light Intensity treatment					
0.5 lx	3.50	2.55	72.8	0.078	3.09
3.0 lx	3.63	2.60	71.9	0.074	2.95
20 lx	3.56	2.60	73.2	0.077	3.01
SEM[3]	0.150	0.160	3.434	0.004	0.199
Temperature-light intensity treatment[1]					
Low-0.5 lx	3.84	2.72	71.1	0.083	3.03
Low-3.0 lx	3.73	2.73	72.9	0.078	2.90
Low-20 lx	3.96	2.89	73.1	0.08	2.81
Moderate-0.5 lx	3.52	2.63	73.5	0.078	3.03
Moderate-3.0 lx	3.91	2.71	69.6	0.065	2.53
Moderate-20 lx	3.65	2.66	72.8	0.078	2.98
High-0.5 lx	3.10	2.29	73.9	0.073	3.21
High-3.0 lx	3.24	2.37	73.1	0.080	3.42
High-20 lx	3.07	2.26	73.6	0.073	3.26
SEM[4]	0.260	0.277	5.948	0.006	0.345
Source of variation	----------------------	----------------------	p-value	----------------------	----------------------
Temperature	0.0001	0.0171	0.8944	0.1833	0.0705
Light Intensity	0.7163	0.9212	0.9245	0.6406	0.7753
Temperature x light intensity	0.6766	0.9651	0.9736	0.1785	0.5938

[1] Means within a column and effect that lack common superscripts differ significantly ($P \le 0.05$)

[2] Carcass without giblets, necks and abdominal fat are expressed as a percentage of live weight, while abdominal fats are expressed as a percentage of carcass weight

[3] Pooled SEM for main effects (n = 12)

[4] Pooled SEM for interaction effect (n = 4)

Table 3: Influence of temperature, light-intensity on breat weights and yields of broilers at 56 d of age[1,2]

Item	Fillet weight (kg)	Fillet yield (%)	Tender weight (kg)	Tender yield (%)
Temperature treatment (°C)				
Low (15.6)	0.739^a	26.56^a	0.158^a	5.71
Moderate (21.1)	0.690^a	25.86^a	0.149^a	5.57
High (26.7)	0.555^b	24.05^b	0.122^b	5.30
Light intensity treatment				
0.5 lx	0.654	25.60	0.143	5.59
3.0 lx	0.666	25.51	0.143	5.50
20 lx	0.664	25.36	0.143	5.50
SEM[3]	0.042	0.302	0.005	0.166
Temperature-light intensity treatment[1]				
Low-0.5 lx	0.733	26.89	0.163	5.89
Low-3.0 lx	0.713	26.07	0.153	5.61
Low-20 lx	0.773	26.71	0.160	5.64
Moderate-0.5 lx	0.673	25.60	0.150	5.64
Moderate-3.0 lx	0.713	26.29	0.148	5.41
Moderate-20 lx	0.685	25.69	0.150	5.66
High-0.5 lx	0.558	24.31	0.118	5.23
High-3.0 lx	0.573	24.15	0.130	5.49
High-20 lx	0.535	23.68	0.118	5.19
SEM[4]	0.073	0.523	0.010	0.288
Source of variation	----------------------	p-value	----------------------	----------------------
Temperature	0.0005	0.0001	0.0001	0.0590
Light Intensity	0.9559	0.7299	0.9868	0.8306
Temperature x light intensity	0.8750	0.2524	0.5544	0.5595

[1] Means within a column and effect that lack common superscripts differ significantly ($P \le 0.05$)

[2] Pectoralis major and minor breast muscles are expressed as a percentage of carcass weight

[3] Pooled SEM for main effects (n = 12)

[4] Pooled SEM for interaction effect (n = 4)

tender weight and fillet yields at 56 d old. Previous research has reported that decrease in carcass composition, meat yield and particularly breast meat yield in broilers due to high ambient temperature

(Howlider and Rose, 1989; Leenstra, 1992; Geraert *et al*., 1996), which are undesirable, considering the economic value of breast meat in broilers. In conclusion, these data indicate that exposure of modern heavy broilers to high ambient temperature of 26.7°C that we used in this study in comparison with low and moderate ambient temperatures at 56 d old has a negative effect on growth performance and carcass characteristics, suggesting that modern heavy broilers need to be grown under lower ambient temperature than previously reported.

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