Agronomy Research **16**(2), 320–327, 2018
https://doi.org/10.15159/AR.18.068

Effect of thermal environment on body temperature of early-stage laying hens

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Abstract. The thermal comfort condition of early-stage laying hens can be verified by means of physiological variations. The mean surface temperature and cloacal temperature are important parameters to demonstrate the effect of the thermal environment on the birds. The objective of the present study was to correlate homeostasis and stress with physiological responses (mean surface temperature and cloacal temperature) of lightweight laying hens of the Lohmann LSL Lite line aged from one to forty-two days when submitted to different thermal environments. A total of 864 birds with the same age, origin and uniform body weight were randomly distributed in four climatic chambers. The characterization of the different environments was as follows: thermal comfort temperature (33.0–19.0 °C), two cold stress levels (28.0–17.0 °C and 25.0–17.0 °C) and one level of heat stress (38.0 °C – 22.0 °C). The experiment was performed in a completely randomized design in the subdivided plots scheme, with four treatments in the plots and the evaluations (days) in the subplots. The means were compared using the Tukey test, adopting the 5% probability level. The birds maintained the physiological responses, based on cloacal and surface temperatures, within the normal range for all evaluated treatments during the period between 01 and 42 days of life. The surface temperature of the birds varied as a function of the air temperature of each breeding environment, with lower surface temperatures for mild cold and moderate cold treatments.

Key words: environmental conditions, poultry, surface temperature, layer chicks.

INTRODUCTION

In poultry farming, maximum productivity is achieved when birds are introduced in an environment that provides minimal energy exchanges and meets the welfare needs of the animal. Birds are classified as homeothermic because they retain (to a certain extent of adversity) body temperature constant or within a tolerable range, even if considerable variations occur in the external environment.

Animals of chicken species, like all homeothermic species, maintain a constant body temperature (41.1 °C) and are quite sensitive to climatic changes, and may suffer from adaptive issues under conditions of variation in the breeding environment (Albino et al., 2014). The amount of thermal energy stored per unit of body mass is determined by the body temperature of the bird, energy that can be increased or decreased by the processes of thermogenesis and thermolysis (Castilho et al., 2015).

Animal welfare is the full state of physical and mental health, in which the animal is in harmony with the environment where it lives, and a perceptual change to the state of comfort of the animal can be verified through its surface temperature (Camerini et al., 2016).

Nascimento et al. (2014), in a study conducted to evaluate the thermal comfort of broiler chickens in two aviaries with different air conditioning systems, found that in conditions of thermal comfort the superficial temperatures of the birds are strongly associated with the surface temperatures of the facility.

The temperature of the cloaca indicates the temperature of the body centre and can be considered as an important parameter to assess changes in the environmental conditions where the animals live (Brown-Brandtl et al., 2003). The variation in cloacal temperature indicates that the superficial heat exchanges of the skin are not enough to maintain the homeothermia (Nascimento, 2010).

To obtain better performance in poultry breeding, it is important to verify the interaction between animal and environment in order to maximize the energy available for production. For this reason researches on interaction between animals and environment have to be incentivized.

In this sense, this research was conducted with the objective to correlate homeostasis and stress with physiological responses (mean surface temperature and cloacal temperature) of laying hens of the Lohmann LSL Lite line, from one to forty – two days of age, when submitted to different thermal environments.

MATERIALS AND METHODS

Characterization of the facilities used during the initial phase

The experiment was developed in four climatic chambers with the following dimensions: 3.2 m long x 2.44 m wide x 2.38 m high, located in the experimental area of the Centre for Research in Ambience and Engineering of Agroindustrial Systems (AMBIAGRO) of the Department of Agricultural Engineering of the Federal University of Viçosa, in Viçosa, Minas Gerais, Brazil**.** Each climate chamber is equipped with an electric resistance air heater with 2,000 W of power, a hot-cold split air conditioner of 3,500 W and an air humidifier with a capacity of 4.5 L and a mist rate (average value) of 300 $ml.h^{-1}$. The heater and humidifier are operated by means of an MT-531R Plus temperature and humidity electronic controller, which has the following specifications: control temperature ranging from -10 °C to 70 °C with a resolution of 0.1 °C, control humidity ranging from 20% to 85%.

The installation has also two AMB axial fans (model FD08025 S1M; DC 12 V, 0.15 A), used for the renewal of the air inside the climatic chambers during the whole experimental period.

In each of the four climatic chambers used in this work four different thermal environments were established, constituting four treatments: one of the temperature ranges was considered as the comfort range recommended in the literature (TCL = Comfort Temperature by Literature) (Management Guide Lohmann LSL LITE, n.d.), the others represented two levels of cold stress, mild cold (MiC) and moderate cold (MoC) and one level of heat stress, moderate heat (MoH). Considering that the thermal requirement of the birds varies with the age, it was tried to represent this requirement in each week of life of the layer hens during the experimental period. The variation of the weekly temperature occurred until the fifth week, and the sixth week remained with a temperature similar to that of the fifth week.

Table 1 shows the different temperatures used during the experimental phase.

Table 1. Air temperature in the internal environment of the climatic chambers, in °C, depending on the treatment and age of the layer chicks

Thermal environment	Temperature (°C)				
	1–7 days	8–14 days	15–21 days	22–28 days	29–42 days
Moderate heat (MoH)	38	31	29	26	22
Literature approach (TCL)	33	28	26	23	19
Mild Cold (MiC)	28	25	23	20	17
Moderate Cold (MoC)	25	22	20	17	17

Management Guide Lohmann LSL LITE (s.d); Albino et al. (2014); Ferreira (2016).

The air relative humidity was monitored and values maintained throughout the experimental period and in all treatments around 60%, in a range between 55 and 65%, since it is considered an adequate value for poultry production, regardless of the age of the birds (Tinôco, 2001; Ferreira, 2016).

Instruments and measurements used in the characterization of environments

Since the birds were subjected to continuous stress, from the first day of experiment the values of air temperature (T_{air}), relative humidity (RH) and black globe temperature (BGT) were recorded every 5 minutes, 24 hours per day, throughout the experimental period.

To measure air temperature and RH, HOBO® T / RH dataloggers, model U14-001 (-20 °C to + 70 °C), with an accuracy of 0.7 °C were installed. In order to obtain the BGT, in each climatic chamber a black globe was installed including inside a Testo temperature sensor, model 174, with a resolution of 0.1 °C, measuring range from -30 to 70 °C and accuracy of ± 0.5 °C. The sensors were installed at the height of the birds, in the centre of each climatic chamber. Based on the records, the Black Globe Humidity and Temperature Index (BGHI) was calculated by means of the Eq. 1 (Buffington et al., 1981).

$$BGHI = BGT + DPT\ (0.36) + 41.5 \quad (1)$$

where BGHI = Black Globe Humidity and Temperature Index; BGT = black globe temperature, in °C; DPT = dew point temperature, in °C.

Management of laying birds during the initial phase

The experiment was carried out with laying birds from one to forty two days old, considered the initial stage for laying hens. During the experimental phase, 864 lightweight laying hens of the Lohmann LSL Lite line were housed in cages, distributed homogeneously in four climatic chambers (four treatments), totalling 216 birds per treatment. The cages are 0.50 m² in surface (0.50 m wide x 1.0 m long) and 0.5 m high, being six units per chamber.

From the first day to the end of the fourth week, each cage housed 36 chickens in order to guarantee a density of 140 cm^2 $bird^{-1}$. From the beginning of the fifth week until the end of the sixth week, the density was of 285 cm^2 $bird^{-1}$, which corresponds to 18 birds in each cage (Patterson & Siegel, 1998; Management Guide Lohmann LSL Lite, n.d., 2016). This procedure was adopted to guarantee the density used by the poultry industry under field conditions, for each of the different ages.

For the period from one to forty-two days the water and feed supply was *ad libitum*, and this management occurred twice a day (7 and 17 h), in order to keep the drinkers and the feeders always supplied.

The experiment was conducted in a completely randomized experimental design, with four treatments (moderate heat, recommended comfort, mild cold and moderate cold), and in subplots with six replications. The data were evaluated through analysis of variance and the means compared using the Tukey test, adopting the level of 5% of probability. The results were interpreted statistically using the System Program for Statistical Analysis and Genetics – SAEG (2007).

Collection of data on physiological variables of birds

The average surface temperature and cloacal temperature of the birds were measured weekly. For this purpose, ten birds from each experimental unit were chosen at random, totalling 60 birds per treatment.

For the measurement of the mean surface temperature (MST), the wing, head, cinnamon and back of the birds were monitored with the aid of a digital infrared thermometer, with a laser sight (Instrutherm® Instruments of Measurement Ltda, São Paulo, BR, model TI-860), amplitude from -30 °C to 270 °C, accuracy ± 2.5% of reading, resolution 1 °C and emissivity fixed to 0.95. The average surface temperature (MST) was calculated on the basis of equation 2 (Richards, 1971).

$$MST = (0.12\ Tw) + (0.03\ Th) + (0.15\ Tp) + (0.70\ Tb) \quad (2)$$

where Tw = wing surface temperature (°C); Th = head surface temperature (°C); Tp = cinnamon surface temperature (°C); Tb = back surface temperature (°C).

RESULTS AND DISCUSSION

The values of temperature and relative humidity of the ambient air, and respective values of BGHI, related to chickens from one to forty two days of life, for each treatment are presented in Table 2.

Table 2. Average and standard deviations of the values of air temperature (T_{air}), air relative humidity (RH) and black globe temperature and humidity index (BGHI) for each climatic condition evaluated in the period from 1 to 42 days

Thermal environment	T_{air} (°C)	RH (%)	BGHI
		(1–7 days)	
Moderate heat (MoH)	37.9 ± 0.2	55.5 ± 2.4	89.0 ± 1.5
Literature approach (TCL)	33.0 ± 0.4	56.5 ± 1.2	82.7 ± 1.3
Mild Cold (MiC)	28.0 ± 0.3	62.4 ± 2.5	76.3 ± 0.5
Moderate Cold (MoC)	25.0 ± 0.2	61.6 ± 1.5	72.3 ± 0.5
		(8–14 days)	
Moderate heat (MoH)	31.1 ± 0.5	60.1 ± 2.0	80.7 ± 0.6
Literature approach (TCL)	28.2 ± 0.5	62.6 ± 2.4	76.9 ± 0.8
Mild Cold (MiC)	25.1 ± 0.6	63.1 ± 1.5	71.8 ± 1.4
Moderate Cold (MoC)	22.1 ± 0.6	62.9 ± 2.0	69.1 ± 1.2
		(15–21 days)	
Moderate heat (MoH)	29.1 ± 0.4	61.1 ± 2.2	76.9 ± 1.1
Literature approach (TCL)	26.0 ± 0.5	60.4 ± 2.4	72.4 ± 0.9
Mild Cold (MiC)	23.1 ± 0.5	60.9 ± 0.2	70.9 ± 1.4
Moderate Cold (MoC)	20.1 ± 0.2	64.1 ± 0.8	66.3 ± 1.1
		(22–28 days)	
Moderate heat (MoH)	26.0 ± 0.6	62.3 ± 0.5	73.8 ± 1.0
Literature approach (TCL)	23.1 ± 0.7	62.8 ± 0.7	70.7 ± 1.2
Mild Cold (MiC)	20.1 ± 0.5	60.3 ± 0.2	66.3 ± 0.8
Moderate Cold (MoC)	17.0 ± 0.5	64.6 ± 0.5	63.6 ± 0.6
		(29–42 days)	
Moderate heat (MoH)	22.1 ± 0.4	64.6 ± 0.2	70.2 ± 2.4
Literature approach (TCL)	19.2 ± 0.5	62.7 ± 1.2	66.4 ± 1.3
Mild Cold (MiC)	17.0 ± 0.2	64.5 ± 0.5	63.8 ± 0.2
Moderate Cold (MoC)	17.0 ± 0.2	64.2 ± 1.3	63.6 ± 0.2

It is observed that the mean values of air temperature and relative humidity remained close to the values proposed for each thermal environment, showing an adequate control of the environment inside the climatic chambers.

Physiological parameters of hens in different environmental conditions

Cloacal temperature

Table 3 shows the mean values of cloacal temperature, in °C, for laying birds of the Lohmann LSL Lite line, from 1 to 42 days of age, for the respective combinations of days and thermal environments (MoH, TCL, MiC, MoC).

It was observed that the thermal environment factor, given by the different temperatures in each of the four climatic chambers, significantly influenced ($p < 0.05$) the cloacal temperature of the birds only when they were at 8 and 22 days of age, with higher values for the treatment moderate heat, compared to the other treatments.

In the first days of life, chickens do not have their thermoregulatory system fully developed yet, so they require that the environmental temperature remains within the comfort range in order to maintain homeothermia. Outside of these thermal ranges, the uncontrolled process begins, with elevation or reduction of the internal temperature of the body, depending on whether the environment is very hot or very cold, respectively.

Based on this premise, it can be inferred that the temperatures used during the trials did not negatively affect the laying birds from the physiological point of view giving a situation of lack of homeothermic control.

Furlan & Macari (2002) cite the 41.1 °C rectal temperature of birds as the lower limit of the thermal stress condition. When this limit is not reached, physiological mechanisms are triggered to maintain body temperature, which characterizes the cold stress condition.

Table 3. Average cloacal temperature values, in °C, for laying birds of the Lohmann LSL Lite line, aged from 01 to 42 days of age, in relation to age and thermal conditions (Moderate heat: MoH; comfort recommended by the literature: TCL; mild cold: MiC; moderate cold: MoC)

Days of age of birds	Cloacal temperature			
	MoH	TCL	MiC	MoC
8	41.57^{a}	41.19^{b}	40.89^{c}	40.70^{c}
15	41.32^{a}	41.11^{a}	41.18^{a}	41.09^{a}
22	41.32^{a}	41.17^{ab}	41.08^{ab}	40.92^{b}
29	41.34^{a}	41.20^{a}	41.26^{a}	41.11^{a}
36	41.37^{a}	41.46^{a}	41.47^{a}	41.33^{a}
42	41.37^{a}	41.51^{a}	41.54^{a}	41.49^{a}

The average values followed by at least one letter in the row do not differ, at the 5% probability level by the Tukey test.

It can be observed that the birds in the mild cold and moderate cold treatments, with the ages of 08 and 22 days, presented stress condition, indicating that the sensible heat exchange mechanism was not totally sufficient for maintain body temperature within acceptable limits. In this situation, birds need to use other mechanisms, such as increased food intake, to maintain body temperature.

This behaviour observed in laying hens during the three weeks of life is in line with the studies of Cassuce (2011). The author evaluated the cloacal temperature of broilers during the initial phase in different thermal environments (39–33, 36–30, 33–27, 30–24 and 27–21 °C) and observed a statistical difference between the treatments in the third week of life of the birds, with lower rectal temperature for birds submitted to temperature of 21 °C.

Thus, birds submitted to the treatments MoH and TCL were able to maintain body temperature within normal values during the whole experimental phase, demonstrating the ability of birds to adapt to higher temperatures, avoiding the occurrence of hyperthermia.

It is also observed that birds with up to 29 days of recommended comfort treatment presented absolute values of cloacal temperature lower than the moderate heat treatment, although for both treatments, the values were within acceptable limits.

It was verified that, in the birds with age of 15, 29, 36 and 42 days of age, the cloacal temperature remained stable in all studied treatments, not differing among them ($P > 0.05$). It can be concluded, therefore, that none of the temperatures used in the trials, for the aforementioned ages, causes a situation of stress due to cold or heat, showing the adaptability of the birds.

Surface temperature

Table 4 presents the results of the average surface temperature (MST) of the birds according to the different thermal environments evaluated (MoH, TCL, MiC, MoC).

It was verified that there was a significant difference ($p < 0.05$) in the results of the surface temperature of the birds in relation to the thermal environment and days of evaluation, being these always higher in the treatment MoH in relation to all the others,

for the birds with age of 08, 15, 22 and 29 days. In birds with age of 36 and 42 days higher surface temperatures were found when submitted to the treatments MoH and TCL in comparison to the others, however without significant differences between the first two mentioned.

These results confirm the direct relationship between the body temperature and the environmental temperature, highlighting the strong effect of the thermal environment on the birds, which can modify the physiological response in relation to the situation.

Andrade et al. (2017), when evaluating the surface temperature of laying birds in the initial stage of creation by means of thermographic images, observed the effect that the different temperatures exert on the birds, being able to modify the physiological response according to the thermal environment.

Table 4. Mean values of mean surface temperature (MST), in °C, for laying birds of the Lohmann LSL Lite line, aged from 01 to 42 days of age, in relation to age and thermal conditions (Moderate heat: MoH; comfort recommended by the literature: TCL; mild cold: MiC; moderate cold: MoC)

Days of ageof birds	MST			
	MoH	TCL	MiC	MoC
8	48.47[a]	45.05[b]	40.28[c]	37.36[d]
15	44.19[a]	42.09[b]	39.00[c]	35.73[d]
22	41.51[a]	39.72[b]	36.75[c]	33.35[d]
29	39.29[a]	37.41[b]	34.09[c]	32.89[c]
36	34.48[a]	34.18[a]	32.11[b]	31.28[b]
42	37.37[a]	37.27[a]	33.83[b]	32.48[b]

The average values followed by at least one letter in the row do not differ, at the 5% probability level by the Tukey test.

During the first and third week of life of the birds, in the cold stress treatments, it was observed that the birds presented in addition to the decrease of the surface temperature, decrease of the cloacal temperature with values lower than the values of the other treatments, which indicates that the birds could not maintain body temperature constant, presenting cloacal temperature below the recommended level.

According to Ruzal et al. (2011), part of the physiological responses that explain the direct relationship between ambient temperature and poultry surface temperature may be related to redistribution of blood flow in the body, because exposure to heat causes peripheral vasodilation.

CONCLUSIONS

The birds submitted to the treatments moderate heat, recommended comfort, mild cold and moderate cold kept the physiological responses, based on cloacal and surface temperatures, within the normal range during the period between 01 and 42 days of life.

Under the specific conditions of the present experiment, the surface temperature of the birds varied according to the air temperature of each breeding environment, with lower surface temperatures for mild cold and moderate cold treatments.

ACKNOWLEDGEMENTS. To CAPES, CNPq, FAPEMIG and the LOHMANN DO BRASIL.

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