

Performance and Heat Tolerance of Broilers as Affected by Genotype and High Ambient Temperature

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ABSTRACT : This experiment was conducted to evaluate the effects of the broiler's genotype (G_t) and ambient temperature (T_a) on performance and core body temperature (T_{core}) of broiler chicks. A factorial arrangement of two G_t (Hubbard and ISA J57 chicks) and two T_a (moderate, $23 \pm 0.5^\circ\text{C}$ and hot, $33 \pm 0.5^\circ\text{C}$) were used in this study. Performance data (body weight gain, feed intake and feed:gain ratio) were determined weekly for six weeks. Chicks' T_{core} was measured using a biotelemetric system between Weeks five and six. Results showed that body weight gain and feed intake were significantly high, and feed:gain ratio was significantly low for Hubbard chicks compared to those of ISA J57 chicks. High T_a significantly reduced weight gain and feed intake. Furthermore, the reduction in body weight gain and feed intake under the hot T_a was more pronounced for Hubbard chicks than those of the ISA J57 chicks resulting in significant G_t by T_a interaction. Chicks grown under moderate T_a had significantly lower T_{core} than those grown under hot T_a . The T_{core} of the Hubbard chicks was significantly lower than that of the ISA J57 at the moderate T_a while under the hot T_a , the magnitude of the change in T_{core} was more pronounced in Hubbard chicks than that of ISA J57; this resulted in a significant G_t by T_a interaction. The results of this study indicate that chicks with higher potential for growth under thermo-neutral temperature are more susceptible to heat stress than chicks with lower potential for growth. This maybe due, at least in part, to their lower body T_{core} under moderate temperature and to the lesser ability of these fast growing chicks to regulate their T_{core} when exposed to heat stress, as was clearly shown on these birds' performance. (*Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 10 : 1502-1506*)

Key Words : Genotype, Ambient Temperature, Performance, Biotelemetry, Body Temperature

INTRODUCTION

The adverse effects of elevated ambient temperature (T_a) on the performance of broilers are well documented (Hurvitz et al., 1980; Austic, 1985; Cahaner and Leenstra, 1992; Cahaner et al., 1993; Belay and Tetter, 1996; Ain Baziz et al., 1996; Geraert et al., 1996; Mendes et al., 1997; Al-Batshan and Hussein, 1999). This necessitated the use of cooling and ventilation systems, which increase the cost of production and do not always completely overcome the adverse effects of hot climates.

Genetic selection that gave today's fast growing broiler chicks no doubt contributed the most to the advancement of the poultry industry. Sherwood (1979) reported that growth rate of a 1979 broilers strain was increased by about 225% over those of 1957 Athens-Canadian Randombred Control, with about 90% of this improvement due to genetics. Similarly, Havenstein et al. (1994a) showed that body weight of a 1991 broiler strain (Arbor Acres) was higher by 270% than that of a 1957 Athens-Canadian Randombred Control. Despite this improved potential of today's broiler chicks, mainly enhanced growth rate and feed conversion, little attention has been given to other production criteria. Thus, livability and skeletal formation (Havenstein et al.,

1994a), organ development (Havenstein et al., 1994b), and immunocompetence (Qureshi and Havenstein, 1994) may have been compromised. Moreover, little or no attention has been given to the effects of various environmental stressors on the ability of today's bird to resist such stressors. Particularly, the ability of today's various broiler stocks to resist heat stress received little attention.

The objective of this study is to further assess the contribution of genetic selection toward enhanced potential for growth on the heat tolerance and performance of today's fast growing chicks under heat stress.

MATERIALS AND METHODS

Experimental design and management

Two hundred and fifty six 1-d-old commercial broiler chicks of two genotypes (128 Hubbard chicks and 128 ISA J57 chicks) were obtained from two local hatcheries. The birds were wing-banded, individually weighed, and divided into 32 groups of eight chicks each. The groups, within genotype (G_t), had comparable mean weights at the start of the trial. Four treatments, the result of a 2×2 factorial arrangement of two G_t of broilers and two T_a , were used. Each of 16 groups (eight groups per G_t) was housed in one of two adjacent windowless environmentally controlled rooms. The rooms had common ventilation and air-conditioning systems and rooms' temperature was set at

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23±1°C throughout the trial and relative humidity was approximately 60±5%. In one room, each group of birds was kept in a separate pen equipped with one trough feeder and two nipple waterers in thermostatically controlled battery brooders at 33±0.5°C during the first week and then the brooding temperature was gradually reduced to 23±0.5°C by the end of the fourth week; thereafter the temperature was kept at 23±0.5°C until the end of the trial. In the other room, each group of birds was kept in a separate pen in thermostatically controlled battery brooders at 33±0.5°C from day one until the end of the trial. Birds were fed *ad libitum* starter (3.150 kcal ME/kg, 23% CP, 0.95% TSAA, 1.30% lysine, 1% Ca and 0.45% available P) and grower (3.200 kcal ME/kg, 20% CP, 0.76% TSAA, 1.09% lysine, 0.90% Ca and 0.35% available P) feeds from 0 to 3 and from 3 to 6 weeks of age, respectively. Light was provided continually. All birds were vaccinated against Newcastle disease and infectious bronchitis at day old.

Body weight, by pen, was recorded weekly and the average daily gain was calculated. Feed, by pen, was weighed at the beginning and the end of each week and average daily feed intake and feed conversion ratio (feed:gain) were calculated. Performance data were collected for six weeks and were summarized for presentation each three weeks. Mortality was very low and was not affected by treatments; therefore it is not reported.

Telemetry system

Core body temperature (T_{core}) was measured using a radio telemetry system. This system consisted of twelve implantable single-stage temperature transmitters (Sirtrack Limited, Private Bag 1403, Goddard Lane, Havelock North, New Zealand) and a programmable-scanning receiver (TR-5) equipped with data acquisition (Telonics Inc, 932 E, Impala Avenue, Mesa, Arizona 85204-6699, USA). The transmitters' frequencies used in this study ranged from 150.10 to 150.24 MHz separated by 0.02 MHz, weighed 7.5 g, and their pulse rate varied with the bird's T_{core} . The transmitters have an accuracy of 0.1°C and were calibrated in a water bath with temperature stability of ±0.05°C. The TR-5 receiver has the ability to step through multiple frequencies and was programmed, using a personal IBM-compatible computer, for high sampling rate by dwelling for each transmitter's frequency for 10 second and acquiring data for 15 second. Qualified pulses (that meet minimum specific number of consecutive pulses with a specific pulse rate and pulse width) were archived and date and time stamped (a maximum of eight reading for each bird per scan interval was programmed). When all transmitters were scanned, the receiver was programmed to repeat the cycle every two minutes for four consecutive days. Acquired data was transferred to an IBM-compatible computer. Core body temperature data were extrapolated

using each transmitter's calibration curve.

Surgical procedure

The transmitters were sterilized by immersion overnight in 70% ethanol and were rinsed with sterile saline prior to implantation. Twelve (3 male chicks per treatment) 5-wk-old broiler chicks were fasted overnight. Fasted chicks were anaesthetized with Ketamine hydrochloride (35 mg/kg BW) (Ketanidor 10%, Richter Pharmacia, C. Richter GesmbH and Co KG, Wels, Austria). Transmitters were implanted in the abdominal cavity 1-cm under the tip of the sternum. The birds returned to normal activity within few hours; however, telemetry data acquisition was recorded three days post surgery to allow birds complete recovery from surgical procedure.

Statistical analysis

Performance data (body weight gain, feed intake and feed:gain ratio) were statistically analyzed by two-way ANOVA using the GLM of PCSAS[®] (SAS Institute, 1998). The following model was used:

$$Y_{ijk} = \mu + G_i + A_j + GA_{ij} + e_{ijk}$$

Where Y_{ijk} is the individual observation; μ is the experimental mean; G_i is the effect of i^{th} genotype; A_j is the effect of j^{th} ambient temperature; GA_{ij} is the genotype by ambient temperature interaction; e_{ijk} is random error.

Core body temperature was statistically analyzed by three-way ANOVA using the GLM of PCSAS[®] (SAS Institute, 1998). The following model was used:

$$Y_{ijkh} = \mu + T_i + G_j + A_k + TG_{ij} + TA_{jk} + GA_{jk} + TGA_{ijk} + e_{ijkh}$$

Where Y_{ijkh} is the individual observation; μ is the experimental mean; T_i is the effect of the i^{th} time of day; G_j is the effect of j^{th} genotype; A_k is the effect of ambient temperature; TG_{ij} is the effect of time of day by genotype interaction; TA_{jk} is the effect of time of day by ambient temperature interaction; GA_{jk} is the effect of genotype by ambient temperature interaction; TGA_{ijk} is the effect of time of day by genotype by ambient temperature interaction; e_{ijkh} is random error. Statements of statistical significance were based on $p \leq 0.05$.

RESULTS AND DISCUSSION

Results of body weight gain, feed intake, and feed:gain ratio are presented in Table 1. Genotype significantly affected body weight gain during 0-3, 3-6 weeks and when averaged throughout the trial. Hubbard chicks significantly outgrew ISA J57 chicks by about 15.4, 16.2, and 16.1% during 0-3, 3-6, and 0-6 weeks of age, respectively.

Table 1. Effects of genotype of broiler (G_t) and ambient temperature (T_a) on the performance of broilers grown to 6 weeks of age¹

Trait	Ambient temperature ²				SEM	Probability		
	Hubbard		ISA J57			G_t	T_a	$G_t \times T_a$
	Mod	Hot	Mod	Hot				
Weight gain, g								
0-3 weeks	680	624	581	548	17.3	0.001	0.024	0.541
3-6 weeks	1,429	1,093	1,138	1,031	31.8	0.001	0.001	0.002
0-6 weeks	2,110	1,717	1,719	1,579	28.1	0.001	0.001	0.001
Feed intake, g								
0-3 weeks	904	857	832	801	18.9	0.004	0.066	0.706
3-6 weeks	2,489	2,001	2,120	1,897	35.2	0.001	0.001	0.002
0-6 weeks	3,393	2,859	2,952	2,698	39.2	0.001	0.001	0.003
Feed:gain ratio								
0-3 weeks	1.33	1.38	1.43	1.46	0.02	0.001	0.107	0.651
3-6 weeks	1.74	1.85	1.87	1.84	0.04	0.165	0.339	0.126
0-6 weeks	1.61	1.67	1.72	1.71	0.02	0.001	0.237	0.107

¹Means of eight replicate pens of eight chicks per pen.

²Birds were kept at either $33 \pm 0.5^\circ\text{C}$ during the first week and then the brooding temperature was reduced gradually to $23 \pm 0.5^\circ\text{C}$ by the end of the fourth week, thereafter the temperature was kept at $23 \pm 0.5^\circ\text{C}$ until the end of the trial (Mod) or constant $33 \pm 0.5^\circ\text{C}$ (Hot) throughout the trial.

Similarly, these chicks consumed significantly more feed by about 7.8, 11.7, and 10.7% during 0-3, 3-6, and 0-6 weeks of age, respectively. Hubbard chicks' feed:gain ratios were significantly reduced compared to those of the ISA J57 chicks by 6.2 and 4.4% during 0-3 and 0-6 weeks of age, respectively.

Heat stress significantly reduced body weight gain by about 7.1, 17.2, and 13.9% during 0-3, 3-6, and 0-6 weeks of age, respectively. However, the magnitude of the reduction in body weight gain of heat stressed chicks was different for the two G_t (Hubbard; 23.5 and 18.6% vs ISA J57; 15.8 and 12.5%, during 3-6 and 0-6 weeks of age, respectively), which resulted in significant G_t by T_a interactions. Feed intake was not significantly affected during 0-3 weeks of age but was significantly reduced by heat stress by 15.5 and 12.4% during 3-6 and 0-6 weeks of age, respectively. Similar to gain, the magnitude of the reduction in feed intake was different for the two G_t (Hubbard; 19.6 and 15.7 vs ISA J57; 10.5 and 8.6 during the periods of 3-6 and 0-6 weeks of age, respectively), which resulted in significant G_t by T_a interactions. Feed:gain ratio was not significantly affected by heat stress. These results on gain and feed intake closely agree with most of that reported in the literature (Ain Baziz et al., 1996; Geraert et al., 1996; Mendes et al., 1997). The severity of the reduction in gain and feed intake as a result of heat stress is dependent on several factors, including the broiler's sex, age, and strain and on the experimental setting used in a particular study. Additionally, feed:gain ratio was reported to increase (Bonnet et al., 1997), decrease (Al-Batshian and Hussein, 1999) or not affected (Al-Batshian and Hussein, 2001) by heat stress.

It is common that broilers are brooded at high temperature early in their life and the temperature is reduced gradually as they grow older. The results obtained

here clearly show that older birds are more susceptible to heat stress than younger birds. Weight gain was reduced by 7 and 17%, and feed intake was reduced by 5 and 15% during 0-3 and 3-6 weeks of age, respectively. Therefore, the reduction in performance was more pronounced in older birds. Similarly, Charles (1986) reported that optimum temperature for performance decreases with age of the bird. May et al. (1998) concluded that warm temperature and increased body weight were detrimental to gain. Cahaner et al. (1998) reported that fast growing chicks were more sensitive to changes in T_a . Therefore, May and Lott (2001) concluded that sex, body weight and the rate of growth of the broiler chick are important factors in the effects of rearing temperature on broiler performance.

Thus, T_{core} was determined with maximum stress in mind (males, heavy and fast growth rate) and its relationship to the bird's ability to regulate its T_{core} . Indeed the results on performance reported herein reflected the design of this experiment as shown in the significant interactions between G_t and T_a for gain and feed intake. These significant interactions clearly showed that fast growing strains are more susceptible to heat stress than those with slow or moderate growth rate.

Average daily T_{core} values are illustrated in Figure 1. Heat stress significantly increased T_{core} of the birds and this is similar to findings of others (Uneo and Otani, 1987; Beers et al., 1989; Yahav et al., 1997). The Hubbard chicks had significantly lower T_{core} than those of the ISA J57 under moderate T_a . However, when these fast growing chicks were exposed to higher T_a , the magnitude of the increase in T_{core} was more pronounced in the Hubbard chicks than those of the ISA J57, resulting in significant G_t by T_a interaction. Cooper and Washburn (1998) reported significant negative correlation between body temperature (i.e., rectal) and gain and feed intake. Although one would

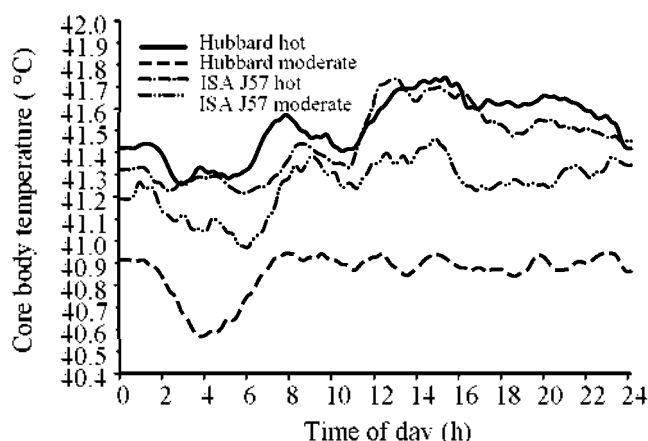


Figure 1. Effects of time of day (T_d), genotype of broiler (G_t) and ambient temperature (T_a) on core body temperature of broiler chicks measured between five and six weeks of age. Chicks were kept at either $33\pm 0.5^\circ\text{C}$ during the first week and then the brooding temperature was reduced at the rate of 3°C per week to $23\pm 0.5^\circ\text{C}$ by the end of the fourth week, thereafter the temperature was kept at $23\pm 0.5^\circ\text{C}$ until the end of the trial (moderate) or constant $33\pm 0.5^\circ\text{C}$ (hot) throughout the trial. (T_d , $p < 0.05$; G_t , $p < 0.001$; T_a , $p < 0.001$; $T_d \times G_t$, NS; $T_d \times T_a$, NS; $G_t \times T_a$, $p < 0.001$; $T_d \times G_t \times T_a$, NS and SEM=0.10 with three chicks per treatment group).

expect to find a higher T_{core} for fast growing chicks given their state of higher and faster metabolic rate needed to meet the demands for their increased gain during this stage of growth, this was not the case. The results obtained from this study proved that birds with fast growth rate and large body size had low T_{core} than those with slow growth rate and small body size under moderate temperature. However, it cannot be determined from this study whether the huge rise in T_{core} for the Hubbard chicks compared to that of ISA J57, when subjected to heat stress, was due to genetic differences between the two strains or was due to the size of the bird per se. There are some reports, however, indicating that birds with higher body weight tended to have lower body temperature (Dunnington et al., 1987). Similarly, Emmans and Kyriazakis (2000) found that adverse effects of heat stress on broilers with higher body weight and more rapid growth were more pronounced than those with lower body weight and growth. It cannot be excluded that these differences could be attributed to genetic differences rather than body weight per se. Uneo and Komiyama (1987) reported that the birds' ability to lose heat or regulate body temperature is genetically controlled. Also, Yalcin et al. (1997) reported that broilers from three breeding companies responded differently under hot and temperate climates despite their similar growth rate.

Regardless of the genetic background of the chicks, it is very clearly shown in this study that the trends in gain and

feed intake, as a result of exposure to heat stress, are inversely related to the rise in the bird's T_{core} . Indeed our results agree with those reported by Cooper and Washburn (1998) who showed a lack of significant correlation between body temperature and economic traits (such as gain and feed conversion) under thermo-neutral conditions. But when these birds were grown under high T_a , significant negative correlation existed between economic traits and body temperature. More important, however, is that these negative correlations become more significant and larger with age (weight) of the broiler.

Whether these differences were due to genetic difference between strains of broilers or to body weight remains to be known. Nonetheless, the results of the present work clearly show that there is a strong association between the G_t of the broiler and its response to heat stress in terms of the depression in performance and the concurrent rise in its body temperature. It is important to note that future breeding programs are expected to further increase the broiler gain that can be detrimental to the poultry industry in countries where climate is of major concern as fast growing chicks are more susceptible to heat stress. It is also more important to consider the changes in the broiler's body temperature in response to changes in T_a rather than the body temperature per se under optimal conditions when identifying and selecting broilers for better ability to resist heat stress. Thus, until such heat-tolerant broilers become available to poultry producers in countries where heat stress can be of a major concern, it appears that birds with slower growth rate are more suitable for production in those countries especially during summer.

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