Effects of a sprinkler and cool cell combined system on cooling water usage, bird performance, and indoor environment of broiler houses

J. Moon[1], J. DuBien[2], R. Ramachandran[1], Y. Liang[3], S. Dridi[4] and T. Tabler[5,*]
[1]*Department of Poultry Science, Mississippi State University, Mississippi State, MS 39762, USA*
[2]*Department of Mathematics and Statistics, Mississippi State University, Mississippi State, MS 39762, USA*
[3]*Departments of Biological and Agricultural Engineering/Poultry Science, The University of Arkansas, Fayetteville, AR 72701, USA*
[4]*Department of Poultry Science, The University of Arkansas, Fayetteville, AR 72701, USA*
[5]*Department of Animal Science, University of Tennessee, Knoxville, TN 37996, USA*
[*]Corresponding author: Tom Tabler, gtabler@utk.edu

Abstract

Climate change is having negative effects on water availability and is a serious challenge to food production around the world. Water scarcity has become a major threat to society, agriculture, and freshwater ecosystems, and the situation is expected to worsen as climate change continues. Sustainability and water efficiency are critical to a poultry industry faced with global production concerns including increased demands for high-quality, affordable animal protein and greater environmental pressures resulting from rising global temperatures, flock heat stress, and limits on water availability. To address these concerns, a commercial sprinkler system used in combination with a cool cell system was evaluated against a cool cell-only system for two summer flocks at Mississippi State University to determine effects of sprinkler technology on cooling water usage, broiler performance, and in-house environments. Environmental and production data were calculated and recorded throughout the flocks. The combination house exhibited a 1.7°C (3°F) (P=0.08) increase in average temperature, numerically lower average humidity (P=0.054), and a 64% (62,039 liters/flock) reduction in average cooling water usage over the cool cell-only house. Litter moisture for the combination house tended to be numerically lower but showed no significant difference at several time points between and across flocks (P=0.11-0.16). Findings are similar to previous reported research and offer additional confirmation that sprinklers in conjunction with cool cells maintain broiler performance while reducing cooling water use, thus lessening the threat to the economic and environmental sustainability of the poultry industry and improving its water efficiency efforts.

Keywords: water efficiency, sustainability, climate change, sprinkler, broiler cooling

Introduction

Commercial broiler chickens are raised in specially designed houses capable of maintaining an environment that allows for optimum performance even during long periods of high environmental temperatures. These houses are the result of decades worth of research to determine the right combination of cooling and ventilation. In recent years, consumers and the poultry industry have placed increasing emphasis on raising chickens in a more sustainable manner. Water conservation is a major emphasis for the poultry industry today as it strives to meet consumers' demands and lessen the industry's overall carbon footprint.

Climate change and heat stress are challenges to sustainable poultry production. Evaporative cooling pad systems, while effective at reducing the temperature of the air entering the poultry house, often result in excessive relative humidity levels of 80% or higher in the house, require large volumes of water, and negatively affect the ability for broilers to dissipate heat through evaporative respiration during periods of high environmental temperatures (Berry et al., 1990; Xin et al., 1994; Tao and Xin, 2003a: Liang et al., 2014; Dunlop, 2018). Broilers typically achieve heat dissipation primarily through respiratory evaporation (Lin et al.; 2005; Hillman, 2009), which is severely hindered by high in-house humidity levels. High in-house humidity level is a known factor that negatively affects litter quality and thereby, animal welfare (Payne, 1967; Weaver and Meijerhof, 1991; Jones et al., 2005; Shepherd and Fairchild, 2010; Dunlop et al., 2016).

Traditional evaporative cooling systems come with drawbacks such as high house humidity, wet litter, and possible negative effects on animal welfare. Sprinkler systems offer water conservation advantages without sacrificing flock performance (Chepete and Xin, 2000; Ikeguchi and Xin, 2001; Tao and Xin, 2003b; Tabler et al., 2008; Liang et al., 2014; Moon et al., 2020; Liang et al., 2020). These sprinkler systems require less cooling water and, when managed correctly, are less likely to result in high in-house humidity typically associated with evaporative cooling systems (Tabler et al., 2008; Liang et al., 2014; Moon et al., 2020; Liang et al., 2020). As a result, sprinklers offer a sustainable best management practice that is precision-focused and capable of maintaining/improving flock performance and increasing animal welfare (better litter quality, lower humidity, improved house environment) while conserving large amounts cooling water and reducing the environmental impact of cooling broilers during summer conditions.

The objective of this study was to determine effects of sprinkler technology on cooling water conservation, in-house environments, and preservation of performance of heavy broilers. The current study will use heavy broilers (>4.3 kg) to test effectiveness of sprinkler technology in a hot, humid environment (central Mississippi) and improve sustainability of the poultry industry.

Materials and methods

Broiler houses

The study was conducted at two commercial broiler houses on the Mississippi State University poultry research farm for two summer flocks from May through October of 2020. The May-July flock contained 13,700 straight-run broilers (1.23 sq. ft/bird) kept for 62 days. The August-October flock placed 14,700 straight-run broilers (1.15 sq. ft/bird) kept for 61 days. The two houses were each 13 m x 122 m (42 ft x 400 ft) and equipped with three lines of pan type feeders and four lines of nipple-type drinkers. Each house contained 15 m (50 ft) of 5 ft x 6 in x 1 ft cool cell on each side of the house. Ten 48-in diameter tunnel ventilation fans (Acme Engineering and Manufacturing Corp., Muskogee, OK) were at the opposite end from the cool cells in each house. Each house was also equipped with two lines of commercial sprinklers mounted to the ceiling and located 3 m (10 ft) from each sidewall above the two outside feed lines. The sprinkler lines consisted of ¾ in (19 mm) PVC pipe running the length of the house. Sprinkler spinner heads were located every 6 m (20 ft) down each line and were directly across from one another (e.g., not staggered). There were 20 spinner heads on each line; a total of 40 per house located 2.1 m (7 ft) above the litter.

The evaporative cooling system remained intact in each house. For the two summer flocks, one house was cooled by the evaporative cooling system only. For this house, the set point temperature on the cool cell pads was 28°C (82°F). The tunnel set point temperature was always 6°F above the house set point temperature for any given day. The other house was cooled by a combination of the sprinkler system as the first stage of cooling with assistance from the cool cell system once house temperature reached 32°C (90°F). This was accomplished by modifying the operational settings on the cool cell set point. The cool cell set point temperature was raised to run water over the pads for 15-20 seconds, but only when the house temperature reached 32°C (90°F). The two houses were switched between the two flocks to remove any house effect (e.g., the cool cell house on the first flock became the sprinkler/cool cell combination house on the second flock and vice versa). The sprinkler system and the evaporative cool cells were allowed to operate from 9:00 am – 9:00 pm.

Sprinkler system

Both houses were equipped with a low-pressure (normal water line pressure of 60 psi) commercial sprinkler system (Weeden Environments, Woodstock, Ontario, Canada) capable of three levels of cooling. The sprinkler controller was mounted in the control room of each house where the main house controller was located. However, there was no communication between the two controllers. The sprinkler system consisted of 2 zones, with 20 spinner heads in each zone and one temperature sensor (at bird height) located approximately in the center of each zone near the north side feed line. The brood end of the house containing the cool cells was one zone, and the non-brood end containing the tunnel fans was the second zone. Each zone was operated independently by activating an electronic solenoid valve assigned to that zone depending on the temperature in that zone. As a result, the 2 zones might run on different schedules and be in different run levels at a given time. We operated the sprinkler at temperature settings higher than recommended by the manufacturer (Table 1).

Table 1: Sprinkler system/cool cell set point temperatures programmed in house controller.

Day	Set temp	Tunnel temp	SS level 1	SS level 2	SS level 3	CC on temp
***	***	+6°F	+10°F	+3°F	+3°F	+22°F TT
						+28°F ST
56	62°F	68°F	78° F	81° F	84° F	90° F

TT = Tunnel temp; ST = Set point temp

Sprinklers in the combination house and cool cells in the cool cell only house were allowed to operate from d 37 until harvest (d 61) for the first summer flock. Cool cells in the combination house were allowed to operate from d 53 until harvest (d 61). During the second summer flock, sprinklers and cool cells in the combination house and cool cells in the cool cell only house were all allowed to operate from d 27 until harvest (d 62).

The three levels of cooling programmed into the sprinkler controller served different functions. The levels recommended by the manufacturer were as follows: Level 1 begins at 2° F above the tunnel set point temperature and operates for 10 sec every 30 min (Table 2).

Table 2: Manufacturer suggested temperature and run time settings.

Level	° above tunnel	Run time (sec)	Idle time (min)
1	2° F	10	30
2	5° F	20	15
3	8° F	20	5-7

It gets the birds to stand up when sprinkled and releases trapped heat between and under the birds. However, upon standing, numerous birds were observed to move to the feeder and drinker lines for something to eat and drink. Level 2 activates at 5° F above the tunnel set point temperature and operates for 20 sec every 15 min. It combines getting the birds up to release trapped heat with increased wind chill on the birds from additional tunnel fans operating and increased sprinkler droplets on the heads and feathers of the birds. Level 3 activates at 8° F above the tunnel set point and operates for 20 sec every 5-7 min, depending on conditions, and creates bird surface wetting that allows maximum wind chill because of the nearly constant evaporative cooling of water droplets off the birds and a steady wind speed of 500+ ft/min. For this study, 8 tunnel fans were running during Level 1, 9 fans during Level 2, and 10 fans during Level 3. Even though the tunnel fan set points were staged 1°F apart, fans 9 and 10 were withheld until the sprinkler system reached levels 2 and 3, respectively. Table 1 lists sprinkler and cool cell settings used in the study. Table 2 lists temperature and run time settings suggested by the manufacturer.

Measurements

In-house temperature and relative humidity data were monitored and recorded by an Intelia data collection system (Intelia Technologies Inc., Quebec, Canada) in each house with data collected every 15 min. Temperature and humidity probes were not recalibrated during the study. Cooling water use by sprinkler and evaporative cooling systems were monitored using water meters containing an electrical pulse output (1 pulse = 1 gal).

Litter moisture content was measured by sampling litter at wks 7 and 9. Litter was collected separately from 16 locations in the cool cell and fan ends of the houses. The 16 subsamples from each end were collected from the top 1-2 cm of the litter surface using a round point shovel and thoroughly mixed in a 5-gal bucket. From this mixed sample, a 946 mL composite subsample was placed in a plastic bag and transported to the Mississippi State University Chemical Laboratory for moisture content analysis. Feed conversion ratio (FCR), live market weight, mortality, and paw quality data were collected from processor records at harvest. However, there were no significant differences in production data; therefore, production data is not discussed in the paper.

Statistical analysis

Humidity data from the Intelia system for the time period 9:00 am to 9:00 pm (when water cooling systems were operational) were collected for the days sprinklers and cool cells were in use. Data were analyzed as a Randomized Complete Block Design using SAS 9.4 with significance indicated by $P \leq 0.10$. Although replication was an issue in this study, as is always the case with whole-house treatments, results are similar to those reported previously (Liang et al., 2014; Moon et al., 2020; Dunlop and McAuley, 2021).

Results and discussion

Sprinkler system operation

In this study, each broiler house was equipped with a commercial sprinkler system and a commercial cool cell system. Two summer flocks were grown between May and October 2020 in which one house used a combination of sprinklers and cool cells for cooling while the other house used only cool cells. The houses were switched between flocks such that the combination sprinkler/cool cell house on the first summer flock was the cool cell only house on the second summer flock and vice versa to remove any possible house effect. Both houses were drop ceiling houses and neither house contained ceiling baffles.

The sprinkler system was operated in combination with the cool cell system and not as a stand-alone cooling system; although previous research has demonstrated successful sprinkler use in a stand-alone setting (Tabler et al., 2008). When operating the sprinkler system, it is important that the house temperature be allowed to run higher and the humidity lower than in a typical cool cell only situation. Otherwise, it will be difficult to evaporate sprinkler water if the house is too cool and humidity too high.

Relative humidity and temperature

The effect of sprinklers on the in-house environment was consistent with previous studies (Liang et al., 2014; Dunlop and McAuley, 2021). The trend was for differences between relative humidity and temperature between the sprinkler/cool cell combination house and the cool cell only house (with the combination house humidity lower and temperature higher, relative to the cool cell only house).

Even though maximum house temperatures in the sprinkler/cool cell combination house were higher (P = 0.082) (Figure 1), this should not be equated with actual bird comfort temperature, because of the numerically lower relative humidity (Figure 2) and the direct cooling effect of the sprinklers on the birds (Figures 3 (birds are dry before sprinkling) and 4 (birds are somewhat damp immediately after sprinkling but dry before the next sprinkling cycle begins), each of which have been found previously to compensate for higher air temperature (Tao and Xin, 2003a; Tao and Xin, 2003b; Liang et al., 2014; Dunlop and McAuley, 2021). High ambient temperatures (<90°F) resulted in use of evaporative cooling pads in the cool cell house and sprinklers in the sprinkler/cool cell combination house.

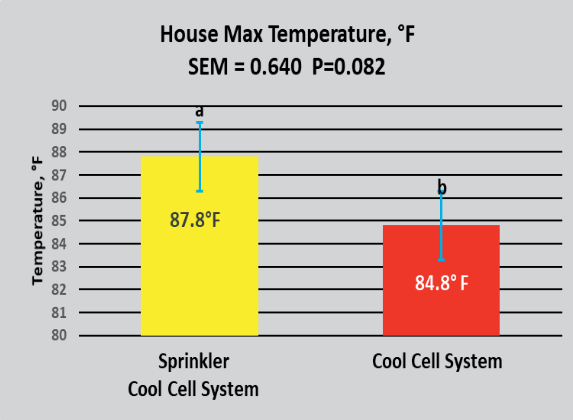

Figure 1: Max. afternoon house temperature.

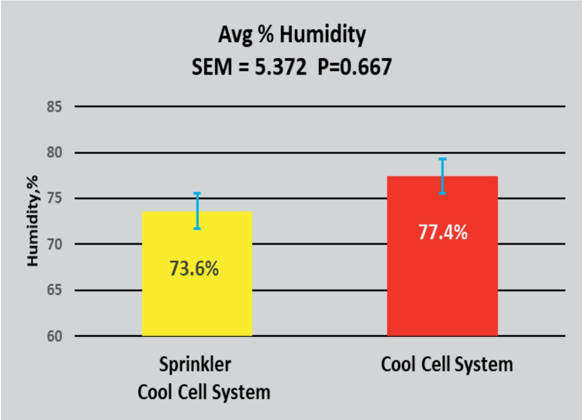

Figure 2: Average percent in-house humidity.

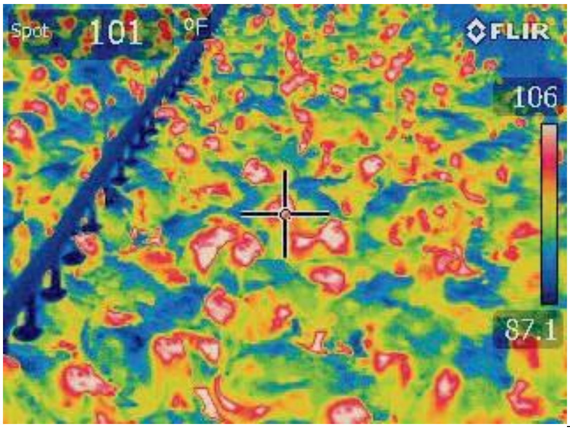

Figure 3: Thermal image before sprinkling.

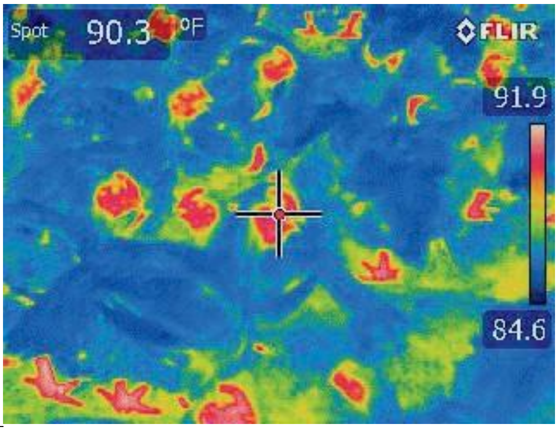

Figure 4: Thermal image after sprinkling.

Allowing cool cell set point temperature in the sprinkler/cool cell combination house of 32°C (90°F) resulted in limited use of cool cells in the combination house to maintain slightly less than 32°C (90°F) in the combination house. As a result, maximum temperature was 3°F higher (P = 0.082) in the combination house than in the cool cell only house (Figure 1). However, the higher temperature was offset by a 3.8% (P = 0.667) lower humidity in the sprinkler/cool cell combination house (Figure 2).

Water used for cooling

A major benefit associated with the sprinkler system is the potential water savings compared to a cool cell only system. Water usage in the sprinkler/cool cell combination house demonstrated a water savings that averaged 64% over the two summer flocks in comparison to the cool cell only house. These savings are in close agreement with Liang et al. (2014) where savings of 67% were reported and Dunlop and McAuley (2021) where savings of 58% were reported. The greatest water savings were observed on days when sprinklers only were in use in the sprinkler/cool cell combination house while evaporative cooling pads were being used in the cool cell house.

Litter moisture

We saw no significant effect of sprinklers on litter moisture in either the fan end (Figure 5) or cool cell end (Figure 6) of the house at either wk 7 or wk 9 of the flock. However, wk 9 litter moisture was approaching significance at $P = 0.108$. This agrees with findings from Liang et al. (2014) who reported no significant effect by sprinklers on litter moisture content. However, it does not agree with research by Dunlop and McAuley (2021) who found moisture content differed with a two-way interaction between growout x sprinklers ($P = 0.002$), with slightly drier litter in the sprinkler house. Dunlop and McAuley (2021) also found a weaker relationship when sprinklers were considered as a main effect ($P = 0.046$), where litter moisture was slightly lower in the sprinkler houses. In the current study, we did see litter moisture approaching significance in wk 9 ($P = 0.108$), with slightly drier litter in the sprinkler/cool cell combination house. The trend was for litter moisture to be slightly drier in the sprinkler/cool cell house compared to the cool cell only house.

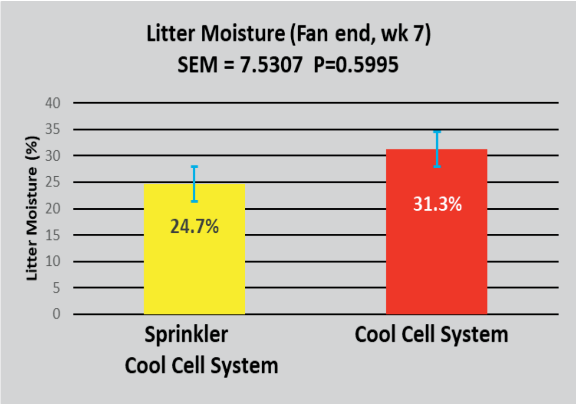

Figure 5: Litter moisture (fan end) week 7.

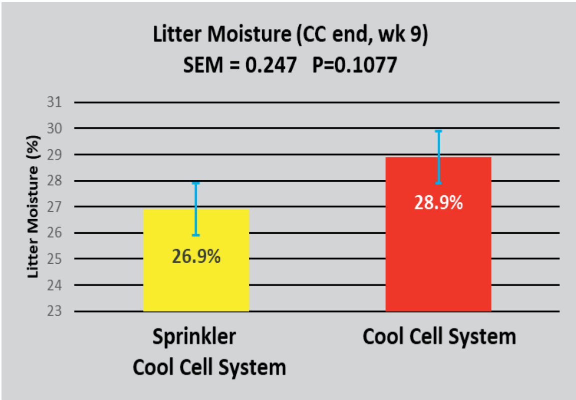

Figure 6: Litter moisture (cc end) week 9.

Conclusions

Sprinklers maintained flock performance and saved 64% of cooling water compared to cool cells alone. Sprinklers appear to perform their best at a house temperature at/near 32°C (90°F), several degrees above where a typical cool cell system usually operates. Sprinklers also perform best when relative humidity is several percentage points lower than in a typical cool cell house. Sprinklers should be the first line of cooling defense, with cool cells used only to prevent extreme conditions, to best achieve the full potential of sprinkler cooling and maintain litter quality.

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