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S139 Heritability of body surface temperature measured by infrared thermography in laying hens exposed to high temperature conditions

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Summary

Improving the adaptation of poultry to heat stress by selection requires having measures that are easy to obtain and that are heritable. Internal body temperature is used to quantify heat stress but is long to obtain and lacks precision. We tested the possibility of infrared thermography to record body temperature (BT) in two commercial lines of laying hens between 28 and 72 wk, submitted cyclically to periods at neutral or high ambient temperatures (19.6°C and 28.4°C, resp.). Mean BT were estimated for the wing, comb and shank areas (N=4465-4481 in line A, 7279-7311 in line B, depending on the trait). During hot periods, mean BT increased by 29.5-32.6% on the wing, by 20.6-22.5% on the shank and by 28.9-29.8% on the comb. Heritability of the mean BT was estimated in both lines. It was very low for the wing (0.03) consistently with the fact that wing BT is mainly linked to environmental temperature and to feather coverage. Heritability of the shank and the comb BT was also low but significantly different from zero (0.08-0.14), which indicates that the capacity of animals to dissipate heat is partly under genetic control. Heritability of the shank BT was the most consistent between the two lines, probably reflecting a higher precision of the measure of this part, the easiest to distinguish from environment. Using infrared thermography in chicken experimentation seems promising but a higher degree of precision is required in order to increase the heritability of these traits.

Keywords: heat, genetics, thermography, stress, laying hens

Introduction

The past decade was the warmest on record and Earth has been growing warmer over the last 50 years (Blunden *et al.*, 2011). The European Environment Agency estimated that the temperature in Europe will continue to increase by 0.75 to 2.00°C between 2020 and 2050, and that the number of warm days per year will increase by 6 to 10 d every decade (<http://www.eea.europa.eu>). Animals will thus have to adapt to these higher rearing temperatures. The animal ability to maintain their body temperature within normal range depends on the balance between the thermogenesis and the rate of heat dissipation. Birds respond to high ambient temperatures by reducing their feed consumption to limit feed induced thermogenesis, by increasing evaporative heat loss through panting and by sensible heat loss through convection and radiation (Mount and Monteith, 1974). The latter has the

lowest energetic cost and consequently a lower impact on production. It would thus be interesting to check whether some birds have a better capacity to dissipate heat through sensible heat loss associated with non-evaporative cooling at high temperatures. The goal of our project was to study the genetic basis of adaptation of laying hens to moderate heat stress. In this talk, we will discuss how thermography could be used to estimate the genetic ability of hens to adapt to heat, by estimating genetic parameters of surface temperature, a key component of sensible heat loss, in two lines of laying hens exposed cyclically to moderate heat and/or feed stress during the whole production cycle.

Materials and methods

Animals and rearing conditions

Two pure lines used in a 4 way cross of commercial laying hens were used in this study. At 15 weeks of age, each line was dispatched among 6 floor pens of 200 birds. From 28 weeks to 77 weeks of age, half of the pens were submitted to 3 successive cycles of stress, interposed to recovery periods at standard conditions (neutral ambient temperature and commercial feed). The other half of the pens were kept at standard conditions throughout the whole production period. Each cycle of stress was composed of three phases: i) 24 d of “feed stress” (i.e. suboptimal diet), followed by 24 d of recovery; ii) 12 d of “heat stress” followed by 12 d of recovery; iii) 24 d of combined feed and heat stress factors (i.e. 12 d of diet change and 12 d with both diet change and heat stress) followed by 24 d of recovery. Ambient temperature and relative air humidity were on average 28.4°C and 46.9% during heat stress periods (HS) and 19.6°C and 68.8% during thermoneutral periods (TN).

Measures

Thermal pictures of birds were taken at the beginning of the experiment (at 28 wks), at the end of each stress period (at 32, 37, 42, 54, 67 and 72 wks) and at the end of each recovery period (at 35, 39, 45, 52, 56, 63 and 70 wks) on all birds for 2 pens per line and on a sample of 50 birds per pen for the remaining 4 pens per line. To take the pictures, birds were placed side-on in a wooden box. When the comb was not clearly visible, a second picture was taken zoomed in on the comb (Figure 1). We used a FLIR B35 camera¹, providing a thermal sensitivity of 0.05°C and an accuracy of 2%. Images were then analyzed with the ThermaCam Pro 2.10 software (© 1997-2010 FLIR systems AB, Sweden). The comb, wing and shank areas were drawn manually, and their mean temperature calculated. Emissivity was set at 0.980 for comb and shank areas and at 0.896 for wing area.

Statistical analyses

Analyses were performed separately for each line. Summary statistics were obtained using PROC MEANS of SAS. An analysis of variance was then performed with PROC GLM of SAS to check which factors were significant. The genetic parameters were estimated using the REML method implemented in the VCE 6.0.2 (Neumaier and Groeneveld, 1998; Groeneveld *et al.*, 2008). Taking into account the result of the GLM analysis, two different models were fitted depending on the trait. Model 1 was used for all traits except for comb area in line A which was analyzed with model 2.

$$y_{ijkl} = \mu + P_i + HS_j + \beta_1 \times A + \beta_2 \times AT + \beta_3 \times RH + NP_k + a_l + e_{ijkl} \quad (1)$$

$$y_{ijkl} = \mu + P_i + HS_j + \beta_1 \times A + \beta_2 \times AT + NP_k + a_l + e_{ijkl} \quad (2)$$

where y_{ijkl} is the body temperature of animal l ($N=4465-4481$ in line A, $7279-7311$ in line B), μ the general mean, P_i the fixed effect of pen i ($N=1$ to 6 for each line), HS_j the fixed effect of heat stress treatment j (j = submitted or not submitted to cycles of heat stress), A the covariate

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of age, AT the covariate of ambient temperature in the pen, RH the covariate of relative air humidity in the pen, β_1 , β_2 and β_3 the regression coefficients corresponding to the 3 covariates, NP_k the fixed effect of the number of pictures taken per bird (N=1 without extra picture comb, 2 with extra picture comb), a_i the random direct genetic effect of animal i (N=990 and 1485 for lines A and B, resp.), and e_{ijkl} the residual effect pertaining to animal j .

Results and discussion

Table 1 shows that under HS, temperatures of all areas increased in the same proportions in both lines, the increase being larger for the wing and the comb (+28.9 to +32.6%) than for the shank (+20.6 to +22.5%). It is to note that the increase of temperature in each zone during HS is strongly dependent on the temperature at TN, the former being higher when the latter is lower. At the contrary, variability was reduced under HS, especially for the shank (CV from 10.4 to 11.4% at 19°C, from 3.3 to 3.6% at 29°C). Heritability of surface temperature was close to zero for the wing area, and low but significantly different from zero for the shank and the comb. These values are consistent with previously estimated heritabilities of body temperature (0.06-0.19) or of surface temperature of the comb (0.02-0.21) in broilers and adult layers at TN for body temperature (Tixier-Boichard *et al.*, 1995; Loyau *et al.*, 2013; de Verdal *et al.*, 2013). A low heritability for wing area could be expected as this zone is isolated by feathers and plays a less important role in heat dissipation than unfeathered zones. Moreover, as hens aged, their feather coverage deteriorated, and wing surface temperature was a mix of feather and bare skin zones, which makes the measure less reliable. Tixier-Boichard *et al.* (1995) found a much higher heritability of temperature in adult males than in females (0.49 vs 0.19), which suggests that the measure of the temperature in adult females can be disturbed by the daily variations due to the ovulatory cycle. In our study, measures of temperatures have been done during the whole day, i.e. at different moments of the ovulatory cycle for females measured in the morning or in the afternoon, which probably introduced an additional noise in the measure. There was also a large variability between birds for the comb size, which might lead to differences in the capacity of birds to dissipate heat through this body part. In our study, the shank was the most suitable area to measure accurately on a large number of animals, as required for genetic studies. The genetic correlation between shank and comb temperatures is moderately positive, indicating that, even if they play the same role in heat dissipation, their genetic control is partly different. For the future, standardizing the measure as proposed by Yahav and Giloh (2012) would probably reduce the noise in the measure and would probably lead to higher values of heritability, compatible with selection requirements. Analysis of the remaining pictures will also enable us to have enough data under HS to be able to analyze TN and HS temperatures as different traits and then to assess whether genetic control of surface temperature under HS or under TN are the same.

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Table 1. Summary statistics of wing, comb and shank temperature.

Line	Temperature	Zone					
		Wing		Comb		Shank	
		N	Mean \pm STD	N	Mean \pm STD	N	Mean \pm STD
A	18°C	3853	26.08 \pm 1.47	3841	28.35 \pm 3.05	3846	31.51 \pm 3.51
	29°C	628	33.77 \pm 1.53	624	36.79 \pm 2.75	628	38.00 \pm 1.24
	All	4481	27.15 \pm 3.05	4465	29.53 \pm 4.20	4474	32.42 \pm 3.98
B	18°C	6484	25.86 \pm 1.56	6452	28.78 \pm 3.24	6478	31.02 \pm 3.22
	29°C	827	34.30 \pm 1.28	827	37.11 \pm 2.65	827	38.00 \pm 1.37
	All	7311	26.82 \pm 3.08	7279	29.73 \pm 4.13	7305	31.81 \pm 3.78

Table 2. Genetic parameters of wing, comb, and shank temperature (\pm SE). Heritability estimates are on the diagonal, genetic correlations above the diagonal.

Area	Line A			Line B		
	Wing	Comb	Shank	Wing	Comb	Shank
Wing	0.03 \pm 0.01	0.09 \pm 0.16	-0.09 \pm 0.16	0.03 \pm 0.01	0.36 \pm 0.12	0.48 \pm 0.10
Comb		0.08 \pm 0.01	0.55 \pm 0.08		0.14 \pm 0.02	0.46 \pm 0.07
Shank			0.12 \pm 0.02			0.14 \pm 0.01

Figure 1. Example of thermal pictures of birds with a zoom in on the comb (1a at TN, 1b during HS), and on the whole body (1c at TN, 1d during HS).

