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Research Article

The use of infrared thermography in the identification of surface temperatures in fast and slow-growing broiler chickens

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ABSTRACT

This study aimed to identify through infrared thermal imaging technology the surface temperature of the eye, beak, head, trunk, leg, and body of fast- and slow-growing broiler chickens at 2, 4, and 6 weeks of age. A total of 140 1-day-old broiler chicks were used in the study. Two treatments were included: fast-growing (Ross 308) and slow-growing (Hubbard JA57), with two replicates for each treatment. Thirty-five broiler chickens were placed in each pen. Beak and leg surface temperatures were consistently higher in fast-growing broiler chickens during the 2nd, 4th, and 6th weeks. Except for the 4th week, the surface temperature differences in the eyes and other feathered areas between fast- and slow-growing broiler chickens were not statistically significant. Eye surface temperature was not influenced by age in either genotype. In both genotypes, the beak and head surface temperatures increased with age, while the body and trunk surface temperatures decreased. Additionally, leg surface temperatures increased with age in fast-growing broiler chickens. The litter surface temperature was consistently higher in pens housing the fast-growing genotypes across all measured weeks. As a result, it was determined that age and genotype affected the surface temperatures of broiler chickens and litter. It is thought that continuous monitoring of potential fluctuations in ambient and body surface temperatures using infrared thermal cameras during the rearing period can contribute to the maintenance of thermal comfort.

INTRODUCTION

Broiler chicken farming is the world's largest terrestrial animal production sector, with nearly 70 billion chickens slaughtered annually (Berg et al., 2021; Wilcox et al., 2024). Over the last century, in response to this high demand, poultry production systems have been intensified to maximize efficiency and productivity (Azarpijouh et al., 2022). Consequently, broiler chickens have been selectively bred for generations to focus on a small range of traits, such as rapid growth and more meat yield. This selective breeding has, however, resulted in broiler chickens developing a genetic predisposition to various health and welfare issues (Wilcox et al., 2024). Therefore, developing new commercial applications in the poultry sector is significant to ensure continued economic production and maintain animal health and welfare. Such advancements are also necessary to tackle the challenges posed by global climate change and the growing need for cost-effective meat sources in response to the world's expanding population (Yahav and Giloh, 2012). Infrared thermographic imaging is a recent technology used to assess housing thermal conditions and their effects on animal welfare (Ferreira et al., 2011). Additionally, it facilitates the monitoring of animal surface temperature, which is a key indicator of an animal's physiological state under various conditions, including stress, fertility, welfare, metabolism, health, and disease detection (Nääs et al., 2014; Castro et al., 2019). Computer systems process these surface temperatures generate a thermal map of the animal and perform a detailed analysis of the temperature profile (McManus et al., 2016). Infrared thermal imaging technology provides a quick, highly sensitive, non-invasive, and contactless method for measuring skin surface temperature. Consequently, it enables the efficient assessment of body surface temperatures for numerous individuals, significantly cutting down on the time and effort needed by managers, while also avoiding any stress on the animals being monitored (Kim et al., 2021). Due to these advantages, infrared thermal imaging technology has been employed in numerous studies in recent years to evaluate animal welfare standard management procedures or health status monitoring in cattle (Nikkhah et al., 2005; Stewart et al., 2008; Schaefer et al., 2012; Alsaaod et al., 2014), poultry (Cangar et al., 2008; Ferreira et al., 2011; Jacob et al., 2016; Bloch et al., 2020; Weimer et al., 2020; Kim et al., 2021), and pigs (Warriss et al., 2006; Caldara et al., 2014). When examining the applications of infrared thermography technology specifically for poultry, it is noteworthy that they are concentrated on the measurement of metabolic heat production (Cangar et al., 2008; Nääs et al., 2010; Ferreira et al., 2011; Damane et al., 2018), evaluation leg health parameters (Jacob et al., 2016; Weimer et al., 2019; 2020) and managing heat stress (Nascimento et al., 2014; Castro et al., 2019; Bloch et al., 2020; Kim et al., 2021). In poultry, the majority of the body surface is covered with feathers, and these feathers are thermal insulators that prevent most of the heat emissions (Ferreira et al., 2011). Therefore, it has been reported that the feathered areas of the body (head, neck, back, wings, chest, thighs) show lower temperatures compared to the featherless areas (eye, ear lobe, comb, legs/feet) (Shinder et al., 2007; Cangar et al., 2008; Nääs et al., 2010; Damane et

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al., 2018). In addition, it has also been reported that body surface temperature varies with age (Tessier et al., 2003; Cangar et al., 2008; Damane et al., 2018). The effect of age on body surface temperature is attributed to the feathering status of the animals (Cangar et al., 2008; Damane et al., 2018). Giloh et al. (2012) reported a strong correlation between body temperature and facial surface temperature in broiler chickens. This suggests that monitoring facial surface temperature could be useful for assessing the comfort or thermal stress of chickens (Nascimento et al., 2014; Cândido et al., 2020). In addition, Weimer et al. (2020) reported that the surface temperature of the eye and especially the beak can be used as stress indicators in broiler chickens.

The broiler industry features a variety of breeds, including fast-growing genotypes that can achieve a target weight of 1.5 to 3 kg in about 30 days and slow-growing genotypes that require a longer period, around 70 to 80 days, to reach the same weight (Torrey et al., 2021). Broiler chickens with faster growth rates consume more feed and require a higher metabolic rate, which leads to increased metabolic heat production (Bloch et al., 2020). Additionally, the development of large body size and breast muscles, combined with a high metabolic rate, suggests that broiler chickens may struggle to maintain thermal balance (Tickle and Codd, 2019). Thermal balance is intrinsically linked to the environmental conditions that broiler chickens are exposed to. Therefore, understanding the metabolic heat production during the rearing period and determining the heat exchange between the animal and its environment is crucial for characterizing the animals' homeostasis (Nascimento et al., 2017). Ambient temperature is a critical climatic factor that strongly influences the maintenance of thermal balance in poultry. Therefore, monitoring the body surface temperatures of the animals can provide valuable insights into how ambient temperature affects their thermoregulatory status (Kim et al., 2021).

We had two hypotheses: first, that surface temperatures would be higher in fast-growing broiler chickens compared to slow-growing broiler chickens, and second, that surface temperatures would increase with age, particularly in fast-growing broiler chickens, due to the higher metabolic heat associated with rapid weight gain. The objective of the present study was to assess surface temperatures in fast- and slow-growing broiler chickens and to investigate how these temperatures vary with age.

MATERIALS and METHODS

Experimental procedure and husbandry

Seventy fast-growing (Ross 308) and seventy slower-growing (Hubbard JA57) 1-d-old broiler chicks were obtained from two commercial hatcheries (EGE-TAV, İzmir, Türkiye, and Orallar, Kocaeli, Türkiye) on the same day. These chicks were randomly allocated to four floor pens (2.6 kg target slaughter weight; 2.6 kg x 35 chickens/33 kg per $m^2 \approx 2.75$ m^2 free floor area per pen) within an experimental room (two replicates/treatment; 35 birds/pen) at the Poultry Research Unit, Faculty of Veterinary Medicine, University of Aydın Adnan Menderes, Türkiye (latitude 37°49'37" N, longitude 27°47'29" E, and an altitude of 31 m). The experiment room had dimensions of 10 m long, 5 m wide, and a height of 6 m. Both genotypes were reared under uniform management and feeding conditions. Within each pen, the water needs of the chickens were met by one drinker line with six nipples (5.83 birds per nipple), providing continuous access to water, and feed was given *ad libitum* using two round plastic feeders with a diameter of 0.4 m (7.18 cm of feeder length per bird). Bedding material consisting of wood shavings (eight cm in depth) was utilized. All diets used in the experiment were based on corn and soybean meal. The diets were prepared in three phases during the trial as specified in the commercial hybrid catalog (Aviagen, 2019). The starter phase was used for the first 10 days (3050 kcal ME/kg, 23.5% crude protein), the grower phase from days 11 to 24 (3150 kcal ME/kg, 22% crude protein), and the finisher phase from days 25 to the slaughter day (3200 kcal ME/kg, 21% crude protein). The stocking density and lighting schedule were adjusted to the levels specified in the European Union Directive (2007/43/EC). The stocking density was 33 kg/m^2. A lighting schedule of 24 hours of light was applied for the first seven days, followed by 18 hours of light and six hours of darkness for the remaining days. In the experimental room, a temperature of 32 ± 1°C was maintained at the chicks' back level for the first three days using electric thermostatic radiant heaters. The temperature was reduced by 3°C per week until 21 days old. Temperature and humidity levels were recorded twice daily using an automatic data logger at 9:00 and 17:00. The data loggers had a humidity resolution of 1% and a temperature resolution of 0.1°C.

Data collection

Infrared thermography (IRT) images were taken of five broiler chickens from each pen at 14:00 on weeks 2, 4, and 6 of the study. The broiler chickens were handled using latex gloves to avoid the influence of heat and moisture from the hands on the temperature of the feathers. All images were taken in the same experimental room. Broiler chickens were placed at a marked point on a table in the experimental room, and images were taken as quickly as possible to minimize stress effects. IRT images were taken from the left side of broiler chickens at a distance of 1 m using an IRT camera (FLIR E6, Flir Systems®, Sweden) with high resolution (240 x 180 pixels). The camera background temperature was set to 22°C, emissivity to 0.95, and transmission to 100%. IRT images were uploaded to a computer and analyzed using FLIR Tools (v 6.4) software (Figure 1). Eye and beak surface temperatures were measured from a single point using the software's spot feature. Head and trunk surface temperatures were calculated by averaging the area within the marked regions using the ellipse feature. Leg surface temperature was determined by averaging the points along the line using the line feature. To determine a body surface temperature (approximately 3.000 data) was averaged of the head, trunk, and leg regions. In addition, the litter surface temperature of each pen was taken from three different points (the side of the wall, under the drinker line, and between the feeders). Ambient temperature and relative humidity were recorded using a data logger in the experimental room, synchronized with the infrared thermal imaging sampling time (Figure 2).

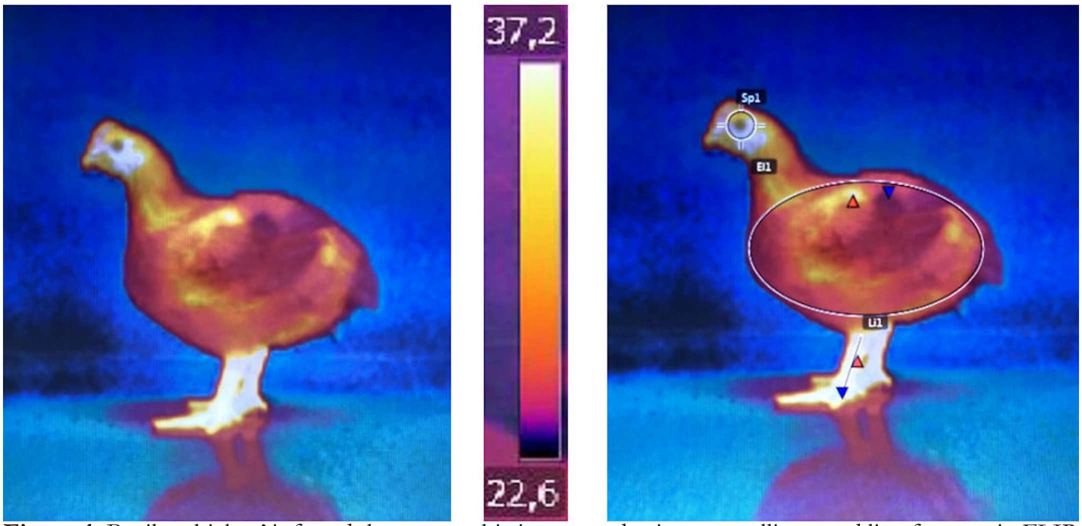

Figure 1. Broiler chicken' infrared thermographic image, and using spot, ellipse, and line features in FLIR Tools (v 6.4) software.

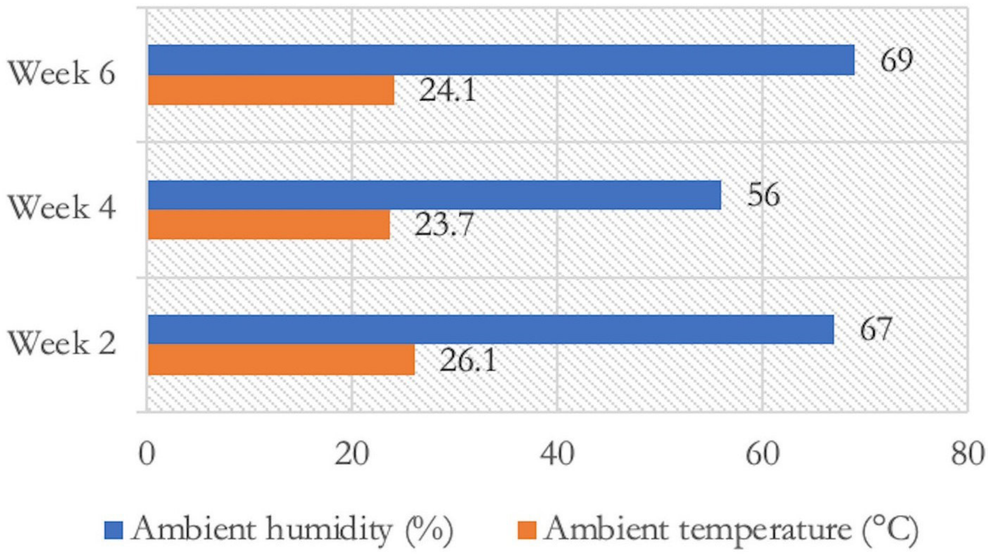

Figure 2. Ambient temperatures and humidity levels in the experiment rooms at 2, 4, and 6 weeks.

Statistical analysis

The data were analyzed statistically using the SPSS software package (version 22.0, SPSS Inc., Chicago, IL, USA). The normality of the variables was assessed using the Shapiro-Wilk test. Levene's test was used to examine the assumption of homogeneity of variances. The evaluation of IRT surface temperatures according to genotype was performed using the independent t-test, while age was conducted using the one-way ANOVA test. In the evaluation according to age for parameters that did not meet the homogeneity assumption, the Welch t-test result was considered as the significant value. For parameters that were not homogeneously distributed, the Tamhane T2 test was used as the post hoc analysis, while the Tukey HSD test was applied for homogeneously distributed data. Differences were considered significant when $P<0.05$. Descriptive statistical parameters, mean and standard error, were used to display litter surface temperatures.

RESULTS

The effects of genotype on IRT eye, beak, body, head, trunk, and leg surface temperatures in broiler chickens at 2, 4, and 6 weeks of age are presented in Table 1. Both genotypes showed similar values with eye and head surface temperatures except for week 4 (P=0.042, P<0.0001). For beak and leg surface temperatures, the fast-growing broiler chickens exhibited significantly higher temperatures compared to the slow-growing broiler chickens in weeks 2, 4, and 6 (Beak surface temperature P<0.0001, P<0.0001, P=0.002; Leg surface temperature P=0.048, P=0.006, P=0.008). No significant difference was found between genotypes for body and trunk surface temperatures in all weeks except for week 4 (P=0.008).

The effects of age on IRT eye, beak, body, head, trunk, and leg surface temperatures in fast- and slow-growing broiler chickens are shown in Table 2. No significant change was observed in eye surface temperature with increasing age in either genotype. In both genotypes, beak surface temperature (fast-grow-

Table 1. Effects of genotype on IRT eye, beak, body, head, trunk, and leg surface temperatures (°C) in broiler chickens at 2, 4, and 6 weeks[1,2]

IRT surface temperatures	n	Fast-growing	Slow-growing	P-value
2nd week				
Eye	10	35.86±0.09	35.69±0.21	0.482
Beak	10	30.94±0.25	28.61±0.41	<0.0001
Body	10	33.99±0.12	33.64±0.14	0.073
Head	10	34.49±0.12	34.30±0.09	0.217
Trunk	10	34.30±0.17	33.99±0.13	0.171
Leg	10	37.04±0.12	36.45±0.25	0.048
4th week				
Eye	10	35.72±0.22	35.16±0.14	0.042
Beak	10	31.79±0.35	29.16±0.25	<0.0001
Body	10	32.98±0.29	31.68±0.32	0.008
Head	10	35.91±0.18	34.92±0.11	<0.0001
Trunk	10	32.71±0.32	31.26±0.37	0.008
Leg	10	37.17±0.16	36.42±0.18	0.006
6th week				
Eye	10	35.63±0.19	35.64±0.24	0.975
Beak	10	32.53±0.45	30.27±0.47	0.002
Body	10	30.32±0.22	30.12±0.23	0.528
Head	10	36.23±0.12	35.91±0.22	0.225
Trunk	10	30.29±0.33	29.61±0.25	0.121
Leg	10	37.54±0.14	36.81±0.21	0.008

[1]Values are presented as mean ± standard error.
[2]Fast-growing: Ross 308, slow-growing: Hubbard JA57.

Table 2. The effects of age on IRT eye, beak, body, head, trunk, and leg surface temperatures (°C) in fast- and slow-growing broiler chickens[1]

IRT surface temperatures	n	2nd week	4th week	6th week	P-value
Fast-growing					
Eye	10	35.86±0.09	35.72±0.22	35.63±0.19	0.657
Beak	10	30.94±0.25[b]	31.79±0.35[ab]	32.53±0.45[a]	0.014
Body[2]	10	33.98±0.12[a]	32.98±0.29[b]	30.32±0.22[c]	<0.0001
Head	10	34.49±0.12[b]	35.91±0.18[a]	36.23±0.12[a]	<0.0001
Trunk	10	34.30±0.17[a]	32.71±0.32[b]	30.29±0.33[c]	<0.0001
Leg	10	37.04±0.12[b]	37.17±0.16[ab]	37.54±0.14[a]	0.044
Slow-growing					
Eye	10	35.69±0.21	35.16±0.14	35.64±0.24	0.135
Beak[2]	10	28.61±0.41[b]	29.16±0.25[ab]	30.27±0.47[a]	0.019
Body[2]	10	33.64±0.14[a]	31.68±0.32[b]	30.12±0.23[c]	<0.0001
Head[2]	10	34.30±0.09[c]	34.92±0.11[b]	35.91±0.22[a]	<0.0001
Trunk[2]	10	33.99±0.13[a]	31.26±0.37[b]	29.61±0.25[c]	<0.0001
Leg	10	36.45±0.25	36.42±0.18	36.81±0.21	0.373

[1]Values are presented as mean ± standard error.
[2]Due to the non-homogeneity of data, the Welch test was applied.
[a,b]Means in the same row with different superscripts differ significantly (P<0.05)

ing P=0.014, slow-growing P=0.019) and head surface temperature (both genotypes P<0.0001) increased significantly with age. Conversely, a significant decrease in body and trunk surface temperatures was noted (both genotypes P<0.0001). Regarding leg surface temperatures, although similar temperatures were observed across all weeks in both genotypes, the temperature increase observed with increased age in the fast-growing genotype was found to be significant (P=0.044).

Litter surface temperatures based on genotype at 2, 4, and 6 weeks are presented in Table 3. Due to the insufficient replicate numbers, only the mean and standard error were calculated for the litter surface temperatures. It was observed that litter surface temperatures were higher in the pens where the fast-growing genotype was reared at all weeks.

ilar temperatures observed in the body, head, and trunk, which are covered with dense feathers, may be attributed to the insulating properties of the feathers. In contrast, the higher leg surface temperature in the fast-growing genotype is likely due to greater metabolic heat production. This higher temperature can be explained by the fact that broiler chickens with faster growth rates consume more feed, leading to accelerated metabolism and consequently higher metabolic heat production (Bloch et al., 2020).

When the surface temperature variation with age was examined, it was found that eye surface temperature was not related to age in either genotype. It was observed that the eye surface temperatures were at similar levels in all measurements. Damane et al. (2018) stated that the eye surface temperature

Table 3. IRT litter surface temperatures (°C) in pens based on genotype[1]

IRT litter surface temperatures	2nd week	4th week	6th week
Fast-growing broiler chickens-rearing pen			
Minimum	25.93±0.40	22.32±0.33	24.85±0.44
Maximum	33.10±0.63	30.82±0.60	32.08±0.48
Average	29.23±0.42	26.57±0.40	28.10±0.56
Slow-growing broiler chickens-rearing pen			
Minimum	24.42±0.61	20.35±0.38	22.92±0.36
Maximum	29.48±0.54	26.78±1.68	27.58±0.75
Average	27.28±0.35	23.07±0.33	24.74±0.39

[1]Values are presented as mean ± standard error.

DISCUSSION

Infrared thermography offers a non-invasive method for evaluating thermal changes in a commercial poultry flock. This technique could enhance climate control systems and detect acute thermal stress, potentially leading to improvements in both flock performance and welfare (Yahav and Giloh, 2012).

In the present study, skin surface temperatures in the featherless areas were consistently higher across all weeks for both broiler genotypes. This observation aligns with previous studies that reported featherless regions, such as the eyes and legs, typically exhibit higher surface temperatures due to the absence of feather insulation (Cangar et al., 2008; Nääs et al., 2010; Damane et al., 2018; Castro et al., 2019). Furthermore, consistent with the findings of Castro et al. (2019), the highest surface temperatures were observed in the leg, eye, and head regions compared to other measurement regions across all weeks for both broiler genotypes in the current study. In comparing the surface temperatures between genotypes, it was observed that differences in the eye, body, head, and trunk surface temperatures were not statistically significant in any week except for the 4th week. Since modern broiler chickens undergo their second natural molt at around 4-5 weeks of age (Leeson and Walsh, 2004), the significant findings observed in the 4th week are likely attributable to this molt. However, the surface temperatures of the beak and legs were significantly higher in the fast-growing genotype across all weeks. The sim-

of broiler chickens increased with age, though the difference between the measurements taken at 4 and 6 weeks was not statistically significant. Considering that surface temperatures obtained with a thermal camera are influenced by factors, such as ambient temperature, humidity levels, and airflow, the differences observed may be challenging to explain due to the limited number of studies with similar experimental setups. In both genotypes, the beak and head surface temperatures increased with age, while body and trunk surface temperatures decreased. Consistent with these findings, Cangar et al. (2008) reported that surface temperatures generally decrease with age in measurements taken on feathered body parts, suggesting that this decrease could be due to the increasing number and quality of feathers, which act as an insulating layer. It has been reported that rapid feather growth begins at the end of the 2nd week in broiler chickens and that the first six weeks are the period when growth is at its highest (Wecke et al., 2017). Yalcin et al. (1997) stated that all broiler chickens are fully feathered at the age of seven weeks. These observations support the decrease in surface temperatures in the feathered areas as increasing age. In all measurements, leg surface temperatures were observed above 37°C in the fast-growing genotype and above 36°C in the slow-growing genotype. The difference in surface temperatures between weeks was statistically significant in the fast-growing genotype but insignificant in the slow-growing genotype. It is thought that this significance may be due to the larger average live weight differences between the 4th and 6th weeks in the fast-growing genotype. Supporting our observation, Nascimento et al. (2017) stated that metabolic heat production in broiler chickens increases linearly with body weight gain.

In the litter surface temperature measurements in the pens where slow- and fast-growing broiler chickens were reared, higher litter surface temperatures were consistently observed in the fast-growing genotype. Supporting this finding, Steenfeldt et al. (2019) reported that litter surface temperatures were higher in the pens where fast-growing broiler chickens were reared.

CONCLUSION

Briefly, feather development on different body parts played an important role in monitoring surface temperature by thermal imaging. Therefore, feathered and featherless parts should be considered separately to estimate the surface temperature of broiler chickens during the rearing period. The results confirmed that age and genotype are the factors affecting surface temperature. It is believed that continuous monitoring of potential fluctuations in ambient and the broiler chickens' surface temperatures using infrared thermal cameras throughout the rearing period is thought to contribute to maintaining thermal comfort and thus can improve the welfare of the broiler chickens.

DECLARATIONS

Ethics Approval

This experiment was implemented under the approval of the Animal Ethics Committee of Aydın Adnan Menderes University (64583101/2024/28).

Conflict of Interest

The authors declared that there is no conflict of interest.

Consent for Publication

Not applicable

Author contribution

Idea, concept and design: SK

Data collection and analysis: SK

Drafting of the manuscript: SK

Critical review: AN

Data Availability

The data that findings of this study are available from the corresponding author upon reasonable request.

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