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Evaluation of Body Surface Temperature in Broiler Chickens during the Rearing Period Based on Age, Air Temperature and Feather Condition

Research Article

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ABSTRACT

Thermal comfort zone is a crucial importance in broiler chickens to preserve body temperature homeostasis. Since surface temperature contributes to thermal comfort, body surface temperature can be used to evaluate thermal equilibrium in animals. The heat flow at the boundary layer between broilers' bodies and the environment differs between feathered and unfeathered areas. The aim of the present investigation was to adopt linear regression models incorporating environmental temperature and age of birds to predict the surface temperatures of the feathered and unfeathered areas. Temperatures of eight different parts on the body surface were measured using an infrared thermometer during the growth period (1-6 weeks). High correlation between the temperature of feathered regions and air temperature showed that these areas respond faster to changes in the rearing environmental temperature. Six equations were developed for predicting mean surface temperature and also differences between the body surface and air temperature as a function of air temperature, age and feathered or unfeathered body parts. As the air temperature increases, mean surface temperature and difference between body surface values raised and declined, respectively ($P<0.05$). Similar to the body surface temperature, the effect of age on difference between body surface and air temperature was different for feathered and unfeathered regions. According to the results, it is proposed that the deferent between the feathered and unfeathered areas should be incorporated in the models which used to predict broiler chicken body surface temperature.

KEY WORDS broiler chicken, infrared thermography, linear regression, surface temperature.

INTRODUCTION

The values of body surface temperature are usually used as a parameter to evaluate the comfort or thermal stress of broiler chickens (Shinder *et al.* 2007; Cangar *et al.* 2008). In birds, variation in body surface temperature depends on peripheral blood flow, which can show that birds are actively attempting to keep their core body temperature. Increased blood flow near the body surface and heat loss through sensible routes may be resulted in increasing surface temperatures (Nascimento *et al.* 2013). On the other hand, peripheral vasoconstriction results in decreases in blood flow; holds in situations which chickens experiencing thermoneutral or cold stress conditions (Nascimento *et al.* 2013). Skin surface temperature is a considerable parameter that changes rapidly according to environmental variations and can be applied to indicate variations in peripheral blood flow and heat exchange. Previous studies showed the contributions of different parts of body to the maintenance of thermal equilibrium (Malheiros *et al.* 2000; Shinder *et al.* 2007). The infrared thermography as a valuable tool to recognize physiological peak incidents in humans and animals provides the possibility for identifying spots of distinct values in radiant temperature (Montanholi *et al.* 2008; Bouzida *et al.* 2009). McManus *et al.* (2016) stated that infrared thermography in animal production is innovative, low cost, fast, and efficient. On the other without the need for physical contact with chickens provides important information. Also, it has been used for different analyses such as metabolic responses to thermal stress (Paim *et al.* 2013). Animal coats have low heat capacities, so surface temperature measurements can be made precisely, without disturbance (Tessier *et al.* 2003; Montanholi *et al.* 2008; Bouzida *et al.* 2009). Physiological response to variations in ambient temperature of birds leads to the corresponding fluctuations in skin temperature (Tessier *et al.* 2003; Shinder *et al.* 2007). However such fluctuations vary according to the part of the body (Zhou and Yamamoto, 1997). Because of the thick insulation coat of feathers on most of the body surface of broilers, the sensible heat loss becomes more efficient on body areas that are featherless such as shanks, feet, wattle and comb (Cangar *et al.* 2008).

Because of absence of sweat glands and high coverage of feathers in birds, body surface temperature is different based on the age of birds (Richards, 1971a). The impact of age on response to environmental conditions is partly attributed to the density of feathers in different parts of the body. Evaporative cooling becomes more important by increasing the temperature, and it is the only way of heat losses when ambient temperature gets similar to the body surface temperature (Kleiber, 1961).

The objective of the present study was to evaluate the body surface temperature of broiler chickens. For this purpose linear regression models were used to incorporating environmental temperature to predict the body surface temperatures of broiler chickens during rearing period. The another purpose of the current experiment was to evaluate the differences between surface temperature and ambient temperatures to understand the driving force in heat loss from the chickens through their commercial growth period of 6 wk (1 to 6 wk). In addition the effect of a potential confounding factor, such as age was also considered to evaluate the age-related changes in body temperature.

MATERIALS AND METHODS

The present study was carried out in the research station of the University of Jiroft, Jiroft city, Kerman province southeastern part of Iran (24 ˚35′ N, 57 ˚48′ E, and 627.72 m above mean sea level) during the Northern Hemisphere autumn (October to November).

Birds and housing

Data on one hundred and fifty male broiler chickens (Ross 308) were obtained from a local commercial hatchery.

The chickens were kept in favourable condition, had no plumage damage and had been exposed to minimal handling during their period of rearing. Birds were leg-tagged for identification. The chickens were housed in 15 floor pens (1 m×1.5 m) with 10 chickens per each. The floor was covered with sawdust as a dry absorbent litter material to a depth of 50 mm. The chickens had free access to a mash form diet and water. The data recording was started from day 4, before that birds were allowed to acclimatize to the floor pen until.

Measurements

Air temperature (T_a) was measured in the ridge cage about 1 m above the floor. Changes of air temperatures during the study period were shown in Figure 1.

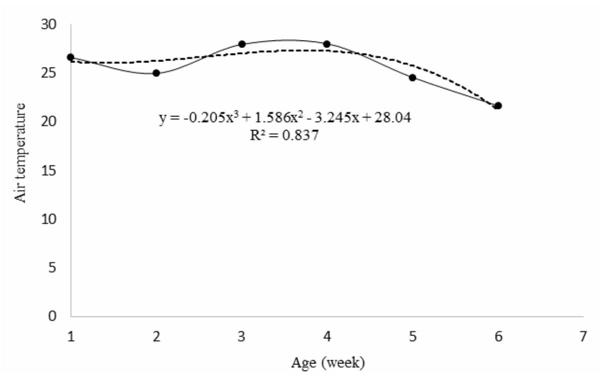

Figure 1 Changes of air temperature and polynomial trend based on age (week) of rearing period

During the experimental period the trends of air humidity and air velocity were almost constant and also the study was more focused on the surface temperatures. Therefore, air humidity and air velocity were not measured.

During the experiment, the T_a, body surface temperature (T_s) and floor temperature (T_{fl}) were measured three times a week. For measuring body surface temperature, two birds from each pen were randomly selected and the temperatures the considered parts of body were recorded using an infrared thermometer UT932 (for animal use). Mean surface temperature (MST) was calculated using the temperatures measured at several chosen body parts. In order to avoid the impacts of heat and moisture of the hands on the temperature of the feathers the latex gloves were used.

Data analysis

One-way ANOVA was performed to detect the significant differences of T_s among the selected parts of the body. As well as, an analysis of covariance (ANCOVA) test was applied to test the effects of main factors including age and temperature body parts, together with continuous variable of air temperature on ΔT.

Calculations were performed using the SPSS 20.0 statistics software (SPSS, 2011). The general linear method (GLM) package was used for modeling of MST and ΔT as a function of age, ambient temperature and feathered or unfeathered body regions.

RESULTS AND DISCUSSION

Depending on the body part and the age of the birds, the gradient of body surface temperatures ranged from 29.20 to 38.41 ˚C. Generally, during the rearing period, warmest parts of the bird were the eyes and underwings ($P<0.01$). It's may be partly due to the absence of isolating feathers in these parts. The head and back cape were the coldest areas ($P<0.01$).

This could be attributed to the feathers coverage in these areas which have a strong isolating property (Cangar *et al.* 2008). Absolute surface temperatures as a function of age and body parts are presented in Tables 1 and 2, respectively.

As shown in Figure 2, generally, the featherless areas including eye, anal skin, under wing and paw showed higher temperatures than the feathered areas including head, back cape, flight feathers and breast ($P<0.01$).

At week 1, the difference between maximum and minimum temperature points was 5 ˚C on the whole body surface, but on week 6 it increased to 8 ˚C. It has been reported that by growing the birds, the gradient of body surface temperature increased that it could be partially due to less uniform feather cover (Cangar *et al.* 2008). By taking the absolute body surface temperatures into account, the general trend of all chickens and body parts decreased with age of birds from 38.5 to 29 ˚C. Richards (1971b), proposed that by improving quality and number of the feathers in different parts of body could act as an isolation layer, therefore decrease the surface temperatures.

It has been pointed out that body surface temperature is strongly affected by air temperatures (Horowitz, 1998; Yahav *et al.* 2009). Due to the correlation between broiler response and air temperatures, the air temperature may be applied to predict the temperatures of body regions (Nascimento *et al.* 2013).

The obtained correlations between the temperature of unfeathered and feathered parts with air temperature (T_a) were found to be 0.42 and 0.58, respectively. In this regard, wings had the highest correlation (0.61) while the lowest correlations were related to paw (0.07). It should be noted that the correlation between air and paw temperature was not significant ($P>0.05$).

Naas *et al.* (2010) reported that that feathered areas respond quickly to changes in the air temperature which is in agreement with the result obtained in the present study.

During the different ages, the highest and lowest correlations between T_s and T_a were obtained in at second (0.84) and fourth (0.15) weeks, respectively. It may be attributed partly to differences in insulation coat of feathers on most of the body surface in the corresponding ages (Naas *et al.* 2010).

Differences between the surface temperatures and the surrounding air temperature were calculated as ΔT (T_s-T_a). In the present study, a significant difference was observed between the feathered and unfeathered of body parts in terms of in surface temperature, which is in agreement with literature (Malheiros *et al.* 2000; Shinder *et al.* 2007). A 2-way ANCOVA test was applied for testing the effects of 2 main factors, the age (in week) and the body part of the chicken, on the mean of the ΔT. There was a negative correlation between air temperature and the main effect of age ($r=-0.40$). Therefore, air temperature effect could be differentiated from the effect of age on ΔT. Yahav *et al.* (2009) showed that air temperature had a major influence on the maintenance of body temperature in broilers. Thus, air temperature was used as a covariate in the present research. As shown in Table 3, main effects of age and body part of the chickens revealed a significant effect on the temperature difference ($P<0.01$). It has been suggested that age is an important environmental factor which affects broiler surface temperature (Cangar *et al.* 2008).

Ambient and the surface temperatures of different body parts of chickens are shown in Figure 3. The ΔTs were at a maximum from the featherless parts of the body whereas it was at a minimum from the feathered parts. It has been reported that feather cover in some parts of body including the head, neck and abdomen region are low; therefore, insulation in these parts is poor (Leeson and Walsh, 2004). During the growth period, the ΔTs were at a maximum in week 6 ($P<0.05$). The differences (ΔT) could be attributed to the physiological change and management systems such as molting the feathers and decreasing of the inside temperature during the rearing periods (Cangar *et al.* 2008).

Effect of age and body regions on ΔT represented on Figures 4 and 5. The box had lines at the lesser quartile, median, and upper quartile values. According to the obtained results (Figure 4), ΔT was influenced by bird age ($P<0.05$). The highest and lowest differences occurred at sixth week (10.73±4.39 ˚C) and fourth week (5.84±3.94) of age, respectively.

Cangar *et al.* (2008) founded that the difference in body surface temperature would increase as a function of broiler age. They also reported that the largest difference occurred on day 28 and suggested that it was probably due to feather molting. This suggestion was not confirmed by the results obtained in the present research, because ΔT decreased according to age equation 2 (Eq. 2).

Table 1 The absolute temperatures (˚C)[1] of certain parts of the chicken at different ages (Mean±SD, n=90)

Part	Age (week)					
	1	2	3	4	5	6
Head	33.14±3.44^{c}	32.47±2.35^{c}	33.27±1.31^{e}	31.69±4.05^{de}	30.69±2.17^{de}	30.49±2.87^{d}
Eye	33.35±1.61^{bc}	33.11±2.37^{bc}	34.35±1.77^{d}	35.11±1.7^{b}	34.62±1.01^{b}	34.49±1.18^{b}
Back cape	34.08±1.34^{b}	33.63±2.03^{b}	35.57±1.17^{c}	31.54 3.42^{e}	30.19±2.66^{e}	29.30±2.74^{e}
Flight feathers	33.51±1.50^{bc}	33.01±2.28^{bc}	34.75±1.28^{d}	33.32±2.50^{c}	31.11±2.50^{de}	29.20±3.13^{e}
Under wing	36.01±1.33^{a}	36.83±1.20^{a}	38.41±0.79^{a}	38.11±1.25^{a}	37.04±1.47^{a}	37.57±1.08^{a}
Anal skin	34.22±1.24^{b}	33.59±1.74^{b}	36.26±1.19^{b}	35.71±2.52^{b}	33.58±3.36^{bc}	31.56±3.34^{d}
Breast	33.91±0.92b^{c}	33.13±2.06b^{c}	34.65±1.24^{d}	32.39±3.41^{cde}	31.46±2.86^{d}	32.88±2.14^{c}
Paw	30.99±2.62^{d}	32.51±1.80^{c}	34.13±2.06^{d}	32.99±4.02^{cd}	33.05±2.31^{c}	33.49±2.70^{bc}
P-value	0.00	0.00	0.00	0.00	0.00	0.00

[1] The temperatures were measured once a week during the rearing period of 6 wk.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).

Table 2 The absolute temperatures (˚C)[1] on certain parts of the chicken body surface and air temperature (Mean±SD, n=90)

Age (week)	Air	Head	Eye	Back cape	Flight feathers	Under wing	Anal skin	Breast	Paw
1	26.60±1.17	33.14±2.84^{a}	33.35±1.56^{d}	34.08±0.95^{b}	33.51±1.05^{b}	36.01±1.08^{d}	34.22±1.12^{b}	33.91±0.83^{ab}	30.99±2.05^{e}
2	24.97±1.03	32.47±1.23^{ab}	33.11±1.38^{d}	33.63±0.93^{b}	33.01±1.12^{b}	36.83±0.89^{c}	33.59±1.16^{b}	33.13±0.95^{bc}	32.51±1.42^{bcd}
3	27.94±1.53	33.27±1.12^{a}	34.35±1.47^{bc}	35.57±0.97^{a}	34.75±0.93^{a}	38.41±0.78^{a}	36.26±1.14^{a}	34.65±1.00^{a}	34.13±1.88^{a}
4	28.02±1.59	31.69±2.78^{bc}	35.11±1.19^{a}	31.54±1.02^{c}	33.32±1.76^{b}	38.11±1.12^{a}	35.71±1.67^{a}	32.39±1.99^{cd}	32.99±1.86^{ad}
5	24.56±1.26	30.69±1.35^{c}	34.62±0.92^{ab}	30.19±1.64^{d}	31.11±2.07^{c}	37.04±1.19^{c}	33.58±2.11^{b}	31.46±2.42^{d}	33.05±2.22^{ac}
6	21.64±2.17	30.49±1.36^{c}	34.49±0.93^{ac}	29.30±2.12^{d}	29.20±1.87^{d}	37.57±1.05^{b}	31.56±3.11^{c}	32.88±1.59^{c}	33.49±2.20^{ab}
P-value	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

[1] The temperatures were measured once a week during the rearing period of 6 wk.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).

Table 3 Results of analysis of covariance test[1]

Source	df	Type III sum of squares	Mean square	F-value	P > F
Age	5	3474.699	694.940	132.321	< 0**
Body part	7	11208.209	1601.173	304.874	< 0**
Age × body part	35	4606.566	131.616	25.061	< 0**

[1] Numbers with an asterisk represent the significant effects, interactions, or both (confidence interval of 99%).

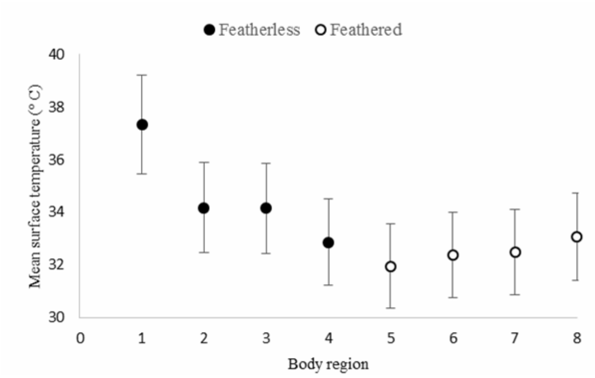

Figure 2 Body region surface temperature organized by clusters (with feathers and featherless) during the rearing period of 6 wk
1) underwing; 2) eye; 3) anal skin; 4) paw; 5) head; 6) back; 7) wing and 8) breast

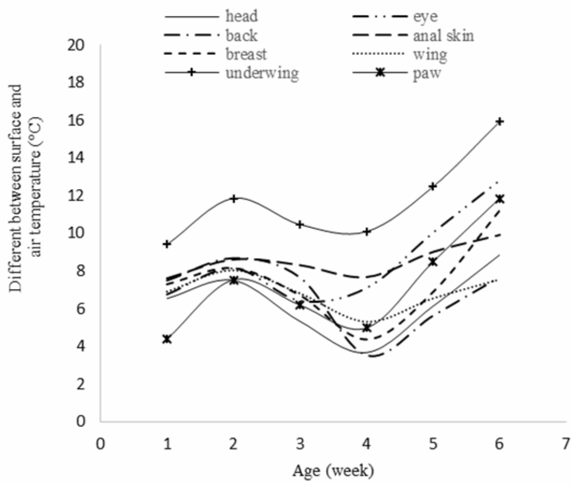

Figure 3 Differences between the air and the surface temperature of different body parts of broiler chickens

Therefore it is suggested that the mentioned differences could be due to development of thermoregulation by the birds. In different parts of body the highest and lowest ΔT were related to under wing (11.71±3.05 ˚C) and head (6.34±3.52), respectively (P<0.05). It may be to some extent attributed to the lack of feathers on the under wing and thin layer of the feather on the head parts.

The trend of ΔT indicating that increase of ΔT in the first two weeks and then decrease up to fourth week (the lowest values), and then increased again until sixth week (Figures 3 and 4).

Leeson and Walsh (2004) demonstrated that one of the factors that could be increase in ΔT from fourth to sixth week of rearing period was molting of the feathers at that specific age. Which, most importantly of them begins at around fourth to fifth week, so that for the modern broiler chickens, this is the only molt of significance. Appearing around the same periods, the increase of ΔT measured by thermogram could be due to this molting.

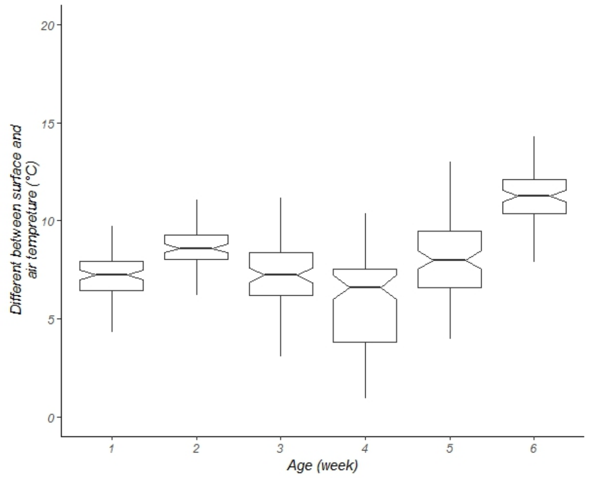

Figure 4 Effect of age on difference between surface and air temperatures (˚C)

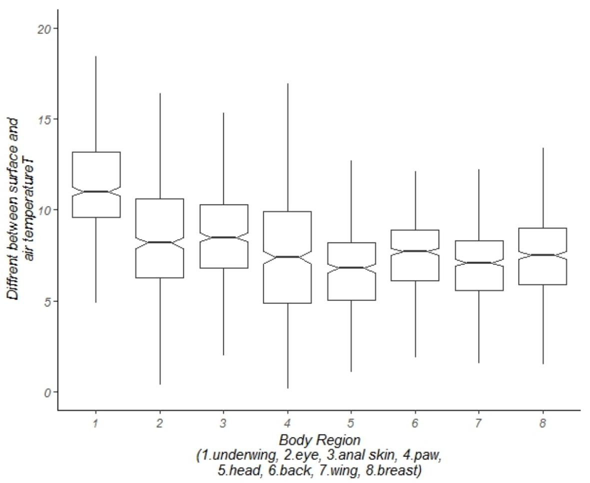

Figure 5 Effect of body regions on difference between surface and air temperatures (˚C)

The second reasons could be the decrease in air temperature in the broiler house during these ages. Maximum ambient temperature occurred at the fourth weeks (Figure 1). Therefore the minimum of ΔT happened at this age. Statistical results from the ANCOVA test proved that decrease in air temperature have a significant effect on ΔT (P<0.05). Also another reason could be development and evolution of thermoregulatory system in the ages. These results were in agreement with the results obtained by Cangar *et al.* (2008).

To establish the linear regression models, all tested variables were included in the initial model. The trend of decreasing birds MST as a function of age is due to an increase in the feathering index of the different body parts, acting as an insulating layer (Nascimento *et al.* 2011).

Eq. 1) MST= 29.1 + 0.31 T_a – 0.29 age – 0.1 T_{fl}
R^2= 0.62

Also it was observed that with increasing in age and ambient temperature ΔT decreased (Eq. 2).

Eq. 2) ΔT= 27.04 – 0.62 T_a – 0.09 age – 0.12 T_{fl}
R^2= 0.74

The following equations can be used to estimate the MST (Eq. 3 and 4) and ΔT (Eq. 5 and 6) as a function of air temperature (Ta), age (in week) and temperature of feathered (head (T_h), back (T_{bk}), wing (T_w), breast (T_{bt})) or unfeathered (eye (T_e), anal skin (T_{as}), under wing (T_{uw}), paw (T_{pw})) body parts. These models showed that the calculation of MST and ΔT as e function of feathered parts were more accurate than unfeathered parts.

Eq. 3) MST= 11.68 + 0.1 T_a + 0.14 age + 0.1 T_h + 0.12 T_{bk} + 0.19 T_w + 0.17 T_{bt}
R^2= 0.86
Eq. 4) MST= 8.72 + 0.1 T_a– 0.4 age + 0.17 T_e + 0.16 T_{as} + 0.25 T_{uw} + 0.1 T_{pw}
R^2= 0.81
Eq. 5) ΔT= 8.02 – 0.9 T_a + 0.24 age + 0.13 T_h + 0.16 T_{bk} + 0.20 T_w + 0.22 T_{bt}
R^2= 0.95
Eq. 6) ΔT= 2.16 – 0.92 T_a– 0.4 age + 0.26 T_e + 0.13 T_{as} + 0.29 T_{uw} + 0.2 T_{pw}
R^2= 0.91

The results obtained from Eq. 1 showed that bird surface temperature decreased with age and increased with air temperature. The highest MST obtained when birds were on third week of age (Table 1), partly due to their thinner body feathering.

Naas *et al.* (2010) developed two functions to predict the temperature of feathered and unfeathered body areas of broilers. However, this model can be applied only to birds on the 42nd day of the rearing period, which greatly limits its practical application. The model described by Richards (1971a), has also been used to predict skin surface temperature. Because of the proposed models (Eq. 3 to Eq. 6) works based on the whole of rearing periods and deferent body parts of chickens, it seems that these models predict more accurately the actual temperature of the body surface compared to previous models.

CONCLUSION

According to the obtained results, development of thermoregulatory and coat system may have a key role in the regulation of body temperature in different parts of body during the rearing period. The results approved that air temperature and age were two important factors that affect body temperature. Therefore, the models used to predict broiler surface temperature must consider the differences between the feathered and unfeathered parts throughout the rearing period. When there is a lack of adequate instruments, such as infrared cameras or infrared thermometers, models obtained in the current study could be useful to predict body surface temperature.

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