The Relationships between Abdominal Temperature and Some Thermoregulatory Responses in Male Broiler Chickens

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ABSTRACT : This study was conducted to determine the relationships between abdominal temperature (Tabd) and some thermoregulatory responses, such as heat production (HP), heart rate (HR), respiration rate (RR), temperature of external ear tract (Tee), comb surface temperature (Tcs) and shank skin temperature (Tss), for revealing the role of deep body temperature in the thermoregulation of broiler chickens. Tabd was divided into 5 zones of 40-41, 41-42, 42-43, 43-44 and 44-45°C, and maintained for 3 hours in each zone by varying environmental temperature from 11 to 33°C. HP and HR had a greater increase with Tabd above 42.5°C. RR increased markedly with Tabd above 41.5°C, and reached a maximum when Tabd was at 42.5°C, then began to decrease. In addition, HP and HR increased significantly with decreased RR during the decreasing phase of panting. Tcs and Tss changed rapidly with Tabd when Tabd was below 41.5°C, and increased more slowly above 41.5°C. Tee was lower than Tabd, and its increase was less than that of Tabd. These results suggest that changes in thermoregulatory responses are induced by an increase in abdominal temperature. Tabd increases to adjust the ratio of sensible and evaporative heat loss when Tabd is below 42.5°C, while the ability in body temperature regulation gradually disappears when abdominal temperature exceeds 42.5°C and heat balance can not be maintained.

(**Key Words**: Thermoregulatory Response, Heat Production, Abdominal Temperature, Broiler Chickens)

INTRODUCTION

Broilers, like mammals, are homeotherms; thus they are able to keep their deep body temperature within a relatively narrow range. However, it is not easy to maintain a constant deep body temperature; that is, deep body temperature is always changing within a range with environmental conditions. The change in levels of the deep body temperature is necessary for maintaining heat balance under given conditions. This will lead to a series of thermoregulatory responses. It has been shown that, in chickens, an increase or recovery in body temperature occurs earlier than those in respiration rate (RR) and shank skin temperature (Tss) (Shishido, 1977; Zhou et al., 1996b). In birds, the conclusions have been summarized as follows (Barnas and Rautenberg, 1987). As body temprature increases, expired minute volume is augmented by large increases in respiratory frequency, although tidal volume is diminished. With further increases in body temperature, tidal volume begins to increase towards normal and respiratory frequency

decreases. How the change of the deep body temperature will influence thermoregulatory responses still remains to be determined in broilers near marketable weight.

The present study, therefore, was conducted to determine the relationships between abdominal temperature (Tabd) and some thermoregulatory responses for revealing the role of the deep body temperature in thermoregulation of broiler chickens.

MATERIALS AND METHODS

Eight male broilers (Chunky), aged 46-55 days and weighed 2.7-3.4 kg, were used in this study. Usually, the birds were kept in individual cages (25 × 45 × 39 cm³) at an environmental temperature of 20/14°C (DBT/WBT, DBT: dry-bulb temperature, WBT: wet-bulb temperature), and provided with food (ME 13.2 MJ/kg, CP 180 g/kg; New Power, Nichiwa Sangyo Co. Ltd., Japan) and water *ad libitum*. The lighting pattern was 14 h light: 10 h dark commencing at 06:00. Tabd was divided into 5 zones of 40-41, 41-42, 42-43, 43-44 and 44-45°C, and maintained for 3 hours at each zone by varying environmental temperature from 11/9.5 to 33/31°C (DBT/WBT); that is, to keep Tabd constant for 3 h within the

expected zone, the environmental temperature was increased or decreased at any time. Figure 1 is an example adjusting environmental temperature to keep Tabd constant within the zone of 44-45℃.
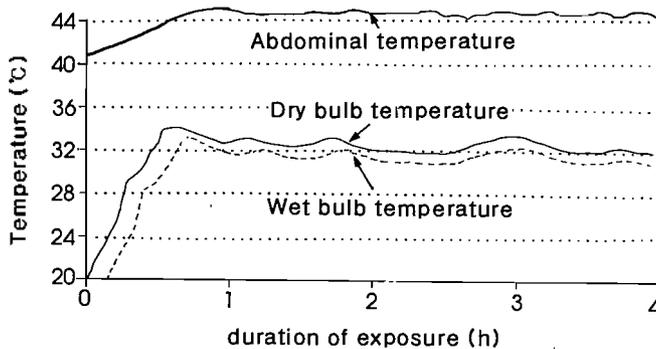

Figure 1. An example adjusting environmental temperature to keep abdominal temperature constant within the zone of 44-45℃.

During the period maintanined in each Tabd zone, heat production (HP) and Tabd (Li et al., 1991), heart rate (HR) and RR (Fujita et al., 1991), and Tss (Zhou and Yamamoto, 1997) were measured continuously. Temperature of the external ear tract (Tee) and comb surface temperature (Tcs) were also measured continuously using copper-constantan thermocouples, as described previously (Zhou et al., 1997). All measurements were conducted during the light period.

The data were the average values at the last hour of measurement each bird in figures 2 and 4 and the average values of 8 birds at the last hour of measurement in figure 3. For reflecting more vividly the changes in other parameteres with Tabd, linear regression analysis was used to determine the relationships between Tabd and other parameters according to the scattered state of those data points. F-test was used to determine the differences between means in figure 3. If the F-test was significant, Tukey's method (Ishimura, 1992) was used for multiple comparisons.

RESULTS

The relationships between Tabd and other parameters are shown in figure 2. The increases in HP and HR with Tabd became greater when Tabd exceeded approximately 42.5℃. RR increased markedly with Tabd above 41.5℃, reaching a maximum when Tabd was at about 42.5℃ and then began to decrease. Tcs and Tss changed very rapidly with Tabd when Tabd was below 41.5℃, but increased slowly above 41.5℃. Tee was about 1.5 to 2℃ lower

than Tabd and increased with Tabd, but the increase in Tee was less than Tabd. The increasing phase of RR was accompanied by a slight increase in HP or HR. However, after maximum RR was achieved, a decrease in RR was accompanied by a significant increase in HP or HR (figure 3).

DISCUSSION

The rate of increase in HP with Tabd became greater when Tabd was above 42.5℃ (figure 2A). This may have been due to the increases of Tabd and RR. The influence of the increase in Tabd on metabolic heat production of animals may involve not only the effect attributable to the traditional Van' t-Hoff's law, but may also involve stress responses of the tissue or organ to heat, such as the increased activity of the respiratory and circulatory organs and the disturbance of bird. According to the results obtained by Marder (1973), only 28% of the increased HP of ravens was attributable to the rise in body temperature, while 72% resulted from the intensive activity of the respiratory system of ravens exposed to heat stress at 45℃. Zhou and Yamamoto (1997) found that HP decreased with the duration of exposure when Tabd increased relatively little (41.1-41.9℃), but HP increased when Tabd rose more markedly (41.2-43.1℃). Additionally, Inoue et al. (1995) noted that, in birds which rectal temperature exceeded 43℃, HP increased significantly, while the increased RR decreased markedly. Zhou et al. (1996a) reported that the birds exposed to high temperature appeared to stand and lie frequently. That indicates that the birds were in a disturbed condition.

RR reached a maximum when Tabd was at about 42.5℃, then began to decrease. This agrees with the results obtained by Zhou and Yamamoto (1997). Kohne and Jones (1975) reported that as the panting RR decreased, the depth or amplitude of respiration increased markedly. Figure 3A showed that HP increased with the decreased in RR during the decreasing phase of panting, while it increased little during the increasing phase. This indicates that deeper, slower panting consumes more energy. According to the results obtained by Hales and Findlay (1968), oxygen consumption of the ox during slower deeper panting increased compared with that during rapid shallow panting.

Panting started at about 41.5℃ in Tabd in the present study. This is consistent with previous results (Zhou and Yamamoto, 1997). However, the results of Richards (1971) showed that the onset of panting was about 42℃ in colonic temperature and 41.8℃ in hypothalamic temperature of laying hens. These differences may be due
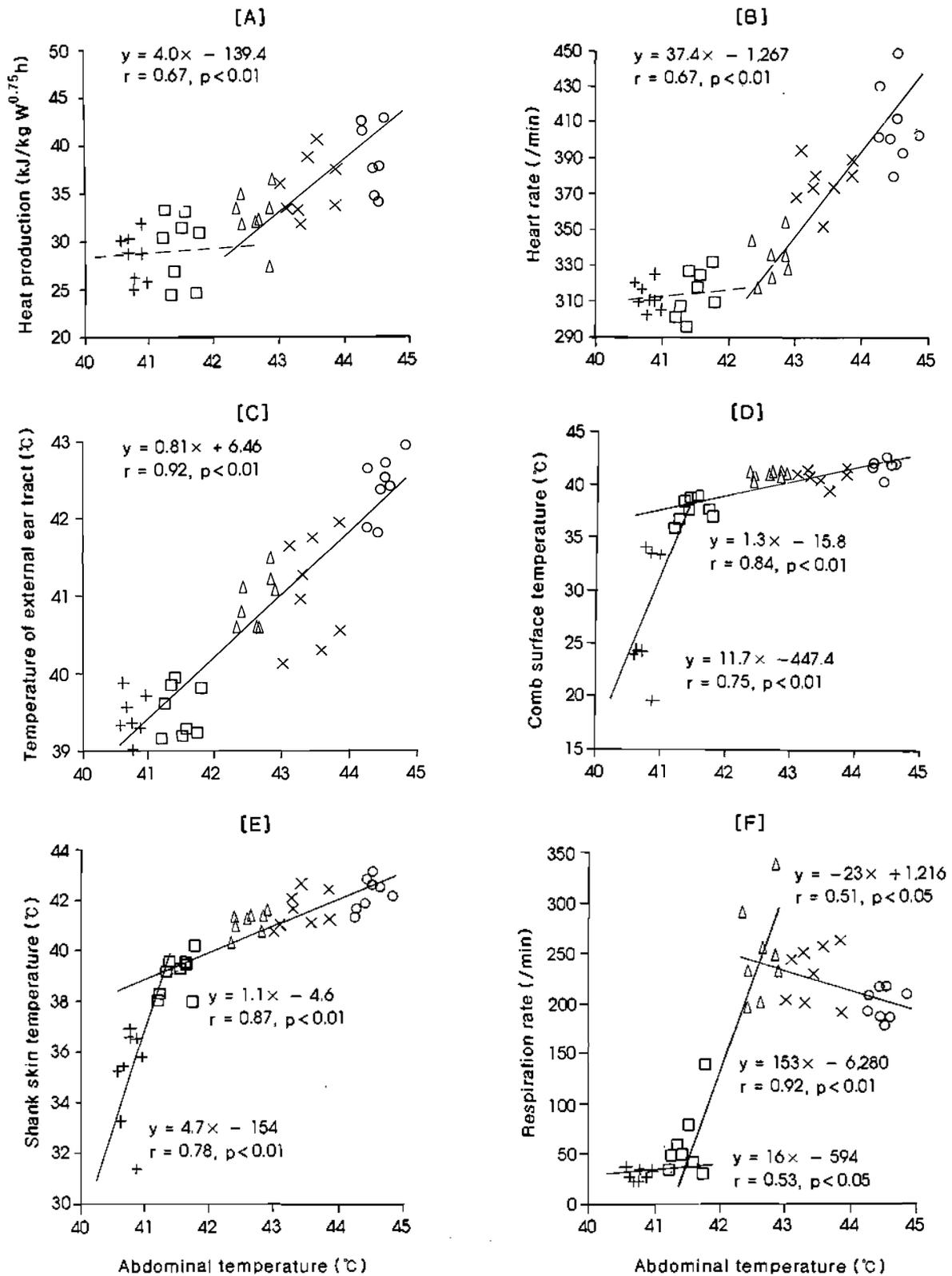
Figure 2. The relationships between abdominal temperature (key below) and heat production, heart rate, temperature of external ear tract, comb surface temperature, shank skin temperature and respiration rate. + : 40-41 ; □ : 41-42 : △ : 42-43 ; × : 43-44 ; ○ : 44-45℃.
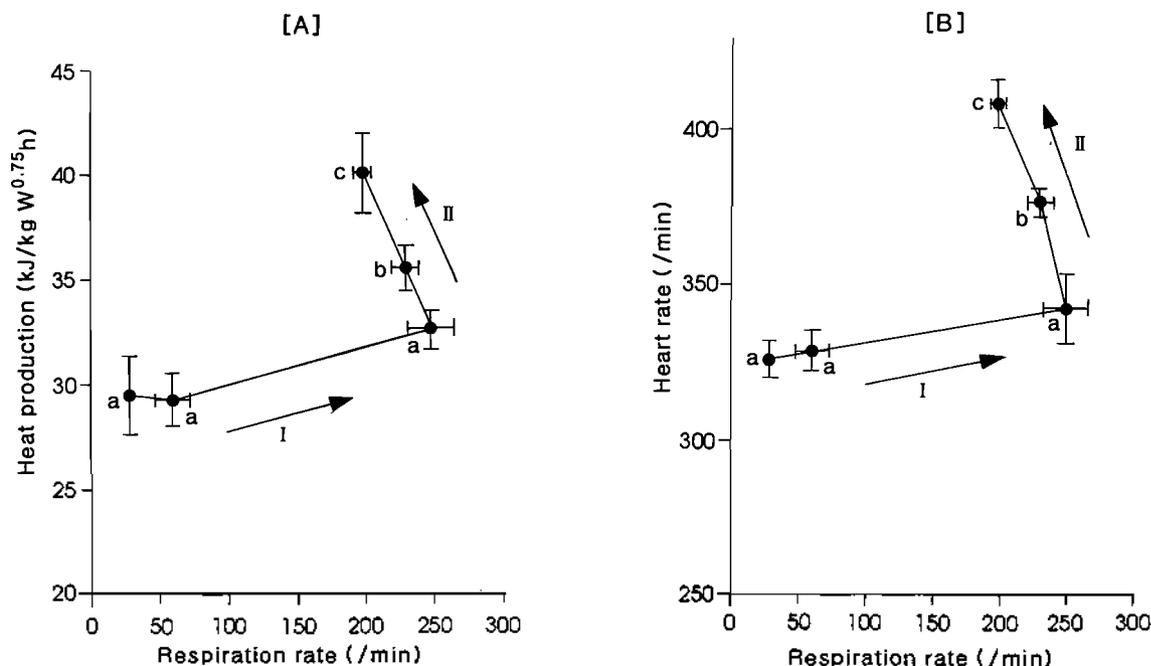
[A]

[B]

Figure 3. The changes in heat production and heart rate with respiration rate. Each point represents mean ± SE of 8 broilers. I and II represent the increasing and decreasing phase of panting, respectively. Points not sharing a common subscript letter are significantly different (p < 0.05).

to the different site of measurement. RR increased rapidly with Tabd when Tabd was above 41.5°C. This may be due to the absence of perspiration in chickens, resulting in the change of heat loss route as described latterly when sensible heat loss becomes limited by the vasodilation of blood vessels in skin.

That the increase in HR with Tabd became greater when Tabd was above 42.5°C (figure 2B) agrees with the results obtained by Katsuda and Taba (1985) using constrained hens. In their experiment, the environmental temperature was gradually increased from 25 to 44°C at an increasing rate of 1°C per 6 minutes. HR, like HP, increased with the decrease in RR during the decreasing phase of panting. Similar results were obtained in hens (Katusda and Taba, 1985) and in calves (Bianca, 1995a, b). That HP and HR changed in parallel with Tabd (Figures 2A, B and 3) illustrated further that the change in HR may reflect the change in HP (Yamamoto et al., 1985; Yamamoto, 1989). This shows that there was still a linear relationship between HR and HR although Tabd increased. Only the coefficient (figure 4) tended toward a lower value than in the results obtained by Yamamoto et al. (1985) in laying hens.

Tee was lower than Tabd and increased with Tabd, but the increase in Tee was smaller than the increase in Tabd. The slope was 0.81. This may be due to the increase in respiratory rate, because the ear tract is very

close to the throat and farther from the trunk. In a previous study, it was found that the increase of Tee became gradually smaller with exposure time, while Tabd continued to maintain at a constant rate of increase (Zhou et al., 1997).

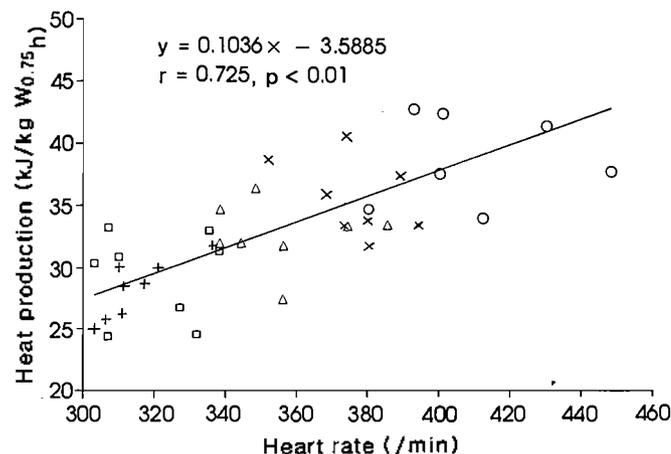$$y = 0.1036x - 3.5885$$
$$r = 0.725, p < 0.01$$

Figure 4. The relationship between heat production and heart rate at different abdominal temperatures (key below). +: 40-41; □: 41-42; △: 42-43; ×: 43-44; ○: 44-45°C.

Tcs and Tss changed rapidly with Tabd when Tabd was below about 41.5°C, but increased slowly above

about 41.5°C. This is consistent with the results obtained by Zhou et al. (1996b). This may be caused by the vasomotion of blood vessels in skin. These changes indicate that the adjustment of sensible heat loss from naked surface is a major response when deep body temperature is below 41.5°C. However, the significant increase in RR replaced the rise in skin temperature as Tabd increased further. This increases respiratory evaporative heat loss (Barnas and Rautenberg, 1987; Li et al., 1989) and evaporative heat loss becomes the major heat loss mechanism.

In conclusion, these results indicate that the change in Tabd induced the change in thermoregulatory responses of broilers. Tabd increased to adjust the ratio of sensible and latent heat loss when Tabd was below 42.5°C, while thermoregulatory ability was gradually lost when abdominal temperature exceeded 42.5°C and heat balance was broken.

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