Applied Animal Behaviour Science 134 (2011) 164–169

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

Roosting behaviour in laying hens on perches of different temperatures: Trade-offs between thermoregulation, energy budget, vigilance and resting

Thorsten Pickel[a,b], Britta Scholz[a,*], Lars Schrader[a]

[a] Institute of Animal Welfare and Animal Husbandry, Friedrich-Loeffler-Institut, Dörnbergstrasse 25/27, 29223 Celle, Germany
[b] Department of Behavioural Biology, University of Muenster, Badestrasse 13, 48149 Münster, Germany

ARTICLE INFO

Article history:
Accepted 6 July 2011
Available online 29 July 2011

Keywords:
Perch temperature
Perching
Laying hens
Behaviour
Thermoregulation

ABSTRACT

Laying hens usually select an elevated position for resting at night-time. A previous study showed that the position a hen takes during resting was affected by perch material, most probably due to its thermal conductivity. The aim of the present study was to analyse the effect of perch surface temperature on resting behaviour and resting comfort in laying hens. In each of two identical trials, three groups of five Lohmann Selected Leghorn hens were housed in each of three compartments in turn ($n = 30$ birds in six groups). Compartments were equally equipped with one smooth, round galvanised steel perch of 34 mm external diameter. The surface temperatures of perches were controlled by passing water through them, giving temperatures of 15 °C, 18 °C (room temperature) and 28 °C respectively in the three compartments. Hen behaviour was observed at night-time by investigating the proportion of active behavioural patterns and resting (standing or sitting), either with 'head forward motionless and neck withdrawn' or 'head tucked backwards into feathers above wing base or behind a wing.' The number of hens perching and the time spent perching were unaffected by perch temperature. Hens' resting postures, however, were strongly influenced. On the warmest perch, hens rested more with their head forward in a standing position and showed more active behavioural patterns compared to both cooler perches ($P < 0.001$). On the cooler perches, hens rested more with their head covered by feathers in a sitting and standing position ($P < 0.05$). Our data show that perch temperature strongly affects laying hens' resting behaviour. In this context, hens are confronted with arising trade-offs between thermoregulatory adjustment of behaviour, optimisation of energy budget, restful roosting and vigilance behaviour.

1. Introduction

Hens and many other fowl-like birds (Galliformes) usually select an elevated position for resting at night-time. Under natural conditions, resting behaviour is performed on branches of trees (Collias and Collias, 1967; Wood-Gush, 1971), whereas in extensive housing systems, hens are offered artificial perches for roosting. As hens display signs of unrest and frustration if access to an elevated resting location is denied, the possibility to roost is pronounced as one of hens' ethological needs (Sandilands et al., 2009). There are different types of resting behaviour in laying hens. A hen's head and bill can either be tucked into feathers above the wing base or behind the wing or its head can be kept forward with the neck withdrawn. Furthermore, a hen's bill can slip down and resting occurs with outstretched neck and drooping head (Blokhuis, 1984; Kruijt,

* Corresponding author. Tel.: +49 5141 3846 132; fax: +49 5141 3846 117.
E-mail address: britta.scholz@fli.bund.de (B. Scholz).

0168-1591/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.applanim.2011.07.003

1964). The type of resting behaviour is not strictly related to the quality of sleep. Van Luijtelaar et al. (1987) conducted electrophysiological measurements in resting hens and found that sleep (REM phases) occurs while hens rest with their head forward motionless and at least one eye closed and also while hens have their head tucked backwards under a wing, both either in a sitting and standing position. Instead of reflecting the quality of sleep, resting postures are likely to serve a thermoregulatory function in hens. Blokhuis (1984) found a negative correlation between outside temperatures and the frequency of hens resting with their head tucked into feathers at night-time when layers were kept at air temperatures between 4 °C to 16 °C in a semi-open housing.

In a recent study, in which hens were kept at air temperatures of about 18 °C, we found that resting postures during night-time were also affected by perch material (Pickel et al., 2010). On round, galvanised steel perches, hens rested more with their head tucked backwards into their feathers and less with their head forward compared to round, hard wood and rubber covered perches. In addition, during resting at night-time, hens stood less and sat more on steel perches compared to the other two materials. These results suggest that different resting positions may also be a consequence of thermoregulatory adaptation resulting from different thermal conductivities of the particular perches. Several authors found that covering head by feathers, especially comb and wattles, minimises layers' heat loss (Deighton and Hutchinson, 1940; Quinn and Baumel, 1990; Van Kampen, 1971). Furthermore, heat loss of sitting hens was described to decrease by approximately 20% to 40% compared to standing hens (DeShazer et al., 1970).

Thus, at cold ambient temperatures or when resting on perches with a high thermal conductivity, hens will choose to reduce heat loss by covering their head with feathers and by resting in a sitting position. At high ambient temperatures, heat dissipation is increased by exposing comb and wattles to the surrounding air and by resting in a standing position. However, changing the resting position for the purpose of thermoregulation at high ambient temperatures is likely to be costly for hens in terms of resting comfort and energy demand. Sitting is the more stable position compared to standing (Blokhuis, 1984; Quinn and Baumel, 1990) and during sitting, metabolism rate is reduced by 40% to 50% compared to standing (Deighton and Hutchinson, 1940). Thus, hens' demand for thermoregulation at high temperatures may be counteracted by their demand for a stable and energy saving resting position. On the other hand, at low ambient temperatures, the resting posture with the head covered by feathers is likely to reduce hens' vigilance.

Until now, the relationship between resting posture and thermal conditions, such as different perch surface temperature, has not been systematically investigated. From these results, conclusions may be drawn whether hens' resting postures can be used to evaluate the temperature condition of perches. Furthermore, our results provide new and interesting information on optimal perch properties with respect to the degree of resting comfort and thermoregulatory adjustment in laying hens.

In the present study, we experimentally varied the temperature of three round, galvanised steel perches (15 °C, 18 °C and 28 °C) and, thus, the possibility for heat dissipation from hens' feet to the perch and observed hens' resting behaviour at night-time. We hypothesised that hens would rest more with their head tucked backwards into their feathers and sit more during resting on cold perches. On warm perches, we expected hens to rest more with their head forward and in a standing position.

2. Material and methods

2.1. Animals and housing condition

A total of 30 Lohmann Selected Leghorn (LSL) laying hens were observed over two identical trials. Hens were cage-reared without access to perches. At the age of 18 weeks, layers were transferred in groups of five individuals to three experimental compartments and housed indoors under standardised conditions with an average room temperature of 18.5 ± 0.4 °C and an average relative humidity of 23.3 ± 6.6%. Room temperature and relative humidity were automatically recorded by a data logger (Testo, Hirschau, Germany), which was centrally positioned in the experimental room, every 15 min throughout both trials. No systematic variation in room temperature or relative humidity could be observed between day- or night-time or in the course of the two experiments. The experimental room was artificially lit with a 14 h light period from 4:00 to 18:00 h (20 lx), including a 15 min phase of dawn and dusk (1 lx). The three experimental compartments (100 cm wide × 200 cm deep × 200 cm high each) were separated by cage-wire, thus allowing hens of neighbouring compartments to see each other. Each compartment had a plastic grid floor and was equally furnished with a nest box and a dust bath area containing sawdust. A commercial standard diet for laying hens and water were provided ad libitum.

Each compartment was equipped with a perch of 100 cm length and provided each hen with 20 cm perching space. Perches consisted of round, galvanised steel tubes with a smooth surface (34 mm outer diameter), which are commonly used in commercial housing systems for laying hens. Perches were installed at a height of 40 cm and 40 cm away from the back wall. In order to investigate the effect of different perch surface temperatures on hens' resting behaviour, warm and cold perch surface conditions were achieved by connecting each perch to a separate hose system, which led to one of three water basins. By a closed circulation system, water was pumped from the basin through the steel tubes and back to the basin again, thus achieving perch surface temperatures above, below and approximately equal to room temperature. One water basin was placed in a refrigerator and the perch of one experimental compartment was cooled to an average temperature of 14.7 ± 0.9 °C (min. 14.0–max. 15.8 °C) (15 °C). Due to technical reasons, a lower perch surface temperature than 15 °C could not be achieved by the water passage. The water of a second basin was heated by an underwater heater resulting in an average perch surface temperature of 28.0 °C ± 0.2 °C (min. 27.7–max. 28.3 °C) (28 °C). The water of the third basin was neither heated nor cooled but also passed through with water. This perch had an average surface temperature of 18.3 °C ± 0.4 °C (min. 17.7–max. 18.8 °C) (18 °C), thus approximately conforming to the room temperature of the experimental stable.

2 m above each perch, a video camera with an infrared, light-emitting diode beam (Sanyo Video AG, Ahrensburg, Germany) was installed to record hens' behaviour during night-time. Video recordings were supported by a PC with self-customised recording software.

At the beginning and at the end of each test period, a general health check of hens was carried out using a scoring scheme according to Rönchen et al. (2008) and Scholz et al. (2008). Only hens without foot pad lesions and with no keel bone deformities were included in the study, thus guaranteeing that data were not affected by impaired physical conditions of hens. In order to distinguish individuals from each other, hens were fitted with numbered backpack marks, which were made of soft PVC (140 mm × 80 mm, approx. 20 g) and attached by straps around their wings. Before the test procedure started, hens were given a habituation period of two weeks, in which they were able to adapt to the backpack marks and to the experimental compartments. In addition, hens learned to reach the elevated perches for night-time roosting. Throughout the habituation period, no water was passed through the perches.

2.2. Test procedure and data collection

After the habituation period, water circulation was started and the three test perches reached their final temperatures (15 °C, 18 °C and 28 °C) within approximately 3–4 h. Throughout the testing period, hen groups were weekly moved between the three experimental compartments, thus having access to the differently tempered perches according to a fixed rotation schedule (latin square design). Hens were moved between the different compartments in order to exclude effects of compartment position within the experimental stable. Each time before hens were transferred to a different compartment, perches were carefully cleaned with water. Six days after hens were moved to another compartment and therefore introduced to a different perch temperature, videos of perching hens were taken during one dark period (18:00 to 4:00 h). Hens' behavioural patterns were recorded using scan sampling method (according to Martin and Bateson, 1993) in 5 min intervals. Analyses were done using 'The Observer' (Version 5.0, Noldus Information Technology BV, Wageningen, The Netherlands).

Behaviours were classified according to two main categories: hens were either off or on the test perch. Hens' behaviour on perch was divided into active behavioural patterns (body or head in motion) and resting behaviour (hen motionless). With relation to resting behaviour, four different postures were analysed: hens rested either with their 'head forward motionless and the neck withdrawn' (resting (head forward)) or with their 'head tucked backwards into their feathers above the wing base or behind a wing' (resting (head back)). Both resting postures were separately recorded for sitting and standing hens (according to Blokhuis, 1984; Pickel et al., 2010). The following different roosting behaviours were analysed: resting (head forward)/sitting, resting (head forward)/standing, resting (head back)/sitting, resting (head back)/standing, active/sitting and active/standing. Results of these behaviours are given in percentage of time a hen showed a particular behavioural pattern within an observation period. Hens which spent less than 10% of time on a test perch during an observation period were excluded from the analysis.

2.3. Statistical analysis

The number of hens on the different test perches and the time spent perching were compared using non-parametrical Friedman test. Data of hens' behavioural patterns were expressed as proportions ranging between 0 and 1 and were therefore transformed by arcsin square root method. Transformed data were then subjected to a mixed linear model (PROC MIXED) of SAS Enterprise Guide 4.1. Perch temperature (15 °C, 18 °C, 28 °C), trial (1, 2), and their interaction were included as fixed factors. Air temperature was included as covariate and hens nested in groups were employed as random factor. In cases of significant effects, a post hoc comparison was performed using Tukey–Kramer test. Figures display back-transformed data together with their 95% confidence intervals (CI) in percent of observation time of a particular behavioural trait.

3. Results

A total of 93.3% of layers spent the night on perch (hens being on perch for more than 10 min) (30 hens, 3 night-time observations each). In six cases (6.7%), layers were excluded from the analysis because they had spent less than 10 min on a test perch throughout a particular night-time observation period. The percentage of hens perching did not differ between the three different perch temperature treatments (Friedman test: $\chi^2 = 0.29$, df = 2, $P = 0.867$; data not shown). In addition, no difference was found with regard to the time hens spent on a particular test perch (Friedman test: $\chi^2 = 2.00$, df = 2, $P = 0.368$; data not shown). In general, resting in a sitting position was observed more often compared to resting in a standing position (80 vs. 20%; $t_{83} = 16.71$, $P < 0.001$; data not shown).

In birds that were standing, time spent resting (head forward) was influenced by perch temperature ($F_{2,49} = 109.68$, $P < 0.001$), whereas no effect was observed in sitting hens ($F_{2,49} = 2.44$, $P = 0.100$; Fig. 1a). In standing hens, resting (head forward) occurred more often on the 28 °C perch compared to test perches of 15 and 18 °C (28 °C vs. 18 °C: $t_{49} = 12.07$, $P < 0.001$; 28 °C vs. 15 °C: $t_{49} = 13.43$, $P < 0.001$). No difference was found between 15 °C and 18 °C perches ($t_{49} = -1.60$, $P = 0.254$; Fig. 1b).

Resting (head back) was affected by perch temperature ($F_{2,49} = 182.29$, $P < 0.001$) in sitting hens and decreased with increasing perch temperature (Fig. 1c). Differences between all pair-wise comparisons were significant (18 °C vs.15 °C: $t_{49} = 3.22$, $P = 0.006$; 18 °C vs. 28 °C: $t_{49} = 14.89$, $P < 0.001$; 15 °C vs. 28 °C: $t_{49} = 17.77$, $P < 0.001$). The level of resting (head back) in standing hens was generally low (Fig. 1d) but was also affected by perch temperature ($F_{2,49} = 7.44$, $P < 0.01$). Whereas hens performed

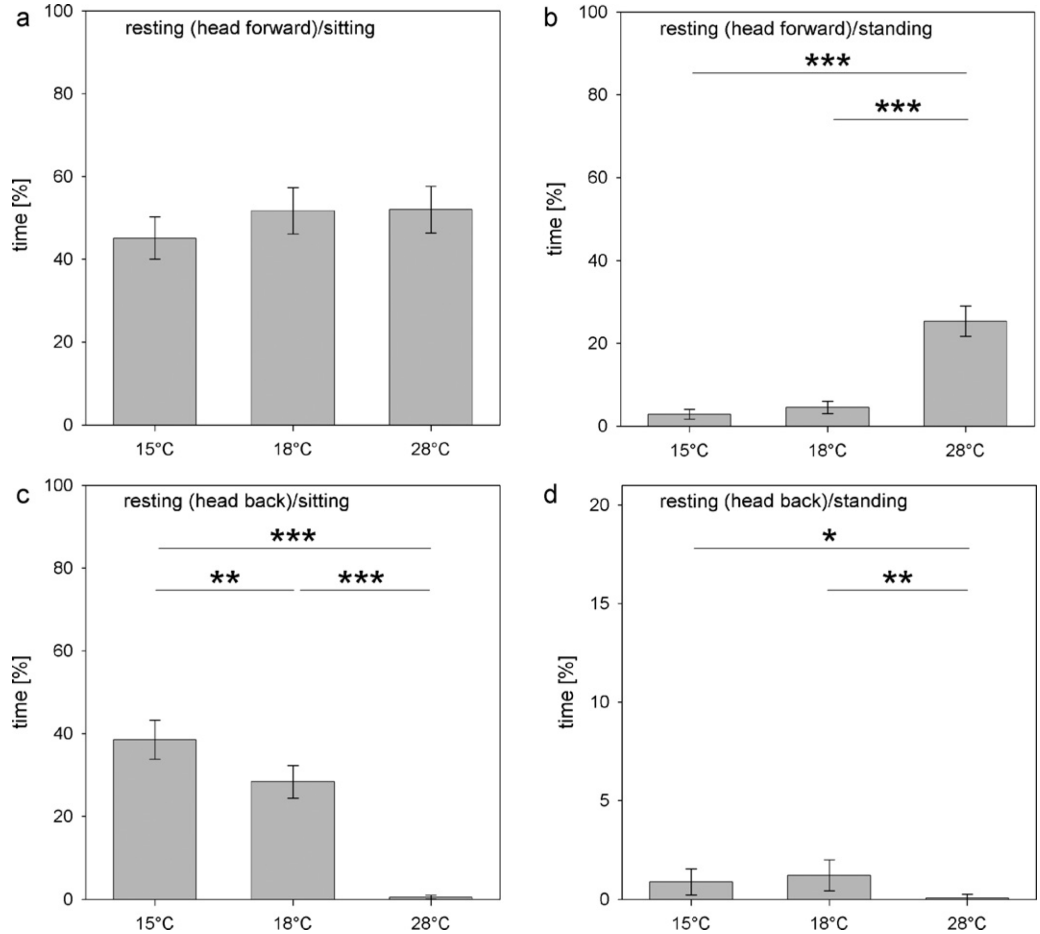

Fig. 1. Percentage of time spent (least squares means and 95% CI) by roosting hens (a) resting (head forward)/sitting, (b) resting (head forward)/standing, (c) resting (head back)/sitting and (d) resting (head back)/standing on perches of different temperatures.

resting (head back) less often on the 28 °C compared to 18 °C (t_{49} = −3.66, P = 0.002) and 15 °C perches (t_{49} = −2.88, P = 0.016), it did not differ between perch temperatures of 15 °C and 18 °C (t_{49} = 0.71, P = 0.757).

In general, hens displayed little active behaviours throughout the observation periods (Fig. 2). However, in sitting and standing hens, perch temperature affected hens' active behaviours (active/sitting: $F_{2,49}$ = 15.63, P < 0.001; active/standing: $F_{2,49}$ = 9.15, P < 0.001). Hens were most often active on the 28 °C perch temperature in a sitting (28 °C vs.18 °C: t_{49} = 3.14, P = 0.008; 28 °C vs. 15 °C: t_{49} = 4.08, P < 0.001; Fig. 2a) and standing position (28 °C vs.18 °C: t_{49} = 4.90, P < 0.001; 28 °C vs. 15 °C: t_{49} = 4.77, P < 0.001; Fig. 2b). No differences were observed between 15 °C and 18 °C perches, neither in sitting (t_{49} = 0.02, P = 1.000) nor in standing hens (t_{49} = −1.02, P = 0.569).

None of the observed resting behaviours was affected by trial or interaction between perch temperature and trial.

4. Discussion

Our results show that hens' resting postures were strongly affected by perch surface temperature. Lower perch temperatures led to a higher proportion of hens resting with their head covered by feathers, both in a sitting and standing position. With increasing perch temperatures, hens performed more resting behaviour in a standing position with their heads forward. These findings fully confirm our hypothesis derived from the thermal demands of laying hens. In addition, on warm perches, hens showed more active behaviours in a sitting and standing position compared to cooler perches.

It is known that unfeathered body areas, such as comb, wattles and legs in laying hens, are important for heat dissipation (Baudinette et al., 1976; Johansen and Millard, 1973; Richards, 1971, 1974; Steen and Steen, 1965). Accordingly, resting in a standing position with the head forward on a warm perch offers hens the possibility to induce heat loss and thereby preventing negative consequences of hyperthermia on physical health. In contrast, on cold perches, a higher proportion of resting with the head tucked backwards into feathers in a sitting position covers the respective unfeathered areas of the body. Thus, hens avoid increased heat loss and prevent negative consequences of hypothermia (Blokhuis, 1984; Deighton and Hutchinson, 1940; DeShazer et al., 1970; Muiruri et al., 1989).

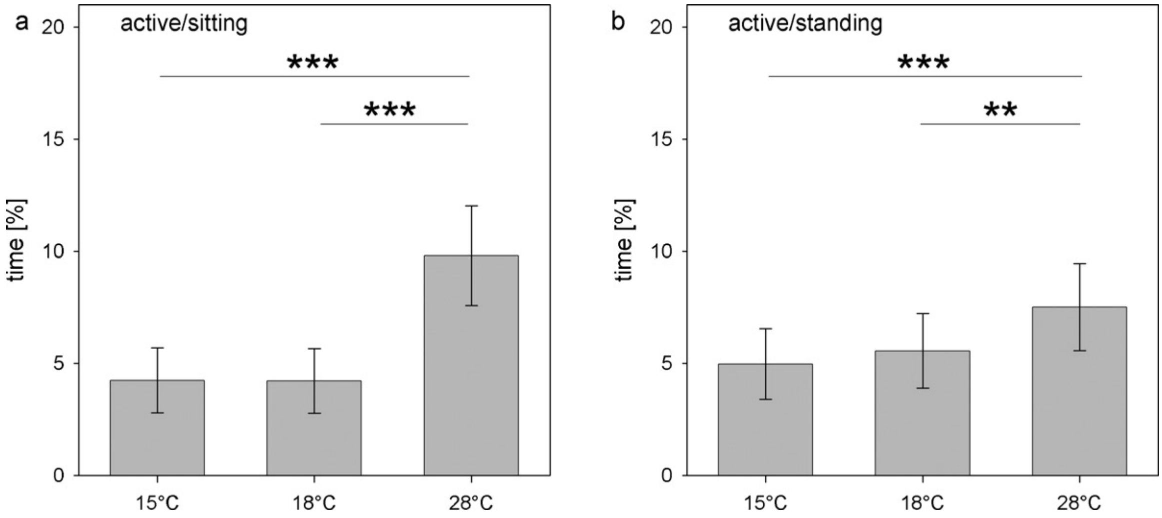

Fig. 2. Percentage of time spent (least squares means and 95% CI) by hens showing active behavioural patterns (a) in a sitting and (b) standing position on perches of different temperatures.

However, it seems reasonable that hens' behavioural adjustment to different thermal conditions of perches leads to a conflict and influences the comfort of resting. The increased proportion of resting in a standing position on the 28 °C perch causes a less stable resting position (Blokhuis, 1984; Quinn and Baumel, 1990) and possibly increases the risk of falling down and physical injury. Furthermore, it is known that resting in a standing position is costly and requires double the amount of energy compared to resting in a sitting position (Deighton and Hutchinson, 1940). Accordingly, if consequences of hyperthermia exceed consequences of energy costs, a conflict arises and hens may be constrained to spend the night in a standing position.

In addition, resting positions may also play a role with regard to the quality of resting behaviour. At warm perch temperatures and a resulting standing position, roosting may be less restful. This assumption is supported by the high proportion of hens, which showed active behavioural traits on the warm perch (28 °C). Warm perches seem to cause interruptions of hens' resting behaviour together with an increase of metabolism rate and higher loss of energy. However, behavioural adjustment may be needed to prevent heat stress. Hence, on warm perches, hens are confronted with trade-offs between behavioural adjustment for thermoregulation, optimisation of energy budget and restful roosting at the same time.

In contrast, resting with covered unfeathered areas to prevent heat loss (Deighton and Hutchinson, 1940; Van Kampen, 1971) saves metabolic energy and is an effective behavioural adjustment to cool thermal conditions. However, tucking head, eyes and ears backwards into feathers above the wing base or behind a wing may result in reduced vigilance behaviour. At least under natural conditions this is likely to result in a higher risk of predation (Newberry et al., 2001). Thus, on cold perches, trade-offs between thermoregulatory, behavioural adjustment in order to prevent heat loss (optimisation of energy budget) and vigilance behaviour arises.

5. Conclusions

The present data clearly show that different perch surface temperatures lead to different resting postures in laying hens. Depending on low or high perch temperature, trade-offs between the four factors thermoregulatory adjustment, energy budget, restful roosting and vigilance behaviour seem to exist. Furthermore, our results provide interesting information on optimal, thermal perch properties and on the degree of resting comfort during perching. In cold housing systems, for example, the use of metal perches may not be adequate as hens seem to be forced to reduce their natural vigilance behaviour in order to avoid heat loss, whereas in warm housings, perches of a lower thermal conductivity may not be appropriate as they may lead to less restful roosting behaviour. As the number of perching hens and the time spent perching were unaffected by perch temperatures, we can further conclude, together with results from other authors, that neither perch temperature nor perch material (Appleby et al., 1992; Pickel et al., 2010; Tauson and Abrahamsson, 1996), perch shape (Duncan et al., 1992) or perch width (Pickel et al., 2010; Struelens et al., 2009) influences laying hens' perch use per se.

Acknowledgement

We would like to thank Günter Jokisch for the technical installations of the experiment.

References

Appleby, M.C., Smith, S.F., Hughes, B.O., 1992. Individual perching behaviour of laying hens and its effects in cages. Br. Poult. Sci. 33, 227–238.

Baudinette, R.V., Loveridge, J.P., Wilson, K.J., Mills, C.D., Schmidt-Nielsen, K., 1976. Heat loss from feet of herring gulls at rest and during flight. Am. J. Physiol. 230, 920–924.

Blokhuis, H.J., 1984. Rest in poultry. Appl. Anim. Behav. Sci. 12, 289–303.

Collias, N.E., Collias, E.C., 1967. A field study of the red jungle fowl in north-central India. Condor 69 (4), 360–386.
DeShazer, J.A., Jordan, K.A., Suggs, C.W., 1970. Effects of acclimation on partitioning of heat loss by laying hens. Trans. ASAE 13, 82–84.
Deighton, T., Hutchinson, J.C.D., 1940. Studies on the metabolism of fowl II. The effect of activity on metabolism. J. Agric. Sci. 30, 141–157.
Duncan, E.T., Appleby, M.C., Hughes, B.O., 1992. Effect of perches in laying cages on welfare and production of hens. Br. Poult. Sci. 33, 25–35.
Johansen, K., Millard, R.W., 1973. Vascular responses to temperatures in the foot of the giant fulmar (*Macronectes giganteus*). J. Comp. Physiol. 85, 47–64.
Kruijt, J., 1964. Ontogeny of social behaviour in Burmese red junglefowl (*Gallus gallus spadiceus*) Bonnaterre. Behaviour (Suppl. 12), pp. I–IX, 1–201.
Martin, P., Bateson, P., 1993. Measuring Behaviour: An Introductory Guide, second ed. Cambridge University Press, Cambridge.
Muiruri, H.K., Gonyou, H.W., Harrison, P.C., 1989. Roost preferences and thermoregulatory roosting behaviour. Poult. Sci. 68 (Suppl. 1), 101.
Newberry, R.C., Estevez, I., Keeling, L.J., 2001. Group size and perching behaviour in young domestic fowl. Appl. Anim. Behav. Sci. 73, 117–129.
Pickel, T., Scholz, B., Schrader, L., 2010. Perch material and diameter affects particular perching behaviours in laying hens. Appl. Anim. Behav. Sci. 127, 37–42.
Quinn, T.H., Baumel, J.J., 1990. The digital tendon locking mechanism of the avian foot (Aves). Zoomorphology 109, 281–293.
Richards, S.A., 1971. The significance of changes in the temperature of the skin and body core of the chicken in the regulation of heat loss. J. Physiol. 216, 1–10.
Richards, S.A., 1974. Aspects of physical thermoregulation in fowl. In: Monteith, J.L., Mount, L.E. (Eds.), Heat Loss from Animals and Man. Butterworths, London, pp. 255–275.
Rönchen, S., Scholz, B., Hamann, H., Hewicker-Trautwein, M., Distl, O., 2008. Foot pad health in lohmann selected leghorn and lohmann brown laying hens kept in different housing systems with modified perch design. Arch. Geflügelk. 72, 97–105.
Sandilands, V., Moinard, C., Sparks, N.H.C., 2009. Providing laying hens with perches: fulfilling behavioural needs but causing injury? Br. Poult. Sci. 50, 395–406.
Scholz, B., Rönchen, S., Hamann, H., Hewicker-Trautwein, M., Distl, O., 2008. Keel bone condition in laying hens: a histological evaluation of macroscopically assessed keel bones. Berl. Munch. Tierarztl. Wochenschr. 121, 89–94.
Steen, I., Steen, J.B., 1965. The importance of the legs in the thermoregulation in birds. Acta Physiol. Scand. 63, 285–291.
Struelens, E., Tuyttens, F.A.M., Ampe, B., Odberg, F., Sonck, B., Duchateau, L., 2009. Perch width preferences of laying hens. Br. Poult. Sci. 50, 418–423.
Tauson, R., Abrahamsson, P., 1996. Foot and keel bone disorders in laying hens - effects of artificial perch material and hybrid. Acta Agric. Scand. A: Anim. Sci. 46, 239–246.
Van Kampen, M., 1971. Some aspects of thermoregulation in the white leghorn fowl. Int. J. Biometeor. 15, 244–246.
Van Luijtelaar, E.L.J.M., Van der Grinten, C.P.M., Blokhuis, H.J., Coenen, A.M.L., 1987. Sleep in the domestic hen (*Gallus domesticus*). Physiol. Behav. 41, 409–414.
Wood-Gush, D.G.M., 1971. The Behaviour of the Domestic Fowl. Heinemann Education Books, London.