Research Article

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Performance analysis of a two stage pad cooling system in broiler houses

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Abstract: The cooling performance of a traditional (control) and two stage evaporative pad cooling system (experiment), including pad and fan with tunnel ventilation, for poultry houses and the growth performance of broilers reared in these systems was compared in a study performed during extreme summer temperatures. The experimental unit had a two stage pad cooling system, which consisted of underground tubes and a box, followed by a pad cooling system with tunnel ventilation. The control unit had a traditional evaporative cooling system, including pad and fan with tunnel ventilation. Air temperature, relative humidity, and saturation efficiency were used to determine the cooling performance of the systems. Live body weight gain, feed conversion ratio, and mortality rate were used to monitor the growth performance of broilers raised in these systems. The air temperature and relative humidity of incoming house and exhausted air in the two stage pad cooling system were found to be significantly lower than those of the traditional system ($P < 0.05$). The cooling efficiency or saturation efficiency in the two stage cooling system was found to be slightly greater than that of the traditional system. Body weight gain was also significantly influenced by the cooling system ($P < 0.05$). The results indicated that two stage pad cooling is a more efficient method to alleviate heat stress in broilers during heat stress conditions and to improve growth performance.

Key words: Broiler house, pad cooling, performance

Broyler kümeslerinde iki-kademeli petek serinletme siteminin performans analizi

Özet: Bu çalışma, petek ve fanlar ile çalışan tünel havalandırma sistemi ile birleşik geleneksel (kontrol) ve 2 kademeli evaporatif serinletme sisteminin serinletme etkinliği ve broyler performansına etkisini araştırmak amacıyla yapılmıştır. İki kademeli serinletme sistemi (deneme) dış hava ile bağlantılı, yeraltından geçen bir boru ile bunun bağlantılı olduğu odanın açıldığı petek serinletme sisteminden oluşmaktadır. Geleneksel evaporatif sistem ise tünel havalandırma sistemi ile birleşik petek ve fanlar ile çalışan bir serinletme sistemi şeklinde düzenlenmiştir. Sistemlerin serinletme performanslarının belirlenmesi için hava sıcaklığı, nem oranı ve doygunluk etkinliği, broyler performansının belirlenmesi amacıyla guruplarda canlı ağırlık artışı, yemden yararlanma ve ölüm oranları tespit edilmiştir. İki kademeli serinletme sisteminde içeri giren havanın sıcaklık ve nem oranı ile kümes içi ve kümesten çıkan havanın sıcaklık düzeyleri geleneksel sistemden önemli düzeyde düşük bulunmuştur ($P < 0.05$). İki kademeli serinletme sisteminde, serinletme ya da doygunluk etkinliği geleneksel sisteme göre çok az düzeyde daha iyi olduğu tespit edilmiş, canlı ağırlık artışı da serinletme sisteminden önemli düzeyde etkilenmiştir ($P < 0.05$). Elde edilen sonuçlar, iki kademeli serinletme sisteminin sıcak stresinin etkisini hafifletme ve broyler performansını geliştirme bakımından kanatlı kümeslerinde daha etkili olduğunu ortaya koymuştur.

Anahtar sözcükler: Kümes, petek serinletme, performans

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Introduction

Heat stress can be a major problem as poultry houses are built longer and wider, especially in countries with very hot climatic conditions. High levels of temperature and radiation not only adversely affect production performance, but also inhibit immune function (1,2). To keep poultry comfortable and productive, many types of cooling systems have been investigated. Evaporative cooling pads alone, or in combination with fogging nozzles, or fogging nozzles alone, are all effective options (3). Properly designed and operated pad cooling systems with tunnel ventilation (4) are also widely used in both commercial layer and broiler houses, and are suitable for breeder houses as well (5). It is well known that the evaporation of liquid water streaming along a wall reduces the temperature inside of livestock farms or buildings (6-10). This technique can also improve the working conditions for employees and the environment for plants and animals. The most desired feature of pad cooling with a tunnel ventilation scheme is the benefit of higher air velocity over the broilers (11,12). However, the system is relatively expensive due to high operating costs determined by the power and need for fan operation (13). As the energy costs are becoming more significant, researchers have put more emphasis on investigating the most economical and efficient means to cool broiler houses. A primary approach was reported by Alchalabi (14), which was based on two stage cooling systems consisting of sensible cooling and evaporative cooling. This study showed that the cooling efficiency and feasibility of two stage air cooling in poultry housing were better than the conventional pad cooling. We developed a new system by combining an outer metal tube with an inner hard polyethylene tube, and water in between the tubes to improve the cooling efficiency of the pad cooling system. This study was conducted to evaluate the cooling efficiency of this two stage pad cooling system and to compare the growth performance of broilers raised under traditional and two stage pad cooling systems.

Material and methods

The experimental procedures conducted under extreme summer temperatures in this study were in accordance with the principles and guidelines set out by the Committee of the Faculty of Veterinary Medicine.

Equipment

The experimental unit had a two stage pad cooling system, which constituted underground tubes and box, followed by the pad cooling system with tunnel ventilation. The underground structure composed a 24-m long metal tube that was 28 cm in diameter, with a 20-cm diameter polyethylene tube inside of it. Water was filled in the space between the metal and polyethylene tubes. The system was buried at a depth of 2.5 m in the soil and was connected to a plyboard box that was 20-mm thick and 15 m^3. Inside of the box was a pad cooling with tunnel ventilation. Placed at the inlet and outlet of the tubes were 2 fans (Figure).

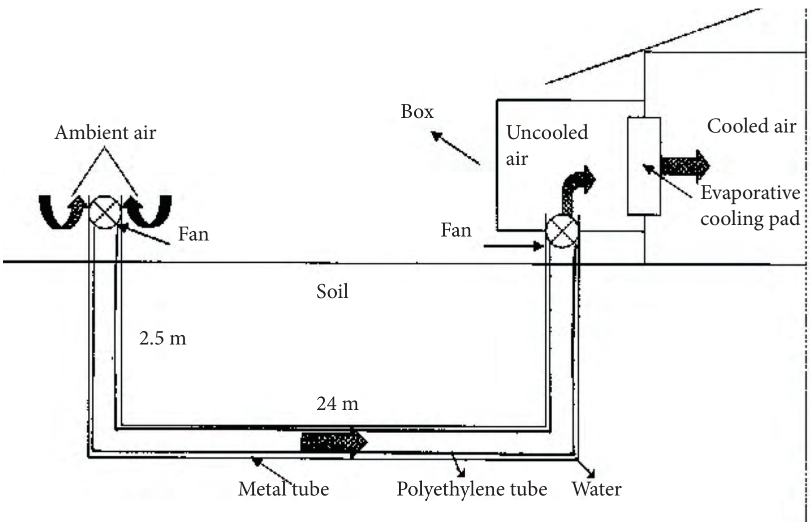

Figure. Design of the two stage pad cooling system.

The control unit had a traditional evaporative cooling system including pad and fan with tunnel ventilation. A total pad area of 15 m^2 (corrugated cellulose pad, 100 mm thickness, mounted vertically) was used in both houses for installation in a 16 × 30 m broiler house with 1.25 m/s air capacity (total fan capacity of 460,000 cfm).

Material

A total of 13,000 day-old broiler chicks (Ross PM3, 6500 chicks each group) were used to monitor growth performance. Standard production practices and standard broiler ration were used during the experiment in both raising houses.

Data

The cooling performance of the control (traditional) and experimental units (two stage) were determined by measuring the dry bulb temperature and relative humidity (RH) of the incoming air, house, and outgoing air. The temperature and RH were measured inside of the box (incoming air) or air inlet, inside of the houses (pad sides and fan sides) and at the air outlet by using an indoor/outdoor Hygro-thermometer (Extech Inst. Coop., Model 445713, Melrose, MA, USA). Ambient temperature and humidity were also recorded. Temperature and RH data were collected at 1 h intervals during the afternoon period, which is accepted as the critical time of the day for broilers, beginning at 30 days of age. During this period of the day, solar radiation and outside temperatures are the highest and heat stress in broilers is more detrimental (2,5). The evaluation of the cooling performance of the systems was done according to saturation efficiency by using the following equation (8,15):

$$\eta = \frac{T_1 - T_2}{T_1 - T_{wb}}$$

where η is the evaporative cooling efficiency in the %; and T_1, T_2, and T_{wb} are the inlet dry bulb temperature, outlet dry bulb temperature, and wet bulb temperature in degrees Celsius of the inlet air, respectively. The values of T_1 and T_2 are the averages of the temperatures that were measured by the Hygro-thermometer during the experiments. The values of the T_{wb} for each T_1 and relative humidity of incoming air were determined by using a psychrometric diagram.

The growth performance of the birds was evaluated by measuring cumulative body weight gain, feed conversion ratio, and mortality rate throughout the experiment. Body weights of broilers were measured individually, between 0 and 42 days of age, with 7 day intervals. Feed consumption and dead birds were recorded on a per group basis. The results for the body weight are expressed as mean values ± SEM.

Statistical analysis

The data, except for mortality rate, were analyzed by Student's t-test (16). The differences for the mortality rate among the groups were analyzed by chi-square test. All tests were performed using SPSS® computer software 13.00 (17).

Results

The cooling performances of traditional and two stage pad cooling systems are presented in Table 1. The average incoming air temperature and RH in the two stage pad cooler (inside the box) and traditional pad cooling system (in front of the air inlet) were measured as 29.60 °C and 49.50%, and 31.65 °C and 59.75%, respectively. The average ambient temperature and RH were measured as 32.18 °C and 31.09% during the experiment. The pad side, fan side, and exhausted air RHs in the two stage pad cooling system and in the traditional cooling system were measured as 50.65%, 37.00%, and 33.50%, and 59.10%, 52.60%, and 53.10%, respectively. The saturation efficiency of the traditional (one stage) and two stage cooling system were found as 42% and 43%, respectively.

Body weight gain, feed conversion ratio (FCR), and mortality rates of broilers raised under traditional and two stage pad cooling systems are presented in Table 2. The cumulative body weight gain in broilers raised in the two stage cooling system was found to be significantly greater than that in the traditional system ($P < 0.05$). Other growth parameters such as feed conversion ratio and survival rate in the two stage system were numerically better than those in the control group.

Table 1. Cooling performance of traditional and two stage pad cooling systems.

	Incoming air (uncooled)	House air (cooled)		Exhausted air	Cooling efficency (%)	Environ. air
	Inside the box or air inlet	*Pad side*	*Fan side*	*In front of the fan*		
Temperature (°C)						
Traditional	31.65 ± 0.77[a]	26.92 ± 0.70	31.06 ± 0.70	31.06 ± 0.65	42.00	32.18
Two stage	29.60 ± 0.87[b]	26.79 ± 0.61	32.01 ± 0.73	32.01 ± 0.58	43.00	31.09
Relative Humidity (%)						
Traditional	59.75 ± 6.5[a]	59.10 ± 1.5	52.60 ± 6.5[a]	53.10 ± 5.9[a]		
Two stage	49.50 ± 6.4[b]	50.65 ± 0.9	37.00 ± 7.3[b]	33.50 ± 3.4[b]		

[f]: Mean ± S.E.M.
a-b: within rows, values with different superscript letters differ significantly (*P < 0.05).

Table 2. Growth performance of broilers raised in traditional and two stage pad cooling systems.

Age	Body weight gain (g)		Feed conversion ratio		Mortality rate (%)	
(weeks)	Traditional	Two stage	Traditional	Two stage	Traditional	Two stage
0-1	111.20 ± 2.26	114.84 ± 1.92	1.21	1.12	0.75	0.83
0-2	363.15 ± 5.00	367.18 ± 5.23	1.28	1.23	1.53	1.58
0-3	777.20 ± 9.55	793.88 ± 8.17	1.34	1.29	2.08	2.16
0-4	1287.84 ± 13.46	1309.65 ± 16.85	1.44	1.34	2.30	2.33
0-5	1713.00 ± 19.88	1733.84 ± 27.85	1.57	1.53	2.56	2.55
0-6	2279.36 ± 31.6[b]	2343.72 ± 33.02[a]	1.63	1.61	2.83	2.81

[f]: Mean ± S.E.M.
a-b: within rows, values with different superscript letters differ significantly (*P < 0.05).

Discussion

In this study, differences for the incoming air temperature and RH were significantly different ($P < 0.05$, $P < 0.05$). The two stage pad cooling resulted in a lower air inlet temperature inside the box. Thus, the time and energy required for cooling the house with the two stage pad cooling system would be much lower than with the traditional system. When compared to the ambient temperature and air inlet temperature or inside of the box temperature, the saturation efficiency of the two stage pad cooling system was greater than that of the traditional system. The cooling performance of the two stage pad cooling system was averaged as 16.74%, with a 5.39 °C reduction in the ambient temperature. The efficiency of a pad cooling system depends on the pad type, pad area installed, RH, and air velocity through the pads (18,19). The incoming air is cooled in 2 steps to reach the final target in two stage pad cooling systems. The first stage uses sensible soil and water cooling. The second stage uses evaporative pad cooling to reduce the air temperature. The air is drawn through pipes buried in the soil and then through an evaporative cooling unit. The air had been found to be at its lowest temperature immediately after passing through the pads in both cooling systems, but it was lowest in the two stage air cooling system.

Within the house in a two stage pad cooling system, the pad side and fan side average temperatures were 26.79 °C and 32.01 °C, respectively. There were no significant differences for the house and exhausted air outlet temperatures between the traditional and two stage pad cooling systems. The average temperatures of the exhausted air outlet in the traditional and two stage cooling systems were 31.06 °C and 32.01 °C, respectively. In both houses, as air moves across the house to the fans, the air picks up heat from the chicks and litter, and the temperature of the air gradually increases. A temperature gradient across the house, with the pad side being coolest and the fan side warmest (20). The pad side, fan side, and exhausted air RHs in the two stage pad cooling system and in the traditional cooling system were measured as 50.65%, 37.00%, and 33.50%, and 59.10%, 52.60 and 53.10%, respectively. The average RH of the pad side and exhausted air in the groups were found to be significantly different ($P < 0.05$). Contrary to the traditional pad cooling, two stage pad cooling reduced the incoming air temperature without raising the RH. This finding is very important because evaporative cooling is only successful under low humidity conditions (3). The lower the RH and the higher the temperature, the greater is the theoretical cooling potential. At 60%-70% RH, the reduction in temperature is in the range of 8-10 °C (18). In this experiment, the saturation or cooling efficiency of the traditional (one stage) and two stage cooling systems were found as 42% and 43%, respectively. This means that the cooling efficiency of the 2 cooling systems were medium. As reported by Bucklin (20), poor or medium cooling efficiency values revealed that each cooling system could be managed poorly. Factors affecting cooling performance of the system such as pad material, thickness, and air velocity were reviewed more carefully. Generally higher efficiencies are obtained with thicker pads, and slower air velocities (21). The average temperatures of exhausted air in each system were found to be similar to the environmental temperature or even higher.

With regard to the effects of the cooling system on performance, broilers reared under the two stage pad cooling were significantly heavier (64.36 g) at the end of the experiment (6 weeks of age). It was observed that a numeric improvement for the FCR values of the broilers was higher in the two stage pad cooling system. As reported previously (22), the presence of the two stage or traditional pad cooling had no effect on mortality throughout the experiment. Based on the data of the present study, and the work by Alchalabi (14), it has been demonstrated that two stage pad cooling improved broiler performance.

In conclusion, this experimental investigation confirmed that combining the 2 processes (underground tubes and pad cooling unit) with tunnel ventilation in the two stage pad cooling system more efficiently reduced the incoming air temperature without raising the RH. The temperature of the ambient air was lower inside the box after passing through the tube in the two stage pad cooling system. The relatively cold soil and water helped to cool the air, reducing electric costs used for cooling the air during heat stress. It could be said that two stage pad cooling in broiler housing is an effective method to alleviate heat stress in broilers during summer conditions and it can be used by producers to reduce energy consumption and to increase growth performance.

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