DIVISION OF AGRICULTURE
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University of Arkansas System

Agriculture and Natural Resources

FSA1068

Water Use Patterns Differ Between Pad and Sprinkler Cooling

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Modern commercial poultry houses in the United States employ tunnel ventilation and evaporative cooling systems, where evaporation takes place in the buildings or in inlet air. Evaporative pads are most often chosen because of their high efficiency, while foggers (or low-pressure misting systems) are often installed as auxiliaries due to their limited cooling potential. Fogging systems, when used after cool cell pads, further increase the humidity inside the chicken house, making it increasingly difficult to provide bird cooling. This inability to effectively cool themselves can result in a large number of heat losses, even though the air temperature in the chicken house may only be in the low 80s.

Low-pressure sprinkler systems have been installed as an alternative to foggers to provide bird cooling during hot weather. The sprinkler system uses a different mechanism than the evaporative pad system for bird cooling – sprinkling coarse water droplets on the birds and taking advantage of immediate evaporation locally on the chicken surface (Liang et al., 2012). As a result, the pattern and quantity of water use of pad and sprinkler systems are different. By incorporating a sprinkler system into tunnel-ventilated houses, the demand for water during hot weather can be reduced without affecting live performance.

What Factors Determine Cooling Water Use in Pad Systems?

The amount of water used by evaporative cooling pads is dependent on three factors – **the amount of air being drawn through the pads, outside temperature** and **outside humidity**. The drier the air, the more water the pads evaporate in the inlet air, the more cooling they produce (larger temperature reduction and humidity increase) and more overall cool cell water is used (Table 1). By assuming a typical cooling efficiency of 75% for a 6-inch evaporative pad, the amount of water used can be predicted based on the hourly outside

Table 1. Cooling water usage (gallon per minute) for a 40' × 400' broiler house with 160,000 cfm fan capacity under various outdoor conditions

Temperature	Relative Humidity						
	30%	40%	50%	60%	70%	80%	90%
70˚F	–	–	–	2.6	1.9	1.2	0.6
75˚F	–	4.4	3.6	2.8	2.0	1.3	0.6
80˚F	5.3	4.8	3.9	3.0	2.1	1.4	0.7
85˚F	5.7	5.3	4.2	3.2	2.3	1.4	–
90˚F	6.1	5.7	4.4	3.3	2.3	–	–
95˚F	6.5	6.1	4.7	3.5	–	–	–
100˚F	6.9	6.5	5.0	–	–	–	–
105˚F	7.2	6.9	–	–	–	–	–

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temp and humidity. Figure 1 shows hourly water use by cool cell pads in a 40' × 400' house ranging from 100 to 280 gallons per hour as ambient temperature rises from 85˚F in the morning to 98˚F in midafternoon on a typical summer day. Daytime cooling water adds up to 3,000 gallons in each house on such a summer day.

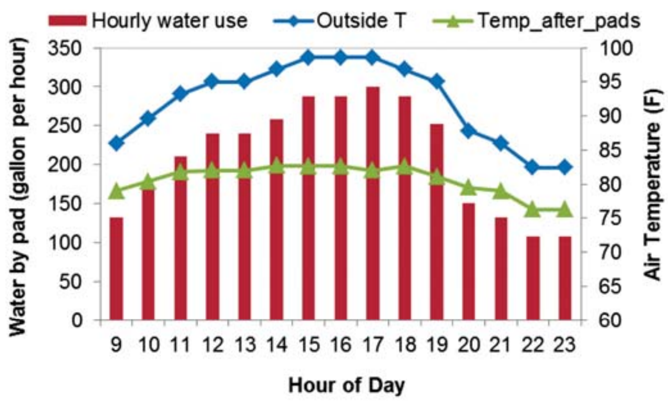

Figure 1. Hourly cooling water with temperature of outside air and air exiting pads on a summer day in a 40' × 400' broiler house with 160,000 cfm fan capacity (total daily water use is 3,000 gallons).

Water use by pads is not directly correlated with bird age once birds reach approximately 4 weeks old. The same amount of water can be consumed at 35 d age or at 45 d age when weather gets that hot (Figure 2). This is because during summer months almost all tunnel fans operate continuously on full capacity, making the daily water usage depend only on how dry the outside air is and, therefore, has little to do with the age of the birds. Instead, pad water usage increases as the number of operating tunnel fans increases over the course of a hot summer day. The high capacity of tunnel ventilation that delivers 600 or 700 feet per minute (fpm) air speed in newer broiler houses, though providing benefits of convective cooling, inadvertently consumes a large quantity of cooling water, reaching 5,000 gallons or more per day. Adding tunnel fans and increasing tunnel inlet areas during retrofit on farms will inevitably increase cooling water usage. Cooling water demand

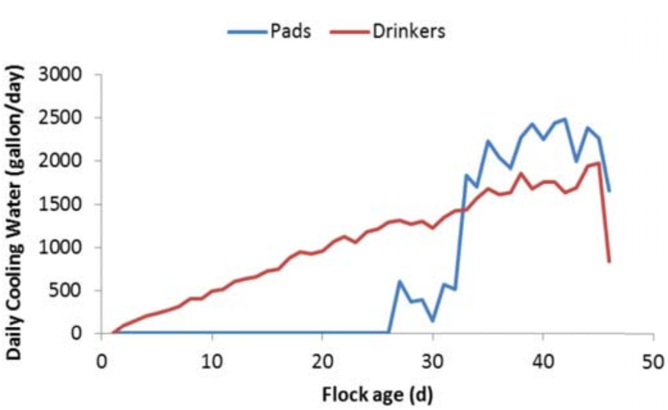

Figure 2. Cooling water of five- and six-week growout could exceed that from drinkers in a summer flock of 19,000 birds.

could exceed daily drinking water for older birds during some extended hot and dry periods (Figure 2).

Sprinkler Water Use Depends on the Age of the Birds

In sprinkler cooling, direct evaporation of water from surfaces of birds releases metabolic heat to ventilation air. Sprinkler cooling attempts to cool individual birds not the environment the birds are living in, as cool cell systems do. There is no need to cool a large mass of ventilation air with cooling pads in order to increase convective cooling. The phase change from liquid to water vapor taking place on surfaces is much more efficient than convective heat transfer between chicken bodies and warm surroundings with a small temperature gradient. This seemingly subtle difference in mode of cooling has big implications. First, because houses are hotter and drier, water evaporates more readily, alleviating wet litter conditions commonly seen at pad areas. Second, because bigger birds need higher metabolic heat dissipation than younger birds (7 pounds versus 3 pounds, Figure 3), sprinkler controllers ramp up sprinkler rates with birds' ages to meet the increased heat production demand (Figure 4). This guarantees

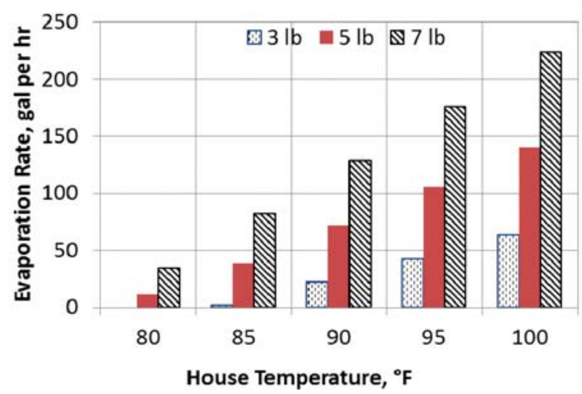

Figure 3. Sprinkler water rates increase positively with house temperature and weight of birds in a 40' × 400' poultry house.

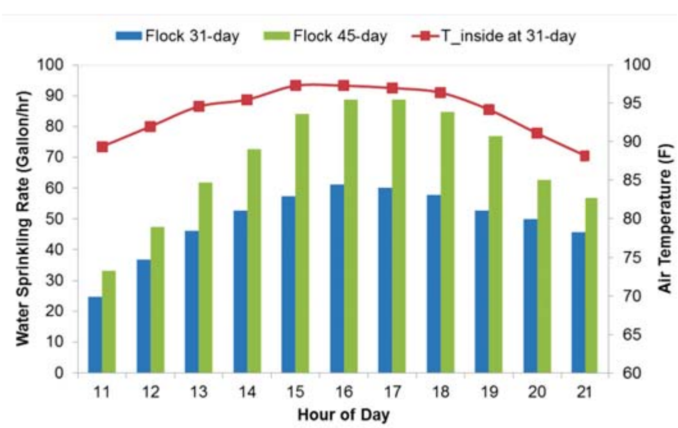

Figure 4. Higher sprinkler water rates with higher heat demands either at older flock age or at higher house temperatures in a trial conducted in a 40' × 400' commercial production house.

precise and more efficient use of cooling water. Third, birds thrive better in a lower humidity environment, due to their being heavily dependent on latent heat loss as the house temperature rises above the thermoneutral zone. Birds can withstand higher air temperatures if the humidity is lower. The combination of heat and humidity tends to cause heat losses.

Research has demonstrated that faster water evaporation translates to higher metabolic heat dissipation. Notice the overall lower sprinkler cooling water use (less than 100 gallons per hour, Figure 4) compared to that in an adjacent pad cooling house (more than 250 gallons per hour during peak hours, Figure 1) at equivalent daytime temperatures.

Sprinkler Cooling Requires Drier Environment

Sprinkler cooling is most effective when the surrounding air is dry. Dry air means more moisture can be absorbed before being saturated (100% relative humidity), regardless of whether the moisture is from the respiratory tract of an animal, a wet chicken or litter surface. Table 2 shows the vapor pressure deficit (VPD) values, which is a measure of how much additional moisture (water vapor) air can absorb before reaching saturation. The dryness of air cannot simply be represented by relative humidity. For example, 40% RH at 95˚F is a lot drier than 40% RH at 85˚F and is, therefore, more "deficit" (3.38 kPa) than air at 85˚F (2.47 kPa). Apparently, hot air can hold more moisture (values in bottom rows versus values in top rows in Table 2) and more readily "grabs" (evaporates) moisture from moist sources in the environment. This includes litter in broiler houses, receiving more than 60% of drinking water as manure, or the wet surface of birds after each sprinkling. Consequently, a sprinkler system in the house should operate before cool cells are wetted – in early flock age and during morning hours. Once the cool cells are wetted, reduce sprinkling rates to avoid adding excessive water in a nearly saturated environment or restrict the operation of cool cells only at higher offset from set point in the program.

The vapor pressure deficit values in Table 2 help explain litter conditions in houses with pad cooling systems. Relatively high humidity occurring in the low 80s has limited drying power (a VPD less than 1.0 kPa, yellow cells) and likely encourages retention of moisture in the litter. Air of 80% relative humidity does not give much chance for the moisture from drinker leaks and manure to escape resulting in wet bedding, especially near the pad area where air temperature is lowest and vapor pressure deficit is lowest.

In most cases, drier air is hotter air, and hot air inside a chicken house with big chickens scares most people. The higher temperatures in the chicken house take some getting used to, but this is when the sprinkler is most efficient and bird performance does not suffer. As long as air flow down the house is adequate, chickens may actually feel more comfortable (because of the wind chill effect created by the fans and the sprinkler) at 90°F and 40% humidity (Table 2, green cell) than at 82°F and 90% humidity. The higher temperature and lower humidity help keep the litter drier and make it easier for the birds to dissipate heat.

A sprinkler cooling system needs less cooling water with younger birds than with older birds in the growout cycle under equivalent weather conditions. On the contrary, water usage from a pad cooling system is not sensitive to bird age but only to weather condition and air exchange through the house. As a result, sprinklers use less water than pad cooling systems. A sprinkler system requires a drier house environment to maximize its benefit of evaporative heat loss, both from birds and any other moist surface such as litter on the floor.

References

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Table 2. Vapor pressure deficit (kPa) of air under summer environmental conditions

Temperature	Relative Humidity						
	30%	40%	50%	60%	70%	80%	90%
75˚F	2.08	1.78	1.48	1.19	0.89	0.59	0.30
80˚F	2.45	2.10	1.75	1.40	1.05	0.70	0.35
85˚F	2.88	2.47	2.06	1.65	1.23	0.82	0.41
90˚F	3.37	2.89	2.41	1.93	1.45	0.96	0.48
95˚F	3.94	3.38	2.81	2.25	1.69	1.13	0.56
100˚F	4.59	3.93	3.28	2.62	1.97	1.31	0.66

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FSA1068-PD-1-2018N