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Floor temperature as a risk factor for the quality of the environment in the chickens

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Abstract. The aim of the work is to analyze the environmental risk factors in chicken breeding in relation to the heat load of animals in summer. The research was carried out at a breeding hall with a capacity of 20,000 ROSS 308 broiler chickens for two summer period, with a breeding time of 39 days each. The indoor air temperature and relative humidity were continuously measured at two locations at a height of 0.8 m above the floor, using PT 100 temperature sensors and RS 800 humidity sensors. Data were recorded via a PLC unit at 10-minute intervals. The surface temperatures of the floors were measured by DS 80 sensors connected to dataloggers in two locations. It was observed that the floor temperature had an increasing tendency – due to heating, heat produced by animals and anaerobic biological processes – even during the second half of the breeding period. During the period from day 26 to day 39, the surface temperature of the concrete floor, as well as the temperature of the straw bedding rise to above 30 °C. The indoor air temperature in the hall was predominantly decreasing from the 26th day with rising floor temperature tendency. Between the day 26 and day 39 of the breeding period, the average litter temperature elevation over the air temperature exceeded 7 °C. Regression analysis showed negative dependence of floor temperatures on air temperature; for a 1 K unit air temperature reduction, an average floor temperature increase of 0.75 and 1.16 K was found, respectively.

Key words: floor construction, microclimatic parameters, summer period, heat load of chickens.

INTRODUCTION

Despite the many challenges faced by farmers, including environmental problems, diseases, economic pressure and feed availability, climate factors are among the primary and decisive limiting factors for animal development in the warm parts of the world (Renaudaeau et al., 2012). Rising fear of production losses due to high ambient temperatures is justified not only for the tropical areas, but also for countries in temperate zone, where thermal stress is an occasional problem during the 2–3 summer months (Nienaber & Hahn, 2007).

In extreme climatic conditions during the summer season, heat stress can cause high animal mortality, leading to economic losses (Bustamante et al., 2012). Broiler breeding is mainly carried out on litter, the condition of which can be affected by the type of material used, type of flooring under bedding, depth of the material, floor area per animal, feed composition, ventilation system and season.

If indoor environment quality and litter quality are not optimal, there is a significant risk of developing respiratory diseases or dermatitis (Cengiz et al., 2013; De Jong et al., 2014). Properly chosen bedding material provides the animals with greater comfort, serves as a good insulator in winter, operates as absorbent and contaminant modifier (Sigroha et al., 2017). Optimal depth of litter, which contributes to environmental hygiene, leg health, and animal stress reduction, is also important, as is the minimalization of insect-related problems. Bedding materials as wheat straw, sawdust or shavings are usually chosen according to their local availability. In conditions of Slovakia, wheat straw (almost 85%) is the most widely used. Floor and bedding directly affect animal welfare. Special attention must be paid to the litter in order to maintain the thermal balance between the chicken body and the environment. The litter temperature is variable (Nawalany, 2012; Boďo & Gálik, 2018) but should be similar to the air temperature in the housing (Fiorentin, 2006).

The aim of this work was to analyze environmental risk factors in broiler breeding in relation to the animal heat load in summer. An investigation was undertaken to observe whether the following indoor conditions were met:

– the average daily indoor air temperature in an insulated breeding hall, evaluated during the whole summer fattening period being within the recommended temperature range for the given breed of chickens,

– the litter temperature and the temperature of concrete under the bedding being equal to or lower than the air temperature during summer,

– the surface temperature of the floor is changing in dependence on the air temperature in the breeding environment during entire period.

MATERIALS AND METHODS

The measurements were carried out in a breeding hall with a capacity of 20,000 ROSS 308 broiler chickens for two summer breeding periods, each with a breeding time of 39 days. The chickens were housed on a deep straw litter with thickness of 100 mm. The total length of the hall is 104 m, with a width of 12.8 m. The breeding area for chickens is 12,684.1 m^2. To decrease heat load of animal there is 13.3 broiler chickens for m^2 in summer time, because initial number of chickens is decreasing to 17,000.

The external walls of the hall consist of two 7 mm thick Ezalit boards, between which polystyrene foam insulation with thickness of 50 mm is input. The roof structure too, consists of a sandwich made of Ezalit, polystyrene, Ezalit and sheet metal cover. The floor consists of 20 mm thick cement screed, 150 mm thick concrete screed, 100 mm thick slag and 150 mm thick gravel backfill.

Thermal insulation of the hall is represented by thermal resistances R in m^2 K W^{-1}. It was calculated according national standard STN 73 0540 (as the quotient of the material thickness ‘d’ in meter and the thermal conductivity coefficient ‘λ’ in W m^{-1} K^{-1} for all particular structural layers): with results for walls R_w = 1.37 m^2 K W^{-1}, for ceiling R_c = 1.42 m^2 K W^{-1}, for floor R_f = 1.72 m^2 K W^{-1}. Air exchange process is ensured by five ceiling fans with an output of 13,800 m^3 h^{-1}, three front fans with a capacity of 36,000 m^3 h^{-1} and 44 suction air flaps with dimensions of 500 mm x 200 mm located on both side walls (Fig. 1).

Ventilation is controlled automatically on the basis of climate sensors located in the center of the hall. The heating of the hall is provided by four ERMAF GP 70 gas heaters with power of 70 kW. Microclimatic parameters are regulated according to the values recommended by ROSS (2018).

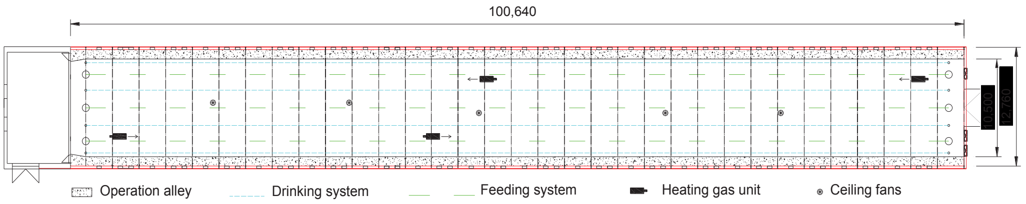

Figure 1. Scheme of chicken house.

The recommended indoor air temperature is defined by an appropriate range of the most frequent relative humidity range of 40% to 70%, with the relative humidity range from 60% to 70% considered as ideal.

Development of interior temperature is controlled in time sequence from the day 1 to day 27 of the chicken age according to the relative air humidity. Accordingly, the desired temperature range varies from 29.2 °C–36 °C on the 1st day of the chicken age to 19.3 °C–24.8 °C on day 27 of the chicken age. After day 27, the temperature usually should have a steady trend.

The temperature and relative humidity of the outside air were measured during the entire period using the COMET S3121 datalogger with a recording rate of 10 minutes, located near the experimental hall at a distance of 50 m. The indoor air temperature and relative humidity were continuously measured at two locations at a height of 0.8 m above the floor using PT 100 temperature sensors (T1, T2) and RS 800 humidity sensors (RH1and RH2) (Fig. 2). Data were recorded via a PLC collection unit at 10-minute intervals. The surface temperatures of floors were measured by DS 80 sensors connected to data loggers at two locations (Fig. 3).

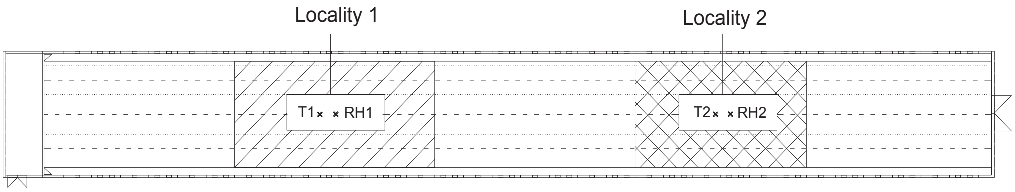

Figure 2. Measurement points of climatic parameters in the experimental hall (T1, T2 – points of measurement of air temperature; RH1 and RH2 – points of measurement of relative air humidity).

The fattening period was divided into three phases: phase P1 (from day 1 to day 13 of the period), phase P2 (from day 14 to day 26 of the period), phase P3 (from day 27 to day 39 of fattening period).

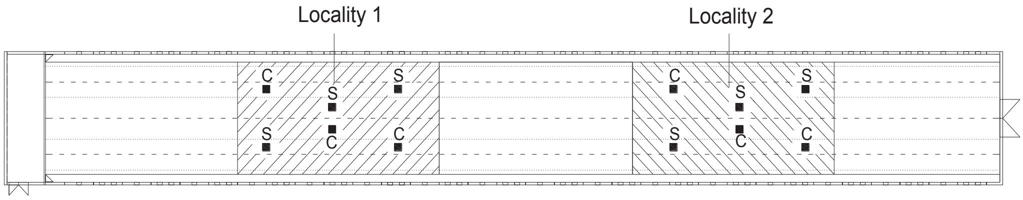

Figure 3. Measurement points of floor surface temperatures in locality 1 and locality 2 (S – straw bed temperature sensors; C – concrete floor surface temperature sensors).

Mortality assessments were performed on the basis of data on daily mortality based on the time dependence of mortality development from the first to the last fattening day. There were evaluated only summer periods where no diseases were recorded, no mistakes were detected in ventilation (with permanently air exchange of 177,000 $m^3 h^{-1}$) and deaths were connected only with hot wave during last phase of breeding period.

Evaluation of the measured data was performed using the 'STATISTICA 10'. By means of a single-factor analysis of ANOVA and the Scheffe test, the measured air and floor temperatures were compared at a significance level of 0.05.

A regression analysis was used to evaluate the floor temperature vs. air temperature, for which the data from the last phase P3 were used.

RESULTS AND DISCUSSION

In phase P3 of both L1 and L2 periods, measured air temperature exceeded the required temperature (ROSS limits, 2018) by 0.9 °C to 8.4 °C for the current relative humidity level. At the same time, it was found that the mortality of animals was demonstrably higher than in the previous phases ($P < 0.05$). No bacteriological infections or diseases were identified in either period, it can thus be believed that the increased mortality was caused by unbearable heat load. In the L1 turnover, the average daily RH ranged from 42.4% to 66.5% with the occurrence of hourly maximum values of up to 79.7%. In the second summer L2 period, RH ranged from 51.5 to 65.8%, with an hourly maximum of 82.4%. However, days with over limit temperatures or relative humidity above 70% were not regularly linked with increased death.

From the results of the measurement of the floor surface temperatures, it was found that the floor constructions temperature has a permanently increasing tendency, due to heating and heat produced by the animals (Figs 4 and 5). During the second third (from day 18 of the period) the surface temperature of the floor constructions also exceeded the required air temperature limits and contributed to the increase in the ambient temperature. The surface temperature of the concrete floor ($T_{f,c}$), as well as the temperature of the straw bedding ($T_{f,b}$), with which the animals are in direct contact while resting, gradually rise to values exceeding 33 °C. The indoor air temperature in the hall had a predominantly decreasing tendency as the floor temperature increased.

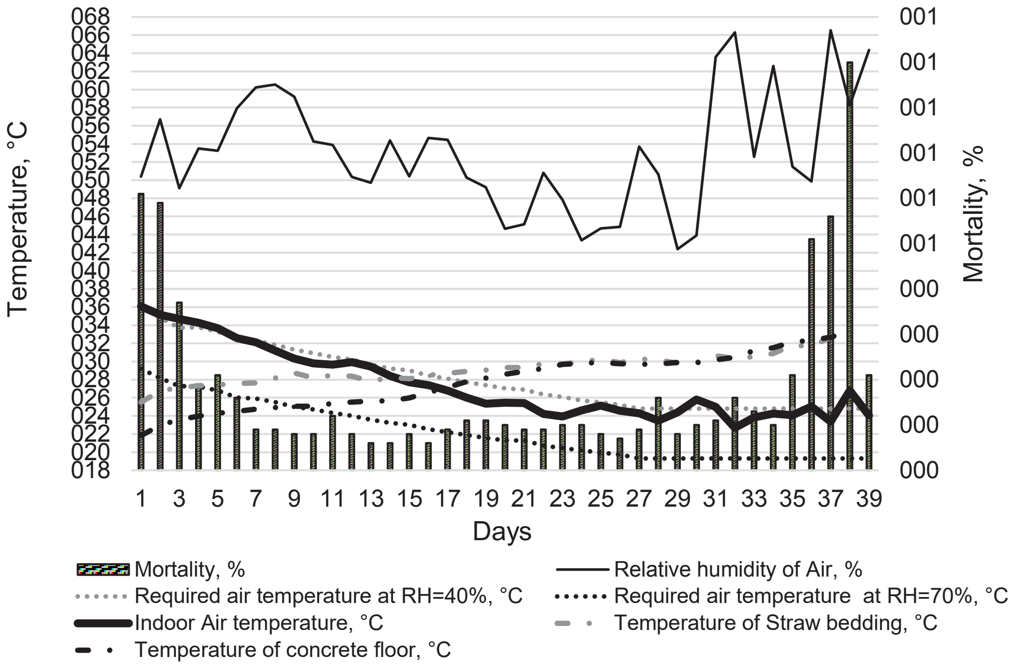

Figure 4. Microclimate parameters and floor surface temperatures and mortality during the L1 period.

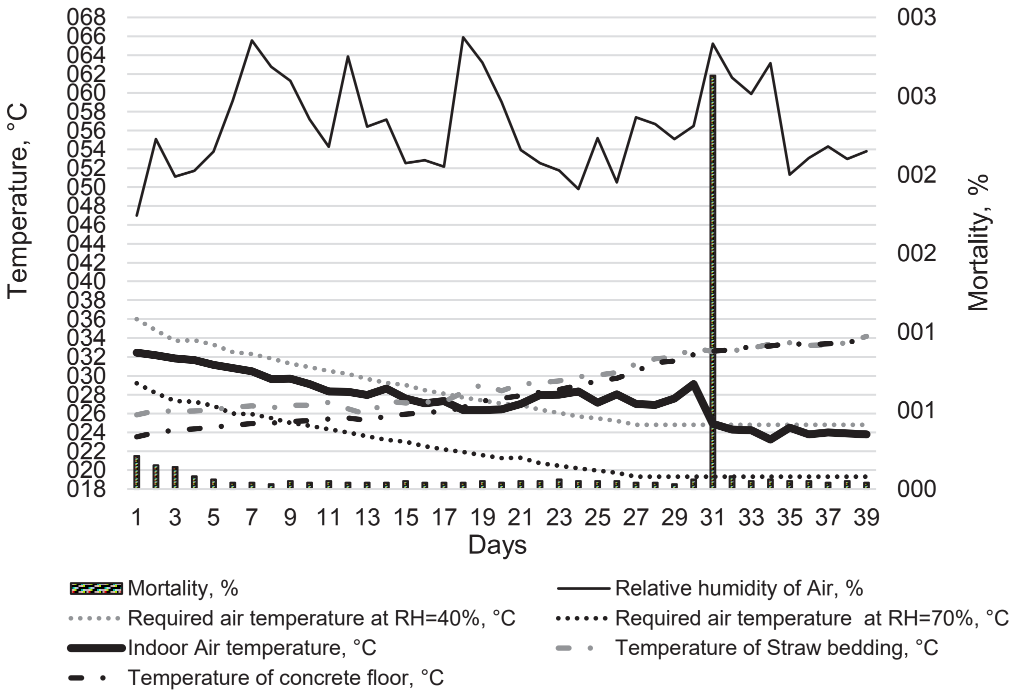

Figure 5. Microclimate parameters and floor surface temperatures and mortality during the L2 period.

The average temperature of 100 mm straw bedding increased from $T_{f,b,d1,L1} = 26.29$ °C to $T_{f,b,d39,L1} = 33.20$ °C in period L1 (similar in period L2 from $T_{f,b,d1,L2} = 25.49$ °C, to $T_{f,b,d39,L2} = 33.20$ °C). The average surface temperature of the concrete floor under the bedding also increased throughout the entire period although at the start of the period it was around 3 °C lower than the bedding temperature. However, the temperatures of straw and concrete gradually equalized. The continuously increasing temperature difference between air and straw reached $\Delta T_{d39,L1} = 8.7$ K and $\Delta T_{d39,L2} = 10.32$ K by the end of the breeding period. Based on the Scheffe contrast test, the average air temperature $T_{a,L1} = 24.42$ °C in the last period P3 (from day 27 to day 39) was shown to be significantly lower ($P < 0.05$) than the average concrete temperature $T_{f,c,L1} = 31.27$ °C and straw bedding temperature $T_{f,b,L1} = 31.15$ °C. A similar trend of temperature development in cases of concrete floor and straw bedding was also observed in the second summer period L2 (Fig. 7). In monitoring the dependence of the floor temperature development on air temperature, a negative interdependence was found: in the L1 period, with a unit air temperature decrease of 1K, an average increase of 0.75 K Was observed; in the L2 an average increase of 1.16 K Was found (Figs 8 and 9).

During L1 and L2 period, a significant difference ($P < 0.05$) was observed between the periods considered, where the average total broiler mortality in the last third of the period (P3) was significantly higher than the mortality in P1 and P2 (Fig. 6).

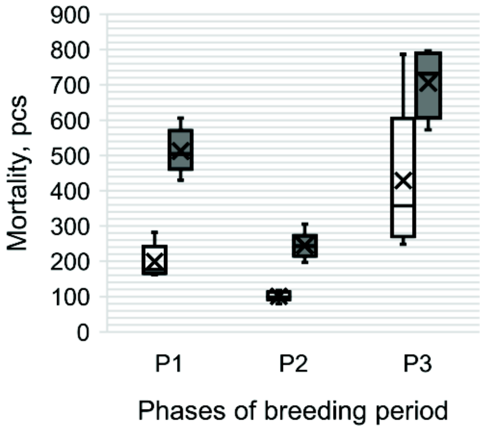

Figure 6. Broiler mortality of all 6 halls in phase P1 (d_1–d_{13}), phase P2 (d_{14}–d_{26}), phase P3 (d_{27}–d_{39}) for fattening period L1 (white boxes) and period L2 (gray boxes); differences between mortality in phase P3 and phase P2 were significant ($p < 0.05$) in both summer periods.

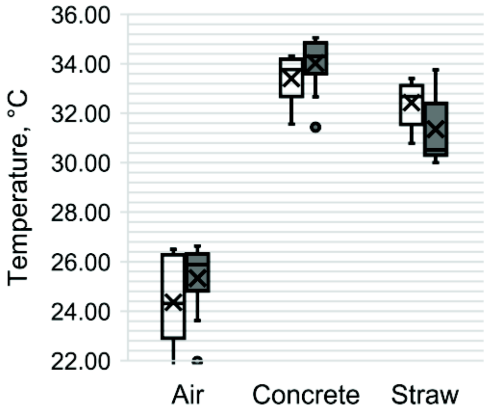

Figure 7. Results of air temperature and floor temperature with F-test during phase P3 in period L1 (white boxes) and L2 (gray boxes); differences between air temperatures and floor temperatures were significant ($p< 0.05$) in both summer periods.

Animal welfare was observed in both monitored periods. In the first half of the breeding, the ambient temperature was in the range of recommended values. However, due to the outside weather, the stabilization period after the 27th day was not without problems, due to the influx of hot waves, which were the most hazardous during the last phase P3 of period L1 and L2, too.

In accordance with the ROSS Industrial Guideline (2018), litter with a temperature of 28 °C−30 °C is emphasized in the early days of chicken age.

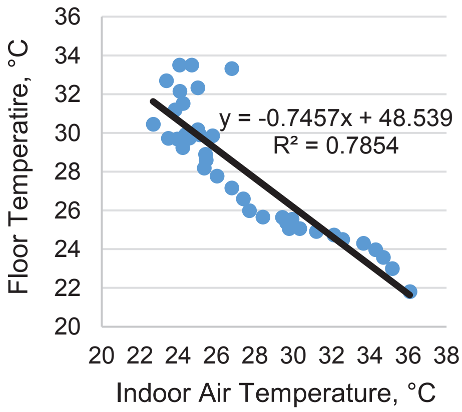

Figure 8. Negative dependence between indoor air temperature and floor temperature in breeding summer period L1 ($R^2 = 0.7854$).

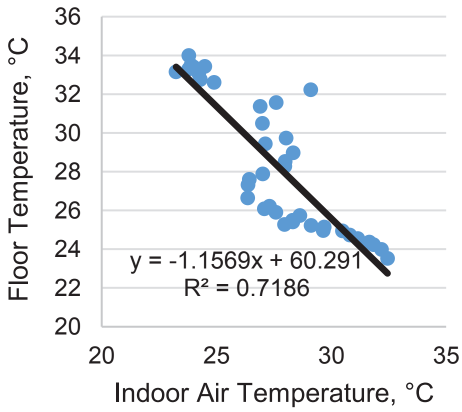

Figure 9. Negative dependence between floor temperature and air temperature in breeding summer period L2 ($R^2 = 0.7186$).

Conditions of breeding environment with overly high temperatures are harmful according to Oliviera et al. (2006), as with age, chickens become more sensitive to high ambient temperatures (Moreira et al., 2004; Nascimento et al., 2018), which results in reduced feed intake, heat dissipation and animal welfare. In industrial poultry farming, the maintenance of homeothermia must be ensured while maintaining animal welfare and minimum production and energy costs (Cangar et al., 2008, Santos et al., 2009). The ability of the birds to dissipate heat is reduced when the ambient temperature and relative humidity increase above the thermoneutral zone (T_{ai} = 24 °C, RH_{ai} = 70%). During the measurements carried out in the summer fattening period L1, an average daily temperature $T_{a,i,30d}$ = 25.1 °C and $RH_{a,i,30d}$ = 63.57% was found, which appeared to be in the tolerable zone of thermal comfort. However, the observed animal deaths pointed to critical circumstances, which were not detected until a detailed analysis of the temperatures at smaller hourly intervals. Increased mortality occurred in the final phase of the fattening period L2, when indoor air temperature exceeded 24 °C for 5 hours or longer and relative indoor air humidity of over 70% lasted for more than 15 hours. The statement by Nascimento (2011) that the surface temperature of floors in the broiler breeding area varies depending on the temperature of air in the breeding environment and is not affected by the age of the broilers is noteworthy in the given context. Some deviations from this statement were noted in the performed experiments. First, the temperature of the floor increased with the age of the chickens, in the last phase of the fattening period even exceeding the air temperature by an average of 6.75 °C during L1 and 8.52 °C during fattening period L2. It can be assumed that the floor was heated not only by air, but also by the litter fermentation processes and the body heat of the growing chickens. Chepete et al. (2005) and Jones et al. (2005) demonstrated the importance of average daily temperature in predicting increased broiler mortality resulting from thermal stress. The average daily air temperatures exceeded the recommended values for critical RH = 40% on days 29, 30, 35 and 37 in the observed fattening period L1 (gray dashed line of desired temperatures in Fig. 3). Elevated temperatures during the first two days (day 29 and day 30) did not cause increased deaths, but humidity remained within acceptable limits and animal weight, and age was lower than for the second two days (day 35 and day 37) when the relative humidity increased with age and animal weights. Then, extremely high mortality occurred on days 36, 37, and 38 of the fattening period. The average daily outdoor air temperature varied from the minimum temperatures of $T_{a,o,min,L1}$ = 14.30 °C to the maximum temperatures $T_{a,o,max,L1}$ = 27.9 °C. Similar findings were made on the L2 period, when air temperature due to high relative humidity on day 29 resulted in increased mortality the following day M_{d31} = 428 animals. The litter temperature should be approximately the same as the air temperature in the housing area (Fiorentin, 2006). In the observed period, the litter temperature at the start of the fattening was 6.54 °C to 9.71 °C lower than the air temperature. However, at the end of the fattening period, it was 7.12 °C to 10.38 °C higher than the air temperature. Abreu et al. (2011) also reported that the temperature was equal to the indoor air temperature after the day 18 of breeding and continued to rise to 30 °C–34 °C over the following days. The litter temperature was slightly reduced or constant by the end of fattening. This trend has been confirmed by the performed measurements, as the litter temperature has been increasing tendency. Increased litter temperature under the sitting chickens is not a necessary result but is related to the fact that litter is usually a good insulator that prevents heat dissipation from the animal's body during sitting. The contact temperature may approach the core temperature of 41.11 °C if the litter produces more heat (Czarick et al., 2016). May & Lott (2000) consider mortality to be the best indicator of environmental temperature impact on efficacy and observed parameters of broiler chicken breeding quality. Heat stress can lead to mass mortality in birds and big losses for farmers over a short time period (Zou, 2014). Measures resulting from multi-annual research monitoring of animal mortality in relation to temperature-moisture balance in real objects will have to be applied very soon in pracitce.

Generally, cooling is achieved by means of rapid removal of heat by high speed air flow ($v > 2.0$ m s^{-1}), any of the evaporative cooling systems (adiabatic coolers, PAD systems, sprayers, etc.), or system combinations. High velocity air flow achieves a significant effect in tunnel ventilation, especially in the final phase of breeding, which compensates for investment costs. Another method of cooling is the combination of underfloor heating and cooling, developed by Nawalany et al. (2010). As early as during entry experiments, they showed that mortality in the 5th and 6th week of breeding is reduced by 50% compared to the traditional method of breeding on the straw.

CONCLUSIONS

The results of the measurements carried out in the chicken fattening hall during the two summer fattening periods can be summarized as follows:

– The average indoor air temperatures obtained from the 24–hour daily measurements over the entire fattening period in the evaluated heat-insulated hall exceeded the recommended temperature ranges for 4 days.

– The continuously measured surface temperature of litter and concrete under the litter in the hall was higher than indoor air temperature during the second half of fattening period, with a predominantly increasing trend; the excess of the litter temperature compared to the air temperature was more than 7 °C even in the third period (from day 27 to day 39).

– Regression analysis has shown a negative dependence of litter and concrete temperature on air temperature; for a 1 K air temperature reduction, an average floor temperature increase of 0.75–1.16 K Was observed.

In breeding practice, on the basis of measurements of climatic parameters and surface temperatures in the thermally insulated hall, other ways of increased animal heat load solutions in summer are profiled in addition to the evaporative cooling solution and tunnel ventilation.

Since it has been found that by the end of period the highest temperature increase is concentrated in the floor and above the floor, it is advisable to install additional methods of animal cooling directly in this area.

Based on practical measurement experience, it is possible to recommend installation of additional evaporation units operating in the transverse direction, followed by directing the developed cooled air into the animal zone, as well as the use of heat pumps and other renewable energy sources.

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REFERENCES

Abreu, V.M.N., Abreu, P.G., Jaenisch, F.R.F., Coldebella, A. & De Paiva, D.P. 2011. Effect of floor type (Dirt or Concrete) on litter quality. *Brazilian Journal of Poultry Science* **13**(2), 127–137.

Boďo, Š. & Gálik, R. 2018. Monitoring of litter quality and temperature in breeding of fattening chickens. In *Acta Technologica Agriculturae* **21**(1), 33–37.

Bustamante, E., Guijarro, E., García, F.J., Balasch, S., Hospitaler, A. & Torres, A.G. 2012. Multisensor system for isotemporal measurements to assess indoor climatic conditions in poultry farms. *Sensors* **12**(5), 5752–5754.

Cangar, Ö., Aerts, J., Buyse, M.J. & Berckmans, D. 2008. Quantification of the spatial distribution of surface temperatures of broilers. *Poultry Science* **87**, 2493–2499.

Cengiz, O., Hess, J.B. & Bilgili, S.F. 2013. Effect of protein source on the development of footpad dermatitis in broiler chickens reared on different flooring types. *European Poultry Science* **77**(3), 166–170.

Chepete, H.J., CHimbombi, E. & Tsheko, R. 2005. Production performance and temperature-humidity index of COBB 500 broilers reared in open-sided naturally ventilated houses in Botswana. *American Society of Agricultural Engineers* **7**, 524–535.

Czarick, M., Hicks, M. & Fairchild, B. 2016. Are birds cooler at night when the lights go out? *Poultry Housing Tips* **28**(3), 1–6.

De Jong, I.C., Gunnink, H. & Hindle, V. 2014. *Implementation of the Welfare Quality broiler monitor on Dutch broiler farms.* Wageningen UR Livestock Research, Wageningen, pp. 56.

Fioretin, L.A. 2006. Reutilization of aviary bed in the context of benchmarking. *Avicultura Industrial* **97**(6), 12–18.

Jones, T.A., Donnelly, C.A. & Stamp, D.M. 2005. Environmental and management factors affecting the welfare of chickens on commercial farms in the United Kingdom and Denmark stocked at five densities. *Poultry Science* **84**(2), 1155–1165.

May, J.D. & Lott, B.D. 2000. The effect of environmental temperature on growth and feed conversion of broilers to 21 days of age. *Poultry Science* [online] **79**(1), 669–671.
Moreira, J., Mendes, A.A., Roça, R.O., Garcia, E.A., Naas, I.A., Garcia, R.G. & Paz, I.C.L.A. 2004. Effect of stocking density on performance, carcass yield and meat quality in broilers of different commercial strains. *Brazilian Journal of Animal Science* **33**(6), 1506–1519.
Nascimento, D.C.N., Dourado, L.R.B., Siqueira, J.C.D., De Lima, S.B.P., Da Silva, M.C.M., Da Silva, G.G., Sakomura, N.K., Ferreira, G.J.B.C. & Biagiotti, D. 2018. Productive features of broiler chickens in hot weather: effects of strain and sex. *Ciencias Agrárias* **39**(2), 731–746.
Nascimento, G.R., Nääs, I.A., Pereira, D.F., Baracho, M.S. & Garcia, R. 2011. Assessment of broiler surface temperature variation when exposed to different air temperatures. *Brazilian Journal of Poultry Science* **13**(4), 259–263.
Nawalany, G., Bieda, W. & Radon, J. 2010. Effect of floor heating and cooling of bedding on thermal conditions in the living area of broiler chickens. *European Poultry Science* **74**(2), 98–101.
Nawalany, G. 2012. A proposal to apply operative temperature for the evaluation of thermal conditions in the broiler living zone. In *Archiv fur Geflugelkunde* **76**(1), 49–54.
Nienaber, J.A. & Hahn, G.L. 2007. Livestock production system management responses to thermal challenges. *International Journal of Biometrology* **52**(2), 149–157.
Oliveira, R.F.M., Donzele, J.L., Abreu, M.L.T., Ferreira, R.T., Vaz, R.G.M.V. & Cella, P.S. 2006. Effects of temperature and relative humidity on performance and yield of noble cuts of broilers from 1 to 49 days old. *Brazilian Journal of Animal Science* **35**(3), 797–803.
Renaudeau, D., Collin, A., Yahav, S., Baselio, V., Gourdine, J.L. & Collier, R.J. 2012. Adaptation to hot climate and strategies to alleviate heat stress in livestock production. *Animal* **6**(5), 707–728.
ROSS. 2018. *Ross broiler management handbook*. Aviagen, 148 pp. Available at: http://en.aviagen.com/assets/Tech_Center/Ross_Broiler/Ross-BroilerHandbook2018-EN.pdf
Santos, P.A., Baêta, F.C., Tinôco, I.F.F., Albino, L.F.T. & Cecon, P.R. 2009. Ventilação em modos túnel e lateral em galpões avícolas e seus efeitos no conforto térmico, na qualidade do ar e no desempenho das aves. *Revista Ceres* **5**6(2), 172–180.
Sigroha, R., Bidhan, D.S., Yadav, CH.D., Sihag, S.S. & Malik, A.K. 2017. Effect of different litter materials on the performance of broiler chicken. *Journal of Animal Research* **7**(4), 665–671.
Šranková, V., Lendelová, J., Mihina, Š., Žitňák, M. & Nawalany, G. 2019. Mortality of broiler chickens during summer fattening periods affected by microclimatic conditions. In *Acta technologica agriculturae* **22**(1) 22–30.
STN 73 0540-2+Z1+Z2. 2019. Thermal protection of buildings. Thermal performance of buildings and components. Part 2: Functional requirements. Consolidates version.
Zou, Y. & Hrnjak, P.S. 2014. Effect of oil on R134a distribution in the microchannel heat exchanger with vertical header. *International Journal of Refrigeration* **40**, 201–210.