Effect of floor heating and cooling of bedding on thermal conditions in the living area of broiler chickens

Einfufluss einer Fußbodenheizung und Kühlung der Einstreu auf die thermischen Verhältnisse in der Umgebung der Hähnchen

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Introduction

Research to date (Kaiser and Van Den Veghe, 1997; Pedersen and Thomsen, 2000; Podgórski and Lebradowicz, 1995; Bieda and Kozbiał, 1999; Bieda et al., 2003; Radoń et al., 2004, Radoń, 2004) has shown a very complex nature of the heat exchange between air, avian body and a medium consisting of bedding, floor and the ground underneath. The welfare and very good health and productivity of broiler chickens can only be achieved by ensuring optimum thermal conditions in the living area of the birds. We believe that thermal conditions in the living area of chickens are significantly affected not only by air temperature (Θ₀) (see Table 1) but also by bedding temperature (Θᵦ). It is generally accepted that the arithmetic mean of the sum of air temperature (Θ₀) and temperature of the barrier, i.e. bedding (Θᵦ), is the value of the effective (operative) temperature (Θₒ) (Standard PN-EN 15251: 2007). To maintain thermal equilibrium between broiler chickens and the surroundings (i.e. air and bedding), Θᵦ temperature should be close to the required temperature of air in the broiler house (Θₒ), i.e. from 33°C at the start of rearing to 18°C at the end (Herbut, 1997). However, this demand is very difficult to achieve in practical rearing. Broiler production practice shows that at the time of placement into the production facility, Θᵦ temperature is the lowest (as much as a dozen or so degrees lower than the required air temperature (Θₒ)). Cold bedding favours the incidence of avian mycoplasmosis, infectious bronchitis, gallinarum infections, coccidiosis, retarded growth and body weight decline. Θᵦ equalizes Θₒ for a short time as late as between 16 and 25 days of the production cycle. Thereafter Θᵦ continues to rise, which coupled with the regularly decreasing Θₒ makes Θₒ higher and higher in relation to Θₒ for each day of the production cycle. Our measurements of bedding temperature from real operating conditions (Figure 1) indicate that thermal conditions in the living area of birds, especially at the early and late stages of growth, are far insufficient. This is mainly due to the fact that during the production cycle, the course of Θₒ differs considerably from that of Θₒ, making Θₒ ≠ Θₒ (Nawalany et al., 2004).

To improve thermal conditions in the living area of broiler chickens, two experiments were conducted in actual production conditions of a poultry house. The aim of the first experiment (Bieda and Nawalany, 2006) was to determine the effect of chicken stocking density on Θₒ. The second experiment (Nawalany et al., 2006) involved the use of thermal insulation under the broiler house floor. The results obtained were partly satisfactory, either for the initial or the final stage of rearing. Analysis of the results led the authors to conclude that optimized thermal conditions in the living area of chickens throughout the production cycle can be expected when using a floor heating and cooling system.

The objective of the present study was to test the usefulness of a floor heating and cooling system for optimization of thermal conditions in the living area of broilers in a poultry house.

Materials and Methods

Temperature measurements were made at the Poultry Farm in Ujazd, Małopolska region in Poland (owner Paweł Kłosek). With a production area of 1000 m², the broiler house is mechanically ventilated and heated with warm air. During cold seasons, several days before placement time, the concrete floor was bedded with an approx. 10 cm layer of litter (long barley and wheat straw) and the production facility was heated with warm air.

In the top part of the production house (Figure 1a), the “A” experimental field of 80 m² area was fitted with a meander layout of ø 1/2” pipes (placed 30 cm apart), which were connected to the existing central heating and water supply systems. After delivering heat to the floor, central heating water returned to the boiler room, and cold water, after flowing through the system, was mixed with drinking water and directed into the broiler house. It was assumed that in the initial stage of rearing, the system will heat the floor and bedding for at least 10–14 days, will be turned off for the next 10 days, and will provide cooling from approx. 20–24 days to the end of rearing. Efforts were made to equalize Θₒ and Θₒ temperatures by manually adjusting the flow of warm and cold water with the aid of valves and using visualization of the temperatures measured on a PC monitor. PT-100 sensors for water temperature measurement were installed at the inlet and outlet of the heating and cooling pipeline. Layer layout of the experimental field is shown in Figure 1b. The “A” field adjoined the “B” control field with existing floor (Figure 1c). Both fields were partitioned off until 36 days of rearing to prevent birds
from moving between the fields. For the final week of rearing, the partition was taken away to enable removal of some birds. Until 36 days of rearing, the stocking density of ROSS 308 birds was identical in both fields and averaged 1536 (winter) and 1496 (summer) chickens per field, which corresponds to 19.2 and 18.7 birds per m$^2$, respectively.

Bedding temperature was measured using 16 PT-100 sensors placed midway through the bedding layer, 8 sensors per field (“A” and “B”). $\Theta_i$ temperature was measured using a PT-100 sensor placed 0.5 m above the bedding. All temperatures were measured at hourly intervals and measurement data were recorded by a multichannel data logger (HP). Water content of bedding (w) was measured at weekly intervals using the weighing method. Measurements were made between 11 August 2006 and 19 March 2008 over 7 full production cycles.

### Results

For the purposes of this research, we show the results obtained during two selected production cycles: winter and summer. The results of measurements are presented graphically, separately for the winter (Figure 2) and summer (Figure 3) production cycles. Diagrams show the course of mean daily temperature of bedding ($\Theta_b$) and mean daily temperatures of internal air ($\Theta_i$) at a height of 50 cm above fields “A” and “B”.

The experiment confirmed that in field “B”, $\Theta_i$ was much lower than $\Theta_b$ during the winter production cycle (Figure 2B). At the start of rearing, $\Theta_b$ was lower than $\Theta_i$ by as much as approx. 13.5K. $\Theta_b$ and $\Theta_i$ equalized as late as 24 days of rearing. During the final days of rearing, the maximum difference between $\Theta_b$ and $\Theta_i$ reached approx. 8K. In field “A” (Figure 2A), the mean $\Theta_i$ from the start of rearing was 4-5K lower compared to $\Theta_b$. In this situation, thermal conditions of the chickens were close to thermal comfort. $\Theta_b$ and $\Theta_i$ temperatures became similar from 17 days of rearing and equal at 22 days. Thus, the final 18 days of the production cycle ensured thermal comfort in the living area of the birds.

During the summer production cycle, $\Theta_b$ in field “B” also diverged considerably from $\Theta_i$ (Figure 3B). Mean $\Theta_b$ was approx. 11.5K lower than $\Theta_i$ in the first days of rearing and approx. 9K higher than $\Theta_i$ at the end of rearing. $\Theta_b$ and $\Theta_i$ temperatures equalized at 19 days of growth. In field “A”, mean $\Theta_i$ and $\Theta_{\text{opt}}$ temperatures were almost identical from 3 to 38 days of rearing (Figure 3A). It is worth noting the significant difference in bedding moisture between fields “A” and “B”. With the initial bedding moisture of w = 4–5% in both fields, bedding moisture at 2 weeks of rearing was considerably lower in field “A” (w = 15%) than in field “B” (w = 35%), which from the first day of broiler placement was characterized by intense condensation of water vapor (absorbed by bedding) on the concrete floor that became cold during downtime. The increase in bedding moisture deprived the bedding of its heating and insulating properties and was detrimental to thermal and hygienic conditions in the living area of the birds.

During the first two weeks of rearing, field “A” floor was heated with central heating water whose inlet temperature was approx. 62–65°C and outlet temperature (after passing through the system) was 27–37°C. As floor and bedding temperature increased, the flow of warm water was gradually decreased, maintaining $\Theta_b$ close to $\Theta_{\text{opt}}$. Flow volume measurements showed that the mean volume of warm water used to heat the floor and bedding over 10–14 days of rearing was approx. 4.0 m$^3$ during both the summer and winter periods. Just 0.5–0.8 kWh·m$^{-2}$ have been sufficient to heat the floor and bedding during this stage of rearing. During the middle stage of the production cycle, the heating and cooling system was turned off for 10–14 days. Over the last 20 days of rearing, the floor was cooled with water from the water supply system whose inlet temperature was approx. 9°C. At the outlet, the temperature of the water increased to approx. 18.5°C on average. Regardless of the season of the year, the volume of cold water used to cool the floor and bedding ranged from 65 to 69 m$^3$. The amount of heat released during this period from the bedding averaged approx. 9.4–10.3 kWh · m$^{-2}$.

To estimate the effect of the floor heating and cooling system used in the broiler house on productivity, birds were routinely weighed at weekly intervals and mortality was recorded. Average production data, obtained during measurement time for reference area (field “B”), were typical for all broiler houses in the farm. In winter/summer production cycles, final life weight of broiler was respectively 2.6/2.55 kg, feed consumption 1.9/1.86 kg per 1 kg weight gain and mortality 2.94/3.83% by stock density of 19,2/18,7 birds/m$^2$ (first value refers to winter- and second to summer-production cycle).
Based on the comparison of the results obtained in fields “A” and “B”, it is estimated that until 36 days of rearing, birds from field “A” had approx. 3% greater body weight and approx 3% lower feed intake. In field “A”, mortality at 5 and 6 weeks of rearing was over 50% lower than in the other parts of the production facility. An interesting observation was made during one of the summer production cycles. When the partition between testing fields was taken away to enable removal of some birds and finally the stocking density decreased considerably, field “A” contained many more chickens than the other parts of the production facility. This led to a situation where bedding in this area was covered with a layer of fresh excrements that the bedding was unable to absorb, which did not discourage the birds from staying in the moist cooled area.

Discussion and conclusions

Inspection of bedding temperature is usually neglected in practical poultry rearing despite the fact that $\Theta_b$ is an important parameter of climatic environment. A steady gain in weight, which increases the birds’ contact area with bedding, especially during rest periods and the associated flow of heat from the birds to the bedding intensify the rotting processes in bedding, resulting in the heat flow (65 W.m$^{-2}$ according to RADON, 2004) directed to the production facility. Systematic measurements of bedding temperature ($\Theta_b$) and comparison with $\Theta_{\text{opt}}$ value should be used when deciding whether to increase the thermal and insulating value of the bedding in situations where it is too cold or too warm.

The application of the floor heating and cooling system proved efficient in adjusting bedding temperature to obtain favorable thermal conditions in the living area of birds. In light of the analysis of the present results, it is obvious that thermal conditions in the living area of chickens should be improved. This challenges researchers and practical breeders to look for better production technologies that are environment friendly and cost- and energy-efficient.

A producer driven by solely economic reasons will invest in new technology if it brings financial profits. Calculation
of exact economic consequences is very difficult, since almost all parameters (price, inflation, production level, energy costs etc.) change greatly in broiler production. An overall calculation of cost-effectiveness of discussed invest-

The results of the experimental research presented in this paper are promising for the idea of popularizing the floor heating and cooling system in broiler houses. The present findings lead us to conclude that in modern broiler chicken rearing technology, it is necessary to maintain identical levels of bedding temperature and required air temperature in the living area of birds.

Summary

Several-year measurements made in a broiler house have shown that bedding temperature is considerably lower than the required air temperature ($\Theta_b < \Theta_{opt}$) at the start of rearing, with an opposite situation at the end of rearing ($\Theta_b > \Theta_{opt}$), which makes thermal conditions in the living area of chickens inadequate during these periods. To improve this situation, a floor heating and cooling system for bedding was designed, used in one part of the broiler house and subjected to 18-month tests. $\Theta_b$ and $\Theta_{opt}$ temperatures equalized as a result of the heating of the floor and bedding in the initial period of rearing and as a result of cooling applied during the last two weeks of rearing. The improvement of thermal conditions in the living area of chickens increased weight gains by approx. 3%, reduced feed consumption by approx. 3% and mortality by approx. 50% compared to the control part of the production facility.

Key words

Broiler house, bedding, thermal conditions, floor heating and cooling

Zusammenfassung

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Die Einstreutemperatur $\Theta_b$ konnte über die Heizung des Fußbodens am Mastanfang und Kühlung in den letzten beiden Mastwochen an die gewünschte Idealtemperatur $\Theta_{opt}$ angeglichen werden. Die Verbesserung der thermi-

Stichworte

Hühnerstall, Einstreu, thermische Bedingungen, Fußbodenheizung und Kühlung

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