Effects of Intermittent Short Term Acclimation to 32°C on Some Thermoregulatory Responses and Standing Behavior of Laying Hens Exposed Acutely to 36°C

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The experiment was conducted to determine the effects of acclimation to heat on thermoregulatory responses of laying hens when exposed to a new higher ambient temperature. The birds were subjected to non-exposure or exposure to 32°C from 1 to 3 days, and then all to 36°C ambient for 8 hours. Abdominal temperature, back skin temperature, shank skin temperature, heart rate, respiration rate, standing time and standing counts were measured during exposure period. When birds were exposed to 32°C, their abdominal temperature, back skin temperature, shank skin temperature and heart rate were greater on the 1st day than the 3rd day, and decreased obviously after lighting off, whereas respiration rate was lower on 1st day than 3rd day before lighting off and increased further for a short while after lighting off. At 36°C, abdominal temperature, back skin temperature, shank skin temperature and heart rate decreased with days of exposure to 32°C. Respiration rate of the birds unexperienced to 32°C did not increase further after lighting off. The unexperienced birds had markedly lower standing time and more standing counts than those of the experienced birds. These results showed that the effects of acclimation to heat on thermoregulation and standing-lying behavior are recognized when the birds were exposed to a high ambient temperature only for 3 days, and the standing behavior of chickens is clearly associated with thermoregulation at the high ambient temperature.

Key words: acclimation, high ambient temperature, thermoregulation, standing behavior, laying hen

Introduction

It is well documented that acclimation (experience) of domestic animals to heat will increase their heat resistance. When broilers have been subjected to several hours heating episodes daily for several days, the mortality of the birds due to heat prostration decreased (REECE et al., 1972; DEATON et al., 1986; DAVIS et al., 1991). The heat production of the acclimated broilers was lower than that of the birds which were unacclimated to temperatures from 2 to 35°C (FARRELL and SWAIN, 1977 a, b). MAY et al. (1987) and TEETER et al. (1992) reported that the acclimated broilers had a significantly lower body temperature than the unacclimated ones. SYKES and FATAFTAH (1986) found that laying hens had a lower oxygen consumption and body temperatures, higher panting rates and decreased evaporative water loss when the birds were subjected to several days of intermittent exposure to a hot environment (38°C). However, INOUE et al. (1995) showed that there was no difference in heat production and rectal temperature.
of broilers between acclimated and unacclimated to a diurnal cycle of 22-38-22°C when exposed to 41°C of ambient temperature.

According to these researches, how chickens acclimate effectively is still unclear. We are not aware of the effects of posture and "light-dark" on thermoregulation of chickens during acclimation process. Therefore, the objectives of this experiment are to determine the effects of daily intermittent short term heat exposure on thermoregulatory physiological responses and standing behavior of laying hens when exposed to a new higher temperature.

**Materials and Methods**

**Birds and management**

Sixteen White Leghorn laying hens (Shaver Starcross 288) were used to conduct the experiment. The average body-weight and age of these birds were about 1.4±0.1 kg and 200-days-old, respectively; their rate of egg production was 90%. A vinyl tube (i.d. 4 mm, o.d. 6 mm) was implanted 5 cm into the abdomen as described by FUJITA et al. (1991) for measuring abdominal temperature. Usually, the birds were housed in single cages (25×45×39 cm) with a room temperature of about 24°C (relative humidity 65–70%). Prior to the measurement period, the room temperature was abruptly increased to 32°C or 36°C (relative humidity 40–45%) and lasted for 8 hours. The birds were allowed access to a commercial mash (CP 17%, ME 11.9 MJ/kg) ad libitum and water at 09:00. The photoperiod was 14 hours every day commencing at 06:00.

**Experimental procedure and collection of data**

The schedule of exposure to high ambient temperature was shown in Table 1, and the duration of heat exposure was 8 hours daily from 15:00 to 23:00 for 1–4 days.

Abdominal temperatures were measured using a copper-constantan thermocouple (Ishikawa Sangyo Co., Ltd, Tokyo, Japan) which was inserted into the tube implanted beforehand in the abdomen of such bird. The back and shank skin temperatures were also measured using thermocouples which were fixed at the cross of topline (back line) and the linked line of two shoulder by a bond (G-Kuriya, Konishi Co., Ltd, Osaka, Japan) and adhesive tape (White Tape No. 25–9, Nichiban Co., Ltd, Tokyo, Japan), and at the middle of leg-shank by the adhesive tape, respectively. Standing time was measured by two series of photoelectric switches (OA-31, Omron Co., Ltd, Tokyo, Japan).

**Table 1. The schedule of exposure to ambient temperature of 32 and 36°C**

<table>
<thead>
<tr>
<th>Groups</th>
<th>n</th>
<th>1st day</th>
<th>2nd day</th>
<th>3rd day</th>
<th>4th day</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4</td>
<td>24–24–24°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>24–36–24°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>24–32–24°C</td>
<td>24–36–24°C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The duration of exposure was 8 hours from 15:00 to 23:00 every day. The boldfaces represent the period of collecting data.

n: Numbers of birds
Japan), which were placed at the position where the beam of photoelectric switch could be blocked by the middle of leg-shank. When both switches were blocked at the same time, it indicated that the bird was in the lying posture. The data of abdominal temperature, back skin temperature, shank skin temperature and standing time were recorded every minute by a digital/trend data logger (TR2723, Takeda Riken Co., Ltd, Tokyo, Japan) with a logging interval of 3 seconds. The data recording started at 14:00 and ended at 23:00 each day. The average value of the data for every 5 minutes were calculated by a personal computer (PC8801 mk II, NEC Co., Ltd, Tokyo, Japan).

The respiration rate and heart rate were measured every 5 minutes as described by Fujita et al. (1991), the data of the last 1 minute being recorded on a polygraph recorder (WT-645G, Nihon Kohden, Co., Ltd, Tokyo, Japan), and calculated by counting the fluctuations within 30 seconds and 6 seconds, respectively. In addition, the standing counts were checked by counting the changes of the trend curves recorded by the data logger. A bout of standing-lying was considered as one standing count.

Statistical methods

The Students' t-test was used to compare the difference of each parameter measured between 1st day and 3rd day of acclimating to 32°C and between light and dark periods. The F-test was used to determine the effects of acclimation on thermoregulatory responses, if the F-test was significant, Tukey's method (Ishimura, 1992) was used to do pairwise multiple comparison.

Results

The abdominal temperature, back skin temperature, shank skin temperature and respiration rate were increased when the birds were exposed to either 32°C or 36°C ; the degree of increase was greater at 36°C than at 32°C (Fig. 1, Fig. 2).

During the period of acclimation to 32°C, the abdominal temperature, back skin temperature, shank skin temperature and heart rate tended to be greater on the 1st day than on the 3rd day after exposure to 32°C for the first 3 hours, but tended to decrease with exposure time. The decrease in heart rate was faster after lighting off (Fig. 1). The respiration rate was greater on the 3rd day than the 1st day during light period for birds exposed to 32°C, but was lower during dark. However, the respiration rate increased further for a while after lighting off before decreasing. Standing time did not decrease after lighting off and was significantly lower on the 3rd day than on the 1st day during dark. Standing counts increased significantly at 32°C compared to 24°C (Fig. 3).

When the birds were exposed to 36°C, the abdominal temperature, back skin temperature, shank skin temperature and heart rate decreased with days of experience to 32°C (Fig. 2). At 36°C, abdominal temperature, back skin temperature and shank skin temperature increased with exposure time in the birds unexperienced to 32°C, whereas decreased in those birds experienced to 32°C for 3 days. With increase in days of experience, respiration rate increased markedly for 2-3 hours and was somewhat decreased slightly. However, the respiration rate of the experienced birds increased further after lighting off and then decreased. Standing time was obviously lower in the
unexperienced birds than in the birds that had experience to 32°C. In general, standing counts was significantly higher (p<0.05) in the unexperienced birds than in the experienced birds (Fig. 3).

In addition, standing time decreased with increase in environmental temperature during light period (Table 2). Standing time was the shortest at 24°C ambient temperature during dark period, and the longest at 32°C. Standing time was lower during the dark than during light period at both 24°C and 36°C. However, standing time during light and during dark period was similar at 32°C.

Discussion

As shown in Fig. 1, the acclimation was recognized when the birds were exposed to 32°C for 8 hours each day for three days. The acclimation to a hot environment, in
fowls, was reflected in the lower body temperature, higher panting rates and lower heat production (SYKES and FATAFAH, 1986; UENO and OTANI, 1987; INOUE et al., 1995). In this study, lower heart rate and lower standing time were also observed. The effects of acclimation are expressed in Fig. 2, when the birds were exposed to 36°C. The abdominal temperature of the birds experienced to 32°C for 3 days was obviously lower than that of the unexperienced birds. This is similar to the results obtained by MAY et al. (1987). These authors showed that the broilers with experienced to 35°C had significantly lower body temperature than the unexperienced ones for 90 to 210 minutes when the birds were exposed to 41°C. In this study, when the birds were exposed to 36°C, the abdominal temperature of the unexperienced birds was higher and increased with exposure time. This could be due to three reasons. Firstly, heat loss
Fig. 3. Changes in the standing counts of laying hens during exposure to 24, 32 and 36°C ambient temperatures (□: light; ■: dark). "E, F, G and e, f, g" represents that there is a significant difference (p<0.01) between the different letters during light and during dark, respectively.

Table 2. Changes in abdominal temperature, back skin temperature, shank skin temperature, respiration rate, heart rate, standing time and feed intake of laying hens exposed acutely to 32 and 36°C for a short term (8 hours)

<table>
<thead>
<tr>
<th>Environmental temperature (°C)</th>
<th>Light¹</th>
<th>Dark²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24</td>
<td>32</td>
</tr>
<tr>
<td>Abdominal temperature (°C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back skin temperature (°C)</td>
<td>39.8±0.6a</td>
<td>40.6±0.7a</td>
</tr>
<tr>
<td>Shank skin temperature (°C)</td>
<td>36.8±0.8a</td>
<td>39.5±0.6b</td>
</tr>
<tr>
<td>Respiration rate (/min)</td>
<td>21±2ab</td>
<td>87±46b</td>
</tr>
<tr>
<td>Heart rate (/min)</td>
<td>288±38a</td>
<td>273±26</td>
</tr>
<tr>
<td>Standing time (min/h)</td>
<td>58.6±1.2ab</td>
<td>52.9±4.3b</td>
</tr>
<tr>
<td>Feed intake (g, 09:00-15:00)</td>
<td>69.3±5.3</td>
<td>59.0±18.2</td>
</tr>
<tr>
<td>Daily feed intake (g)</td>
<td>87.3±14.5</td>
<td>79.3±19.2</td>
</tr>
</tbody>
</table>

¹, ²: There is a significant difference between the data with different superscripts within the same item (p<0.05);

³: There is a significant difference between light and dark within the same item (p<0.05);

¹: Abdominal temperature, back skin temperature, shank skin temperature, respiration rate, heart rate and standing time are the average values of three hours (17:00-20:00) before turning off the lights at 20:00;

²: Abdominal temperature, back skin temperature, shank skin temperature, respiration rate, heart rate and standing time are the average values of three hours (20:00-23:00) after turning off the lights at 20:00; Mean±SD (n=4).
from body surface was less, because the surface of sensible heat loss was decreased due to less standing time. DeShazer et al. (1970) reported an increase between 20 and 40% in sensible heat loss when hens changed from the sitting to the standing position. The standing time of the unexperienced birds was less, the abdominal temperature of the birds was correspondingly greater in this study. Secondly, heat production might be higher in the unexperienced birds. In this study, heart rate was higher for the unexperienced than the experienced birds. This may suggest a higher heat production. Yamamoto (1989) reported that heat production increased with the increase in heart rate in farm animals. The increased heart rate can be explained by the more frequent standing and lying behavior in the unexperienced birds during exposure to 36°C (Fig. 3). Finally, the respiration rate was found to be lower in the unexperienced birds. The increase of respiration rate resulted in increase of heat loss (Richards, 1976; Li et al., 1989).

Abdominal temperature, back skin temperature and shank skin temperature decreased obviously at 24 and 32°C after light was off (Table 2, Fig. 1). This may be due to lower heat production and a temporary increase in respiration rate during dark period. MacLeod et al. (1988) and Nishibori et al. (1989) showed that heat production was lower during the dark than during light periods. In this study, the heart rate decreased significantly at 24 and 32°C after lighting off, and the respiration rate increased further at 32°C. This suggests that after lighting off chickens rely on increasing respiration rate and decreasing heat production to reduce their body temperature. However, at 36°C, the abdominal temperature of the birds unexperienced to 32°C did not decline and conversely rose after lighting off. The back and shank skin temperature also increased with the increasing abdominal temperature. This was probably due to the fact that these birds had less standing time, higher heart rate and lower respiration rate than the experienced birds, which lead to less heat loss during the dark period.

The standing time decreased significantly at 24°C after lighting off, but did not decrease at 32°C (Table 2, Fig. 1). Similar results were reported by MacLeod et al. (1988) and Li et al. (1991) for birds kept at 24°C. Similarly, the standing time of the birds experienced to 32°C did not decrease at 36°C after lighting off. However, the standing time of the unexperienced birds was lower at 36°C under both light and dark periods, and the birds appeared to be disturbed (frequent standing and lying behavior) (Fig. 3). This resulted in the higher body temperature and heart rate in the unexperienced birds. Murphy and Preston (1988) suggested that the rather high ambient temperature might have encouraged birds to make frequent changes in posture and location.

In summary, the effects of aclimation on thermoregulation, which involved the elimination of disturbance and the increase in the standing time, are recognized when the birds were exposed to a high ambient temperature for 3 days. The standing time and the standing–lying frequency of chickens are related to thermoregulation at the high ambient temperature. This shows that it is also important to investigate the standing–lying behavior when we investigate the characteristic of thermoregulation of chickens.
References


産卵鶏の体温調節性生理反応と起立行動に及ぼす
短期高温順化の影響

周 維統・藤田正範・伊藤敏男・山本禎紀

産卵鶏の体温調節性生理反応と起立行動に及ぼす周期性高温順化の効果を明確な条件を加えて検討した。鶏を32℃の温度に未経験あるいは1から3回経験させてから、36℃に8時間暴露した。測定した反応は、腹腔内温、背部皮膚温、脛部皮膚温、心拍数、呼吸数、起立時間及び起立横臥回数である。32℃経験により、腹腔内温、背部皮膚温、脛部皮膚温および心拍数は、経験第3日のほうが第1日より低くなり、消灯後いずれも低下した。呼吸数は経験第3日のほうが早く増加し始め、数も多くなり、消灯後再び増加する傾向が認められた。36℃感作による腹腔内温、背部皮膚温および脛部皮膚温についても、32℃未経験が経験鶏より高く、いずれも暴露時間の経過とともに上昇する傾向を示した。心拍数も未経験鶏で高かった。呼吸数は暴露初期には同じように増加し、その後、経験鶏でやや低下し消灯後に一時増加する傾向が認められた。通常に消灯すると減少する起立時間は、32℃では減少せず、36℃では未経験鶏で減少した。起立横臥回数は未経験鶏で増加し、消灯しても休息状態に入らず不安や覚醒状態にあることを暗示し、頻繁な起立横臥行動が認められ、これらに対応した心拍数の増加も認められた。未経験鶏の体温の上昇は、これらと関係しているものと思われた。本実験の結果から、高温順化の効果は3日に認められ、その順化は生理反応だけでなく、高温に対する不安の解消や、安定した起立時間の延長などと関連しているものと思われた。

キーワード：順化、高環境温、体温調節、起立行動、産卵鶏