Research Note

Abdominal Skin Temperature Variation in Healthy Broiler Chickens as Determined by Thermography

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ABSTRACT Abdominal skin temperature of healthy broiler chickens was determined by thermography to estimate the normal range of between- and within-bird temperature variation. Effects of potential confounding factors, such as bird's contention duration, abdominal side, age, and time of day, were also estimated. Mean skin temperature was estimated from thermogram pictures by computer image analysis of a predetermined abdominal area. Results demonstrated that skin temperature was not significantly affected by contention duration. However, skin temperature was higher on the right abdominal side in younger birds and at 1200 h. Between- and within-bird variation in healthy birds was small (<0.5°C) when age, abdominal side, and time of day were taken into account. This work suggests that skin temperature measurement using thermography can be adapted for the study of skin temperature in broiler chickens.

(*Key words*: healthy broiler chicken, circadian cycle, abdominal skin temperature, thermography, image analysis)

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INTRODUCTION

Medical thermography is an imaging technique that can be used to estimate mean temperature of an area of skin by measuring infrared energy emission within a predetermined spectral range. A thermal detector converts the infrared energy to an electrical signal proportional to the surface temperature. The estimation of skin surface temperature can be visualized by a numeric picture, referred to as a thermogram, composed of different temperature zones associated with different shades of gray or colors. This technique has been widely used in various human medicine fields (Black et al., 1990; Armstrong and Lavery, 1997). The technique has also been used on horses (Tessier, 1996; von Schweinitz, 1999) and other species (Zinn et al., 1985; Gabor et al., 1998) to visualize skin temperature patterns associated with underlying inflammatory foci. However, the use of thermography in poultry has been limited so far to a single experimental study on naked neck chickens subjected to different ambient temperatures (Yahav et al., 1998). In birds, limitations arise because feathers block most of the infrared skin emissions.

We believe that thermography can be adapted for experimental studies on broiler chickens and may be useful to study temporal skin temperature variation related to cellulitis lesions. At the abattoir, cellulitis is commonly found unilaterally on the abdomen (right or left side) in male broiler chickens (Messier et al., 1993). Therefore, this skin area is currently selected for experimentally induced cellulitis studies (Peighambari et al., 1995; Gomis et al., 1997). Before using thermography in experimental studies on cellulitis, it is necessary to describe the range of between- and within-bird temperature variation observed over time and as a function of age in healthy male broiler chickens. Moreover, it is necessary to determine whether mean skin temperature varies with abdominal side, time of the day, and the duration of contention before actual temperature measurements. Therefore, the objectives for this study were 1) to estimate the effect of handling and contention duration on skin temperature, 2) to compare right and left abdominal skin temperature, and 3) to describe normal bird abdominal skin temperature variation over time for young and older broiler chickens.

MATERIAL AND METHODS

Animals and Housing

Forty-two Ross × Ross male chicks were obtained from a commercial hatchery. In our experimental unit, they were fed with a commercial broiler starter formulation and had unlimited access to feed and water. Birds were raised in pens with litter shavings and were grouped according to their age. All groups were exposed to a continuous 12-h light program from 0600 to 1800 h. Feath-

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FIGURE 1. Left defeathered abdominal area (approximately 2.5 cm × 2.5 cm) of a 14-d-old male broiler chicken.

ers of the right and left lateral abdominal areas were plucked at least 3 d prior to skin temperature measurements. Each plucked area represented approximately a surface of 2.5 cm × 2.5 cm (Figure 1). Regrowing feathers were removed on a regular basis during days in which no temperature measurements were taken. When birds reached 18 d of age, room temperature was decreased to 23 ± 1°C and maintained within this range until the end of the experiment. During each measurement session, luminosity was temporarily reduced to minimize handling-related stress. Contention of birds was performed by holding birds with one hand placed under wing articulations and the other one between the legs.

Infrared Thermal Device

An infrared camera[2] was connected to a computer for recording and visualizing skin areas on thermograms. The mercury-cadmium-tellurid detector of the camera was sensitive to a spectral range of 8 to 12 μm. The temperature scale ranged between 35°C and 45°C. This range was divided into 256 thermal zones providing a theoretical precision of ±0.04°C (10°C/256). However, due to measurement errors, the actual attainable precision was ±0.1°C. The camera was fixed on a three-legged stool to fix the camera position. A graduated ruler was attached to the lateral side of the camera's objective to ensure a standardized view angle (90°) and a constant camera-skin distance between birds. As the chickens grew in size, bird-camera distance was increased accordingly to keep constant the size of the initial skin area visualized on the monitor.

Computer Image Analysis

Mean skin temperature of a standardized ovoid shape surface (15,274 pixels) was estimated on each thermogram. The first two thermal zones (t_1 and t_2) were excluded from the calculation because they were associated to the coolest temperatures associated with regrowing feathers. Temperature measurements were based on the number of pixels associated to the other 254 thermal zones (t_3, t_4 … t_{256}). Mean skin temperature (T) was estimated according to the following equation:

$$T = t\text{min} + \left(t_p\left(\frac{n_3{\cdot}3 + n_4{\cdot}4 + \ldots\ n_i{\cdot}i}{(n_3 + n_4 + \ldots\ n_i}\right)\right)$$

where T_{min} was the minimum temperature of the selected range, T_p the temperature precision for each thermal zone (0.04°C), and n the number of pixels associated with temperature zone i (i = 3, 4, …, 256).

Experimental Procedures

Trial 1: Effect of Contention Duration. Effect of contention duration on skin temperature was estimated on nine 18-d-old male chickens. Birds were held continuously by the manipulator as described previously for a 10-min period, and temperature measurements were taken every 2 min.

Trial 2: Effect of Abdominal Side. Skin temperature on the right and left lateral abdominal area was estimated on thirteen 20-d-old male chickens (at time 0). Thermography measurements were taken on birds between 1000 and 1300 h on 9 different days over a period of 20 d. For each session, temperature recordings of the right and left lateral abdominal areas were alternated between birds to minimize possible handling effect on skin temperature.

Trial 3: Effect of Time of Day. Skin temperature variation over time was estimated for two groups of 10 male chickens belonging to two different age groups (initially 18 or 35 d old). Measurements of skin temperature on the right abdominal side were taken every 6 h over a 140-h period (6 d) on all birds. The first measure was taken at 1200 h (time 0) and the last one at 0600 h (time 140). To simplify bird-camera distance adjustments, all birds from one age group were measured first. However, the group order was alternated between measurement sessions.

Statistical Analyses

Data were analyzed using repeated measures analysis of variance (MIXED procedure)[3] (Littell et al., 1998). In all models, the contribution of each bird was treated as a random factor (compound symmetry covariance structure). The subject and the residual variance components

[2]Inframetrics, model 760, Flir Systems, Portland, OR.
[3]SAS Institute Inc., Cary, NC. SAS User's Guide. Version 8.

TABLE 1. Expected mean temperature (°C), between- and within-bird temperature variation (SD) in healthy male chickens in four different trials

		Variation (SD) (°C)		
Trial (age at t0, n)	Mean at t0 (°C)	Between (σ_b)	Within (σ_w)[1]	Total[2]
1 (18 day-old, 9)	39.2	± 0.5	± 0.3	0.6
2 (20 day-old, 13)	39.5	± 0.3	± 0.3	0.4
3 (18 day-old, 10)	39.3	± 0.4	± 0.3	0.5
3 (35 day-old, 10)	38.9	± 0.2	± 0.3	0.4

[1]Within-bird variation and measurement error (residual).

[2]Total measured variation at a fixed time can be estimated by $\sigma = \sqrt{\sigma_b^2 + \sigma_w^2}$.

are respectively estimates of between- and within-bird variance. All fixed effects were tested using type 3 F-tests, and the significance level was set at $P < 0.05$ for all tests. Change of skin temperature over contention duration was modeled and tested with a slope over time parameter (time = 0, 2, …, 10). The difference between right and left abdominal side temperatures was tested after correcting for mean age effect. Temporal variation of mean skin temperature suggested linear and circadian cyclical variation. Therefore, it was modeled according to the following equation:

$$Y_{ijt} =$$

$$\mu_j + \alpha_j t + \beta_{1j} \sin\left[\frac{2\ \pi t}{24}\right] + \beta_{2j}\cos\left[\frac{2\ \pi t}{24}\right] + s_{ij)} + e_{t(ij)}$$

where μ_j is the intercept for each j age group, α_j is the linear trend parameter, β_{1j} and β_{2j} are the amplitude parameters of the two 90° out of phase 24-h sinusoidal cycles, and $s_{i(j)}$ and $e_{t(ij)}$ are, respectively, the bird and the residual effect.

RESULTS

Feathers of the abdominal area were easily plucked from all birds. Plucking apparently caused no evidence of skin inflammation 3 d later. Few regrowing feathers had to be plucked throughout the course of the study. Room temperature variation was small (<0.3°C) over the duration of the study. Bird growth led to bird-camera distance adjustments every 4 to 5 d. Birds were generally calm, and recording time per bird, including handling time, was usually short (<5 min).

The effect of duration of contention was either absent or small (0.01°C/min, $P = 0.43$) compared to between- (±0.5°C) and within-bird (±0.3°C) temperature variation (Table 1).

Temperature on the right abdominal side was warmer (0.15°C, $P = 0.0005$) than on the left side ($P = 0.0005$). However, this effect was small compared to between- and within-bird (±0.4°C) temperature variation (Table 1).

Time-series analysis indicated a significant circadian 24-h cycle and linear temporal skin temperature effects ($P < 0.0001$) (Figure 2). The amplitude of the 24-h cycle was equal to only one of the amplitude parameters (β_{2j}, max = 1200 h). Consequently, the highest and the lowest mean skin temperatures were observed, respectively, at 1200 h and 2400 h (Figure 2). The amplitude of the circadian cycle was marginally higher ($P = 0.06$) in younger birds (0.15°C) than in older birds (0.09°C) (Figure 2). Moreover, mean skin temperature tended ($P = 0.1$) to decrease more rapidly over time in older birds (–0.0026°C/h) than in younger birds (–0.0015°C/h) (Figure 2). Consequently, mean skin temperature at time 0 was higher for the younger birds (Table 1). Moreover, between-bird variance was higher for younger birds (Table 1).

DISCUSSION

Application of thermography in broiler chickens is generally considered difficult because feathers have good insulating properties. Feathers can be easily removed, and the contribution of regrowing feathers to the estimated mean skin temperature can be corrected numerically by excluding the corresponding pixels in calculations. However, an adequate room temperature is an important factor because it influences the feather regrowing rate. Our study suggests that environmental temperatures ranging between 21 and 25°C are adequate to minimize refeathering. This temperature range provided good contrasts between skin and background temperatures.

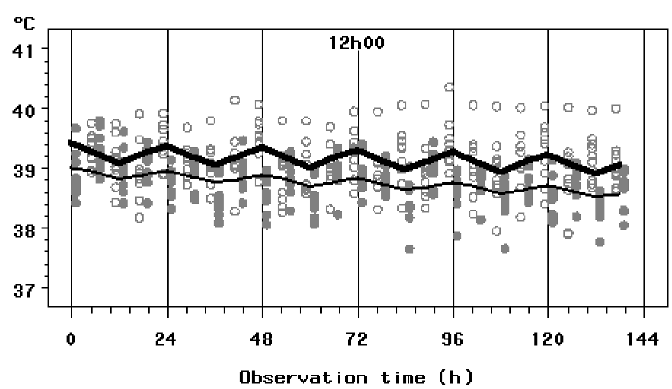

FIGURE 2. Mean skin temperature over 144 h for young (18 d-old at time 0 = thick line and open circles) and older birds (35 d-old at time 0 = thin line and closed circles). Expected mean temperature (°C) over time "t" can be predicted by the following formula: $Y_{18d} = 39.3 - 0.00015t + 0.15\cos\lfloor\frac{2\pi t}{24}\rfloor$ and $Y_{35d} = 38.9 - 0.0026t + 0.009\cos\lfloor\frac{2\pi t}{24}\rfloor$.

Here, contention of the birds over a 10-min period did not influence significantly mean skin temperature, a finding also reported by Cabanac and Aizawa (2000) for three chickens. In their experiment, crest temperature increased in two birds and decreased in one bird after 18 min of contention. Such variability in individual pattern of skin temperature variation was also noted here as skin temperature increased in six birds and decreased in three. However, the mean effect over birds was null and within-bird variation over time proved to be small (±0.3°C) (Table 1). Therefore, the effect of contention duration can be considered negligible.

The cause of differences in mean skin temperature between abdominal sides is not clear. This can be related to higher thermal conduction of small intestines compared to the gizzard, which are located, respectively, on the right and left side of the abdominal cavity. This result indicates that a control for side effect during skin temperature measurements on chickens may be needed.

Our results demonstrated that skin temperature varies during the course of the day and as a function of age (Figure 2). The circadian cycle is most likely related to the cycle of feeding activity induced by the 12-h light program, which began at 0600 h and ended at 1800 h. Amplitude of the circadian cycle (0.09 to 0.15°C), although significant, was small compared to between- (±0.5°C) and within-bird (±0.3°C) variation (Table 1). This variation could easily be controlled if skin measurements were taken at the same period of the day. The significant age effect is relatively important (Figure 3). Indeed, the expected temperature for the 35-d-old bird is almost half a degree colder than that of a 18-d-old bird. This age effect (0.4°C, Table 1) was similar or higher than the estimated between-bird variation (≈ 0.2 to 0.4°C, Table 1). The lower mean skin temperature observed in older birds is most likely the consequence of larger size. Indeed, core temperature is normally constant in birds (41°C), but it decreases over the peripheral zone. The younger chickens are most likely losing more heat through the skin than the older ones. Significant changes in temperature associated with age suggest that this factor should be taken into account when attempting to compare skin temperature among birds.

Finally, small between- and within-bird variation in temperature observed here suggest that this infrared technique could be used to detect inflammatory processes that increase abdominal skin temperature by more than 0.5°C.

This work suggests that skin temperature measurement using thermography can be adapted for the study of skin temperature in broiler chickens. Between- and within-bird variation in healthy birds is small (< 0.5°C) when room temperature, age of bird, abdominal side, and time of day are taken into account. Therefore, we believe that this noninvasive imaging technique could be a useful tool to study abdominal skin temperature variation associated with subcutaneous inflammatory processes, such as cellulitis.

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