The effect of sprinkler cooling on water conservation, house environment, and broiler performance

Jonathan W. Moon
Mississippi State University, jwm133@msstate.edu

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The effect of sprinkler cooling on water conservation, house environment, and broiler performance

By

Jonathan W. Moon

Approved by:

Jessica B. Wells (Major Professor)
Thomas Tabler
Gary Daniel Chesser Jr.
Yi Liang
Committee Member Name
Kelley G. S. Wamsley (Committee Member/Graduate Coordinator)
Scott T. Willard (Dean, College of Agriculture and Life Sciences)

A Thesis
Submitted to the Faculty of Mississippi State University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Agriculture in the Department of Poultry Science

Mississippi State, Mississippi

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Maintaining performance and mitigating heat stress of the modern broiler is a challenging task during hot weather conditions. Increased demand of high quality reasonably priced animal protein and predictions of future limited water availability make sustainability and water conservation a worthwhile goal for the poultry industry. The most used form for cooling broilers after wind speed is evaporative cool cell (CC) systems. Though highly effective at cooling the incoming air, they substantially increase the relative humidity inside the house, which hinders the bird’s ability to cool itself through evaporative respiration. Cool cells also utilize mass amounts of water. The objective of this research was to evaluate the effects of sprinkler technology on broiler performance, cooling water usage, inhouse environments, conservation, and sustainability, while providing information on how to successfully utilize sprinkler cooling in conjunction with an evaporative cool cell system.

Key Words: Water conservation, Sustainability, relative humidity, sprinkler, cooling broilers
DEDICATION

I would like to dedicate this work to my late mother Linder Moon, she always believed in me, and I know she would be proud.
ACKNOWLEDGEMENTS

The author would like to express his gratitude to everyone that assisted and supported him throughout this journey. A special thanks is due to Dr. Jessica Wells, for all the support and guidance during the last leg of this journey and insisting that quitting was not an option. Also, a special thanks goes out to Dr. Tom Tabler, for guidance and allowing me the freedom and room to learn how to manage the sprinkler systems. Thank you to the committee members Dr. Kelley Wamsley, Dr. Yi Liang and Dr. Daniel Chesser. To the farm crew and grad students, I would like to thank you for the help on the farm and in the classroom, when I was struggling. Thank you to my family for the continuous support when my studies made me unavailable at times. The author would also like to acknowledge Dr. Walter Bottje, USDA-NIFA (grant #2019-69012-29905), USDA-AFRI Sustainable Agriculture Systems, and Weeden Environments, Inc. (Woodstock, Ontario, Canada) for making the research possible.
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CHAPTER I
INTRODUCTION

The broiler industry has changed significantly since the 1950’s (Schmidt et al., 2009). Likely, the single most significant change is the genetic evolution of the broiler chicken itself, supported heavily by modern nutrition regimes, that exhibit substantial increases in growth performance and efficiency (Havenstein et al., 2003). Thus, leading to a larger bird which in turn creates a need for improved ventilation and cooling systems. As the broiler changed, housing had to become more inventive and sophisticated in order to provide an environment at which the bird could reach its full genetic potential humanely (Fairchild, 2005). Growing this modern broiler during hot summertime conditions can be quite challenging due to declines in production efficiency and increased mortality (Liang et al., 2012; St. Pierre et al., 2003; Purswell et al., 2018; Liang et al., 2020). Birds experiencing heat stress spend less time eating and more time drinking and panting in attempts to cool themselves (Lara & Rostagno, 2013). The most commonly utilized and possibly most effective form of cooling is wind speed. This is accomplished through tunnel ventilated houses, created by negative pressure ventilation fans (Liang et al., 2020). However, at some point, wind speed (the primary cooling method) reaches a plateau and secondary cooling must be used (Liang et al., 2020).

The most common form of secondary cooling is the modern recirculating evaporative cool cell system (Liang et al., 2012; Liang et al., 2014; Liang and Tabler, 2018; Purswell et al., 2018; Tabler et al., 2019; Liang et al., 2020). Evaporative cool cells do effectively reduce the
temperature of the incoming air that tunnel ventilation cannot cool. However, they consume large volumes of cooling water and substantially increase the humidity level inside the house. These increased humidity levels make it more difficult for birds to cool themselves through respiratory evaporation, resulting in production efficiency losses and even increased mortality (Liang et al., 2014; Liang and Tabler 2018; Purswell et al., 2018; Tabler et al., 2019). Even though evaporative cool cell systems are effective, their increased amount of water usage has brought about numerous conversations when climate change and environmental footprints are topics of discussion. In recent years, sustainability and water scarcity have become a hot topic in the poultry industry and around the world as a whole (Liang et al., 2020; liang et al., 2014). Today, multiple poultry integrators have entire departments focused on improved sustainability and lessening the poultry industry’s environmental footprint. This includes such high impact areas as water conservation and Scope 1, 2, and 3 greenhouse gas emissions. Consumers want to know what the poultry industry is doing to save the planet and sustainability, water conservation, and reductions in greenhouse gas emissions are major emphasis points.

Therefore, the purpose of this research was to compare a commercial sprinkler system (SS) to an evaporative cool cell system and evaluate their effectiveness at maintaining production gains, bird welfare, environmental conditions, improved sustainability, and water conservation efforts.
CHAPTER II
LITERATURE REVIEW

2.1 The Broiler Chicken

Since the commercial broiler industry’s inception in the early twentieth century, large strides have been taken to advance the industry, resulting in it evolving into what we observe today (Havenstein et al., 2003; Schmidt et al., 2009). One of the most important changes is the evolution of the commercial broiler itself. The commercial broiler of the 1950’s was a small and slow growing bird with a poor feed conversion ratio (FCR) of 3.00 (Prakash, 2020, Schmidt et al., 2009; Thomas et al., 1958; Warren, 1958; Griffin and Goddard, 1994; Konarzewski et al., 2000). The commercial broiler of today is a large and fast-growing bird with a much better FCR, a Ross 308 at 42 days can weigh 5.9lbs with a FCR of 1.62 (Havenstein et al., 2003). The growth rate and efficiency of the modern commercial broiler is primarily due to genetic selection and nutrition; with most of the improvements coming from advancements in genetic selection (Siegel 2014). As genetics have improved, growth rates and feed conversion ratios have also improved in efficiency, resulting in the observation of higher average market weights achieved in shorter growout periods (Bradshaw et al., 2002; Tallentire et al., 2016). With this increase though, other issues have arisen such as increased heat loads inside broiler barns due to increased metabolic rate (Liang et al., 2012), and increased heat stress susceptibility by broilers (Tabler et al., 2008).

Broilers do not tolerate heat stress well due to the absence of sweat glands, and being primarily covered in feathers (Song, 2015). When a bird becomes heat stressed, its body changes
physiologically, which can result in reduced feed intake in order to reduce metabolic heat production (Teeter and Belay, 1996). This ultimately leads to lower growth rates and a reduction in feed efficiency (Geraert et al., 1996). It has also been well documented that high temperatures can decrease feed consumption, cause high mortality in broiler chickens, and result in lower body weight gain (Cahaner and Leenstra, 1992; Eberhart and Washburn, 1993; Yalçin et al., 1997; Mushtaq et al., 2005; Ahmad and Sarwar, 2006; Star et al., 2008; Quinteiro-Filho et al., 2010). Therefore, it is imperative that a proper management routine focuses efforts on combating heat stress in broilers.

Primary focus of this issue resides in summer months when reducing heat stress is more of a challenge, especially since the majority of broiler production in the United States occurs in southeastern states (Paudel and McIntosh, 2005). Summertime flocks often experience extended periods of hot weather and heat stress, which can result in significant economic loss. This means that managing heat stress continues to be problematic (Purswell et al., 2018; St. Pierre et al., 2003). Therefore, removing heat and cooling broilers is key to alleviating heat stress and guarding economic losses.

Sensible heat dissipation and evaporation are two mechanisms by which poultry release body heat (Liang et al., 2020). Sensible heat loss is achieved through convective heat transfer to the air around the body (Fairchild and Czarick, 2005). Convective heat loss is aided by air movement, which creates a wind chill as air is moved over the bird and heat is removed (Bucklin et al., 2009). The wind chill effect can be improved as air velocity is increased thus enhancing weight gain and production efficiencies are observed (Liang et al., 2020; Simmons et al., 2003; Yahav et al., 2001; Yahav et al., 2008). As ambient air temperature increases, convective heat loss decreases, the bird then begins to rely on respiratory evaporation (panting) to move air
through its lungs, by using evaporating moisture, and in turn removing heat (Liang et al., 2020). Respiratory evaporative cooling works well in low humidity environments, but as humidity increases the rate of moisture that can be evaporated decreases, thereby decreasing the cooling effect (Fairchild and Czarick, 2005).

2.2 Housing Evolution

Although many strategies surrounding genetics, nutrition and feeding, and environmental control have been evaluated; ultimately, the producer and the housing environment carry most of the load when it comes to mitigating heat stress (Tabler et al., 2008; Lin et al., 2006). As the commercial broiler evolved to the larger bird of today, so did requirements for improved environmental management that necessitated better housing designs. The increased body weights and floor densities to raise this bird have resulted in the increased need for better cooling systems to relieve high-temperature heat stress in broilers (Berry et al., 1990). Early on, the typical broiler house was a simple open-sided house with sidewall curtains, utilizing natural ventilation and/or mechanical assisted stir fans for cooling (Donald, 2008). Houses then evolved and were built with fans down one sidewall in efforts to cross-ventilate diagonally and move additional air across the house to aid ventilation (Oloyo and Ojerinde, 2019). The large amounts of heat produced by chickens metabolizing high energy feed, coupled with high summertime temperatures, led to the modern broiler house of today, evolving over decades, into solid-wall, power ventilated, evaporative cooled, tunnel houses with many large fans located at one end of the house (Dunlop and McAuley, 2021). These 48”+ size exhaust fans are used to pull a negative pressure inside the house and bring incoming air through tunnel inlets (sized to match the total cubic feet per minute air capacity of all the tunnel fans) at the opposite end of the house,
creating higher wind speeds down the house to help remove heat and cool the birds (Bucklin et al., 2009)

2.3 Fans and Windspeed

There is no argument that air speed, creating improved windchill, is the most important factor regarding summer ventilation, and is responsible for most of the cooling within commercial tunnel houses (Tabler et al., 2019; Donald, 2000), especially during warmer seasons (Czarick et al., 2014). The evaporative cool cell system exists to compliment the tunnel fans and their ability to move air, not the other way around. When one is concerned with cooling broilers during summer flocks, it is important to make sure the ventilation system is performing at its best. Some simple ways to maintain optimum wind speeds are to make sure all your fans are in proper working order (Campbell et al., 2009). Before each flock, all fans should be thoroughly washed (both inside and out) to remove the built-up dust that accumulated on the blades and louvers during the previous grow out; this dust creates drag and hinders fan performance (Campbell et al., 2009). Campbell et al. (2009) also recommends that fan belts, pulleys, and bearings should be checked periodically and tightened, greased, or replaced when worn. Donald et al. (2004) states fan belts should ride high in the motor drive pulley to run at optimum rpm’s. One can expect as much as 30% decrease in fan efficiency if you have dirty fans and worn or slipping belts, pulleys (Donald et al., 2004). This loss of efficiency is often difficult to keep track of because the buildup of dirt and dust, slipping belts, and worn pulleys is a gradual occurrence that happens over time. A grower may note that all the fans are running, but are they running efficiently? If every fan has lost 30% of its efficiency, given a house with 15 or more tunnel fans, that’s like shutting off 4 or more fans. That much loss of efficiency will have serious detrimental effects on bird performance and welfare (Donald et al., 2004; Campbell et al., 2009). As such,
these factors will force the fan to work harder and use additional electricity while performing less efficiently and reducing wind speed down the house, which increases heat stress on the flock (Donald et al., 2004). One should inspect fans on a regular basis to and grease main bearings twice a year or per manufacturer specifications (Campbell et al., 2009). Taking time to do proper fan maintenance and replacing or making adjusting where necessary can minimize downtime and insure proper performance of your ventilation system (Dunlop and Brown, 2015).

Growers often try adding additional fans to increase wind speeds; though before doing this, calculations to determine if the house size, current fan cubic feet a minute and tunnel inlet opening is sufficient to support the additional cubic feet per minute each additional fan will provide. Too little tunnel inlet opening will increase the static pressure is the house and force the fans to work harder, thereby reducing their efficiency and air moving capability. When the cross-sectional area and size of the house allows for additional fan cubic feet a minute to be added, one may need to increase the inlet opening, this will increase air flow therefore lowering the static pressure. Fans can then operate with less resistance, achieving higher and more uniform wind speeds.

2.4 Air Deflector Baffles

Adding wind defectors inside open ceiling broiler house is another strategy to increase windspeed (Purswell et al., 2014; Czarick and Lacy, 1994; Donald, 2013). These baffles are typically installed in the ceiling, 40 ft (12.2 m) behind the tunnel inlet and every 40 ft (12.2 m) down the house, terminating 40 ft (12.2 m) from the first fan. The theory behind these baffles is that they are taking the air movement in the peak of the barn and deflecting it down towards the floor where the birds are sitting and creating an additional cooling effect. These air deflecting baffles were not recommended to be used in drop ceiling houses as they were initially designed
to increase air velocities in open truss houses (Purswell et al., 2014; Czarick and Lacy, 1994; Donald, 2013). However, Purswell et al. (2014) state that air deflectors are becoming more common in drop ceiling houses, and a significant ($p< 0.0001$) 11% decrease mean fan capacity and a 0.045 increase in mean static pressure was observed.

2.5 Secondary Cooling

Although wind speed is the primary means of cooling commercial broilers, relying on some secondary cooling systems is necessary (Czarick et al., 2014). Secondary cooling systems utilize water’s evaporative cooling properties when wind chill has reached its maximum effectiveness, but effective cooling is still not achieved. It seems as if water has always been used to some extent for cooling broilers. Historically, stories from veteran growers have been shared, recalling sweltering summers days, where they would walk the outside of their open-sided houses wetting chickens through the sidewall openings with a hose pipe in efforts to keep them alive. With the evolution and increase in technology advancements, more common water-use systems today include evaporative cool cells, in-house fogging/misting systems, and in-house sprinkler systems.

2.6 Cool Cell Systems

Most U.S. broiler houses today are tunnel ventilated and equipped with evaporative cool cell systems, these systems are generally chosen for their high efficiency (Liang and Tabler., 2018; Tabler et al., 2019) at lowering inside air temperature, despite the huge increase in house humidity. They are located on both sides of the tunnel inlet end of the house where air is drawn through a bank of pads. Air is then distributed into and down the house by the tunnel fans. At a desired air temperature, water is delivered to the pads, by way of a header pipe. As the air is
pulled through the wet pad, water is evaporated and heat is absorbed from this air, dropping the temperature as it enters the house (Liang et al., 2012; Liang et al., 2020) while at the same time raising the humidity. Keep in mind that we did not destroy the heat, we simply changed its form (from sensible heat (temperature decrease) to latent heat (humidity increase)). According to the Munters (a manufacturer of cool cell pads) website, their pads are constructed of a cellulose paper material that are chemically treated to resist deterioration and the cross flutes have a self-cleaning, low pressure drop design that mixes the air and diverts water to the pad face.

Over the years there has been many different pad designs. Some of the first systems were spray on systems that used 2” pads with a series of spray nozzles on the outside that were set to cut on and off with the use of thermostats and solenoid valves. These systems consumed and wasted a great deal of water and often had issues with clogged spray nozzles which led to poor pad water coverage (Donald et al., 2000) According to ACME Kool-cel (a manufacturer of cool cell pads), a 4” and a 6” pad design was introduced that could handle a bit more air velocity for cooling, a face velocity of at least 250 feet per minute (fpm) for 4” and 400 fpm for 6” is recommended. The modern cool cell system applies water through a shielded header pipe, which deflects the water downward onto the top of the 6” pad (Campbell et al., 2006). The water that is not evaporated through the pad is collected and recirculated through the system, and new water is added to the system by way of a float valve and storage tank system (Campbell et al., 2006). These new systems do a much better job cooling than spray on pad systems and use water more efficiently than past systems.

Despite all the improvements that the cool cell system has seen over the years, it is still accompanied by a couple of major deficiencies of its own. First, cool cells are highly efficient at cooling the incoming air using evaporation, but as this heat exchange is occurring and the
temperature is dropping there is a considerable increase in the relative humidity inside the house (Xin et al., 1994; Liang et al., 2014; Dunlop and McAuley, 2021). Increased humidity levels (>70% RH (Liang et al., 2012; Liang et al., 2020)) hinder the bird’s ability to cool itself during hot weather (Tao and Xin, 2003; Dunlop and McAuley, 2021) naturally through respiratory evaporation (Genc and Porter, 2005; Liang et al., 2014). “High relative humidity is also recognized as one of the multifactorial factors that negatively affects litter quality” (Payne, 1967; Weaver and Meijerhof, 1991; Dunlop et al., 2016; Dunlop and McAuley, 2021) “and, by association, influences health and welfare outcomes” (Jones et al., 2005; Shepherd and Fairchild, 2010; de Jong et al., 2012; de Jong et al., 2014; Taira et al., 2013; Kaukonen et al., 2016; Dunlop and McAuley, 2021). Second, evaporative cool pad systems use large amounts of water to operate during warm weather (Liang et al., 2012; Liang et al., 2014; Liang and Tabler, 2018; Tabler et al., 2019; Liang et al., 2020). On a hot day with large chickens, the cool cell system can consume more water than the house of chickens will drink that day. The amount of water an evaporative cool pad system consumes is dependent on three factors: the amount of air being drawn through the pads, the outside temperature, and the outside humidity (Liang and Tabler, 2018; Tabler et al., 2019; Liang et al., 2020). On a typical summer day with temperatures of 85°F (29.4°C) in the morning and afternoons of 98°F (36.7°C), a modern broiler house capable of wind speeds of 700+ fpm can consume up to 280 gallons or more of cooling water an hour (Edge et al., 2018; Liang et al., 2020)

2.7 Fogging System

Fogging or misting systems are another form of evaporative cooling that have been utilized in broiler houses for years. These indirect cooling systems can be low pressure misters of at least 150 psi or high-pressure foggers of 1,000 psi that deliver small water droplets directly...
to the air inside the barn (Liang et al., 2014). The idea is for the water to evaporate quickly before reaching the bird thus being able to cool the environment the bird lives in, but not the bird itself (Timmons and Baughman, 1983; Bottcher et al., 1991; Liang et al., 2014). These foggers/misters are typically used following cool cells as supplementary cooling; however, they tend to further saturate the air with moisture, and in turn further hinder the bird’s cooling ability through evaporative respiration (Liang et al., 2012; Liang and Tabler, 2018; Tabler et al., 2019). This can potentially lead to increased mortality (Tabler et al., 2019). In addition, the small fogging nozzles are prone to stop up with debris and mineral deposits and can be a maintenance headache (Bucklin et al., 2009). Fogging systems could decrease wind speeds and hurt cooling ability for the birds by wetting fan belts and pulleys causing them to slip and operate inefficiently (Tabler et al., 2019). From personal experience, it was observed that when foggers were implemented in a house, the temperature inside increased. One possible explanation would be that this increase in temperature is possible by further saturation of the air and slowing wind speeds allowed heat to build up faster than it could be removed. In addition, fog is often exhausted through the fans which wets the fan blades, belts, and pulleys and causes the belts to slip, decreasing the fans’ efficiency and reducing the number of cfm’s the fan can move.

### 2.8 Sprinkler Systems

Sprinkler cooling is an alternative to evaporative cool pad and foggers systems (Tabler et al., 2019). Sprinkler cooling utilizes low/line pressure (Tabler et al., 2019), and coarse water droplets to achieve surface wetting, causing direct cooling by evaporation off the surface of livestock (Turner et al., 1992; Wolfenson et al., 2001; Ikeguchi et al., 2001; Liang et al., 2012; Liang et al., 2020). Even though the surface of the bird is being targeted and not the environment, there is a cooling effect from light evaporation occurring as water droplets fall to
the ground that can be seen in a one-to-five-degree reduction in temperature (Czarick et al., 2014).

Sprinkler systems have been successfully used in the dairy, beef cattle, (Morrison et al., 1981; Turner et al., 1992; Gaughan and Tait, 2005; Liang et al., 2014) and hog industries to relieve heat stress during warm weather (Liang et al., 2012). Milk production increases in dairy cattle have been observed when they were sprinkler cooled in holding pens; and one study illustrated a production increase of five pounds when cows were cooled thirty minutes five times a day in holding pens (VanDevender, 2021). When referring to poultry specifically, chicken plumage thermal resistance has been shown to be approximately cut in half when feathers were wet (Webb and King, 1984; Liang et al., 2020). For a thermal image visual representation of before and after sprinkler cooling on broilers, see Figure 2.1 images A & B.
Figure 2.1  Thermal image of birds immediately A) prior to and B) after sprinkling
2.9 Differences in Water Usage of Cooling Systems

The most significant difference between sprinklers and cool cells is what they are designed to cool, and as a result, the amount of cooling water used by each system. Due to their high efficiency, cool cells use large amounts of water to cool the air entering a broiler house (Liang et al., 2014). Cool cell systems are like air conditioning and are designed to cool the environment where the birds live. Sprinkler systems are designed to cool individual chickens (Czarick et al., 2014), not the environment the chickens live in (Liang and Tabler, 2018; Tabler et al., 2019). “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” (Liang and Tabler, 2018). Basically, meaning that the evaporation effects are much higher as outside humidity is decreased, which will give lower inside house temperatures and higher humidity, and this is seen by increased water usage and it is not dependent on age of birds (Table 2.1 (Liang and Tabler, 2018)).
Table 2.1  Cooling water usage (gallon per minute) for a 40'x400' broiler house with

<table>
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<tr>
<th>Temperature</th>
<th>Relative Humidity</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
<th>60%</th>
<th>70%</th>
<th>80%</th>
<th>90%</th>
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<tbody>
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<td>70°F (21.1°C)</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.6</td>
<td>1.9</td>
<td>1.2</td>
<td>0.6</td>
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<tr>
<td>75°F (23.9°C)</td>
<td></td>
<td>-</td>
<td>4.4</td>
<td>3.6</td>
<td>2.8</td>
<td>2</td>
<td>1.3</td>
<td>0.6</td>
</tr>
<tr>
<td>80°F (26.7°C)</td>
<td></td>
<td>5.3</td>
<td>4.8</td>
<td>3.9</td>
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<td>2.1</td>
<td>1.4</td>
<td>0.7</td>
</tr>
<tr>
<td>85°F (29.4°C)</td>
<td></td>
<td>5.7</td>
<td>5.3</td>
<td>4.2</td>
<td>3.2</td>
<td>2.3</td>
<td>1.4</td>
<td>-</td>
</tr>
<tr>
<td>90°F (32.2°C)</td>
<td></td>
<td>6.1</td>
<td>5.7</td>
<td>4.4</td>
<td>3.3</td>
<td>2.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>95°F (35°C)</td>
<td></td>
<td>6.5</td>
<td>6.1</td>
<td>4.7</td>
<td>3.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>100°F (37.8°C)</td>
<td></td>
<td>6.9</td>
<td>6.5</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>105°F (40.6°C)</td>
<td></td>
<td>7.2</td>
<td>6.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
</tbody>
</table>

160,000 cfm fan capacity under various outdoor conditions (Liang and Tabler, 2018)

Sprinkler systems on the other hand are designed to intermittently apply water based on bird age, and the water usage tends to increase the older the flock becomes (Liang and Tabler, 2018; Tabler et al., 2019). More recent research using sprinklers has demonstrated significant reductions of core body temperatures, head, and dorsal surface temperatures (Mutaf et al., 2009; Liang et al., 2020) and reduction of core body temps (Sharifabadi et al., 2017; Liang et al., 2020), however, insignificant temp differences were observed by Liang et al., 2014 and Liang et al., 2020. Additionally, increased levels of corticosterone are the #1 stress marker, and sprinklers have been shown to reduce corticosterone levels under heat stress, as well as reduce heat shock proteins (HSP60 and HSP70) and their transcription factors (HSF1 and HSF4) (Sharifabadi et al., 2017).
2.10 In-House Environment

With both cool cells and fogging, these systems are attempting to cool the house environment through evaporative cooling. As evaporation lowers the air temperature, the humidity levels are increasing inside the house to over 80%. This is less than desirable and hinders the bird’s natural ability to cool itself through respiration (Dunlop, 2018). High in-house humidity can also lead to wet litter (Payne, 1967; Weaver and Meijerhof, 1991; Dunlop et al., 2016; Dunlop and McAuley, 2021), which is detrimental to paw quality, bird health, and can become an animal welfare issue (Jones et al., 2005; Shepherd and Fairchild, 2010; de Jong et al., 2012; de Jong et al., 2014; Taira et al., 2013; Kaukonen et al., 2016; Dunlop and McAuley, 2021). When referring to sprinklers, these systems use more precision-type farming techniques, cooling the surface of the bird and not the entire environment. When sprinklers are used in place of or in conjunction with cool cells, there are two key differences in the in-house environment. These differences are temperature and humidity. As we stop or delay the use of cool cells, we will see an increase in house temperature and a reduction in humidity level, which evaporates water quicker from the surface of the bird. This can cool, and promote natural evaporative cooling (Liang et al., 2018).

2.11 Sprinkler/Cool cell Implementation

When using a sprinkler system in conjunction with an evaporative cool cell system it is important to keep in mind that these systems are used during summertime conditions to aid in cooling and the tunnel fans are our first line of defense (Tabler et al., 2019; Donald, 2000). Both the sprinkler and cool cell systems need wind speed to properly function and evaporate cooling water efficiently. Ideally, the majority, if not all, fans are utilized before starting any type of evaporative cooling (Tabler et al., 2019). After the houses are in tunnel mode, and all the fans
have been staged in, one can now determine where to start complimentary cooling (Tabler et al., 2019). When using these systems together, the sprinkler system will be implemented prior to the cool cells (Tabler et al., 2019). A sprinkler system needs a higher temperature and a lower humidity to properly work (Liang et al., 2018). The use of cool cells must be delayed and set to a much higher temperature than normal to achieve the proper temperature and humidity for sprinkler systems to operate properly (Liang et al., 2018). Operating sprinklers at a house temperature less than about 88° F will not allow sufficient evaporation of sprinkler water. The house must be operated at a high enough temperature and a low enough humidity for the sprinkler water to evaporate between sprinkling cycles. If this is not done, sprinklers will not give satisfactory results and the litter will likely become wet. The higher than usual house temperature that sprinklers require to operate effectively scares many growers and integrators. However, chickens can tolerate fairly high temperatures and still perform well if the humidity is lower. And higher air temperatures are usually accompanied by lower humidity’s. Sprinkler cooling is more effective at lower humidity’s where birds can also cool themselves easier through respiration, and this also promotes an environment conducive to drier litter (Liang and Tabler, 2018). Sprinklers require an open-minded thought process because sprinkling approaches cooling chickens from a different angle than the cool cell systems everyone is familiar with. Accepting the fact that the house must run several degrees hotter than one may be used to in order to drop the humidity level 20-30% in the house is a prerequisite to managing a sprinkler system successfully. Operating the house at 82-84°F (27.7-28.9°C) while also operating sprinklers is a recipe for wet litter.
2.12 Equipment cost

According to Weeden Environments, Inc. (a commercial sprinkler manufacturer), depending on house size, a sprinkler system will run between $2,000 and $2,500 for the controller, solenoid valves, sprinkler heads, and piping, with labor for the install running around $1,500. The total cost for a sprinkler system installed will be $3,500 to $4,000 per house. With a sprinkler system there is virtually no parts to wear out and replace. Cool cell systems on the other hand run quite a bit more. A quote obtained from a local poultry supply house states a small recirculating cool cell system is $8,900 and installation will be around $4,400. Even the smallest system installed will be around $13,300 at minimum. All quotes were obtained during the spring of 2021.

2.13 Water Conservation

Sustainability and water conservation are two highly talked about topics in not only the world today but particularly in agriculture. The poultry industry relies on large amounts of water to produce quality protein for the world, so sustainability and water conservation are important concepts to keep in their sights. One small 40 x 400 ft (12.2 x 121.9 m) broiler house can use 20,000 to 40,000 gallons of cooling water per flock (Liang et al., 2012). It is predicted the water demand of people and agriculture will grow significantly in the next several decades and will be accompanied by a reduction in surface and ground water availability for both human and agriculture usage (Liang et al., 2020). One method to potentially aid in reduction of water usage in poultry production is sprinkler systems. During warm weather sprinklers can reduce cooling water demand without affecting performance (Liang and Tabler, 2018). Previous research has shown that sprinklers can reduce cooling water usage by 67% (Liang et al., 2014) and 58% (Dunlop and McAuley, 2021). Liang et al. (2020) estimated a national daily broiler cooling water
usage of 825 million gallons/day and implementing the use of sprinkler technology could
potentially save 544.5 million gallons/day in the U.S. alone. These water savings alone warrant a
closer look by the poultry industry as they are key to sustainability of broiler production.

As mentioned previously, heat stress can be detrimental to the efficient production of
broilers. Therefore, many cooling systems are utilized to aid in proper management of heavy
broilers during summer months. However, when utilizing these systems water usage must be
closely monitored considering the emphasis placed on sustainability and water conservation in
today’s society. Therefore, it is imperative to determine the effectiveness of utilizing sprinkler
technology in conjunction with an evaporative cool cell system and evaluate its effects on broiler
performance, litter conditions, water conservation and in-house environment (temperature and
humidity), while determining the appropriate setpoints for both sprinklers and cool cell systems.
Liang et al, (2014) stated “application of surface wetting to cool chickens has been limited” and
the author feels that this is still the case in the Southeastern region on the U.S. and specifically
Mississippi and Alabama. The author feels that if one can get past the aversion of applying water
directly inside the chicken house and change the way of thinking, sprinkler cooling will have
tremendous impacts. Change is not an easy concept for the poultry industry. The industry is
comfortable with what it understands and products that have a long-proven track record.

Sprinkling broilers is a fairly new concept that requires a radical change in thinking compared to
cool cell operation. Unfortunately, some growers and integrators have not understood how to
properly operate a sprinkler system and have lost confidence in the system’s abilities. However,
sprinkler cooling technology has many benefits to offer the poultry industry once the initial fear
of high house temperatures and hesitancy to accept the system is overcome.
CHAPTER III
SPRINKLER COOLING BROILERS TO OPTIMIZE WATER CONSERVATION AND PRODUCTION BENEFITS

3.1 Abstract

Raising broilers during hot, humid weather can be especially challenging when trying to maintain adequate performance gains. Prior to data collection at Mississippi State University (MSU), data mining techniques were used to evaluate past flocks reared at the University of Arkansas. Recent analysis of the experimental sprinkler data collected by the University of Arkansas was the basis of the current research. These data illustrated a significant reduction in cooling water usage and average mortality from day 35 to sell for sprinkler systems over conventional evaporative cool cell systems. Although not significantly different, sprinkler systems showed a trend of increased grower pay per pound over cool cell systems. The purpose of this study was to monitor broiler performance and cooling water conservation during hot weather conditions when utilizing sprinkler technology in conjunction with evaporative cool cells. Prior to this study, grow outs were done where sprinklers were used in conjunction with cool cell systems at increasingly higher setpoints in order to find the appropriate cool cell set point. These data suggest that sprinkler technology when used in combination with cool cell systems can maintain broiler performance and conserve water.
3.2 Introduction

Estimated overall water usage will continue to increase as the world population increases. This will exacerbate existing challenges of reduced reserves of surface and ground water availability for both human and agricultural use (Liang et al., 2020). The poultry industry relies heavily on large volumes of water annually in order to produce quality protein for both the domestic and global protein markets. The poultry industry must be on the front lines in addressing water scarcity and the future.

At the broiler farm level, water is utilized in two ways. The first being for consumption in the form of drinking water. Broilers will consume 1.7 to 2 pounds of water for each pound of feed that is consumed (Williams et al., 2013; Purswell et al., 2018). If a broiler flock has a target weight of 9.5 lbs. and an average FCR of 1.98, it can be estimated that each bird will consume approximately 4.5 gallons of water for growth only. Other factors that will impact water use is size of and the number of houses, as well as the stocking density. In addition to drinker water, water is also used for cooling purposes. Environmental management and appropriate bird comfort levels are crucial to optimize weight gain, FCR, flock welfare, and livability (Tabler et al., 2019). When growing broilers in hot humid conditions, heat stress is a major concern that will negatively impact both performance and mortality (Tabler et al., 2008). As heat stress occurs, birds will begin to consume more water and eat less feed while trying to stay cool (Wasti and Mishra, 2020). The first line of defense in cooling broilers is wind speed. Once in tunnel ventilation mode and air speed is maxed out with all fans running, historically, evaporative cool cell pads have been used to decrease the temperature of the incoming air in order to cool the birds (Tabler et al., 2019). Although 6” recirculating evaporative cool cell pads work better than previous models at conserving water and lowering the air temperature, they still consume a
large amount of water for cooling purposes alone. When cool cells are in use, they will increase the humidity level inside the house, sometimes exceeding 80% relative humidity, hindering the birds respiratory evaporative cooling ability (Tabler et al., 2019). This makes evaporative cool cells somewhat less than ideal at maintaining adequate performance. The objective of this study was to determine if sprinklers are an effective cooling technique in broiler houses as well as what the optimal setpoints are when ran in conjunction with evaporative cool cells during hot weather.

3.3 Materials and Methods

Experimental sprinkler data mined from the University of Arkansas was evaluated and analyzed. This data was recorded from two 40 x 400ft (12.2 x 121.9 m) broiler houses, one of which was equipped with tunnel ventilation and an experimental sprinkler system, the other using tunnel ventilation and an evaporative cool cell system. The measured variables collected for each flock were average body weight, cooling water usage, drinking water consumption, daily mortality (day 35 to harvest), FCR, and grower earnings. Each flock consisted of one cool cell, and one sprinkler system replication. This data was obtained from 17 separate summer flocks ranging in date from 1995 to 2005.

This research was conducted in two commercial sized (42 X 400 ft (12.8 X 121.9 m)) broiler research houses located at MSU’s Poultry Research Farm. For this trial, Cobb 700 straight run broilers (16,016) were placed in each house for a 63-day 2019 summer grow out phase (June-August). Both houses were equipped with a commercial sprinkler system that was used in conjunction with a commercial evaporative cool cell system. The independent sprinkler system controller (separate from the house controller) delivered controlled volumes of water in the form of large water droplets directly to the surface of the bird (as a function of/based on bird age and in-house air temperature). House temperature, house humidity, water consumption and
cooling water usage was monitored with 1 pulse = 1 gal electrical output water meters and recorded in the Chore-Time Chore-Tronics-3 controllers in each house. The sprinkler heads were suspended from the ceiling in two rows above the outside feed lines, 7 ft (2.1 m) off the litter and spaced evenly 20 ft (6.1 m) apart.

Preliminary data were collected prior to the onset of this study to determine the optimum set point of house air temperature for triggering sprinkler systems. Grow outs were completed where sprinklers were used in conjunction with cool cell systems at increasingly higher cool cell setpoints in order to find the optimum setting. A variety of cool cell settings were used for this preliminary data, increasing from 86°F(30°C) /2018 to 86°F(30°C) and 90°F(32.2°C) /2019. As the cool cell set point was increased, more of the cooling demand was placed on the sprinkler cooling system. It was determined that the setting of 90°F(32.2°C) would be used for this current study at Mississippi State University. Therefore, during the two-house farm study completed in 2019, summer flock sprinkler cooling was held off until day 23 to allow for ample fan cooling. Cool cells were then set to run at 90°F(32.2°C) and allowed to operate from day 45 until slaughter. This study implemented the same systems in both houses. Therefore, data collected were not analyzed for differences, but rather observed for water usage, average weight, paw scores, and feed conversion ratio. It was then compared to the rankings of other farms (who are in the same commercial company and do not use the sprinkler system) for the performance metrics to determine if the system could potentially be effective at conserving water usage without having detrimental effects on performance metrics. For this research the sprinkler system followed Weeden’s guidelines of implementing the sprinklers 2°F (-1.1°C) above tunnel temp but followed this to lower temperatures than the manufacturer recommended (Table 3.1). The sprinkler systems runtime and idle times were set to Weeden’s recommendations (Table 3.2)
Table 3.1  Setpoint temperatures for Sprinkler Systems (SS) levels and Cool Cells when used in combination 2018/2019

<table>
<thead>
<tr>
<th>Day</th>
<th>Set Temp</th>
<th>Tunnel Temp</th>
<th>SS Level 1</th>
<th>SS Level 2</th>
<th>SS Level 3</th>
<th>CC on Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>***</td>
<td>***</td>
<td>+6°F</td>
<td>+2°F</td>
<td>+3°F</td>
<td>+3°F</td>
<td>10,14°F (-12.2, -10°C)</td>
</tr>
<tr>
<td>56</td>
<td>62°F(16.7°C)</td>
<td>68°F(20°C)</td>
<td>70°F(21.1°C)</td>
<td>73°F(22.8°C)</td>
<td>76°F(24.4°C)</td>
<td>86, 90°F (30, 32.2°C)</td>
</tr>
</tbody>
</table>

Table 3.2  Weeden’s recommended temperature and runtime and idle time settings

<table>
<thead>
<tr>
<th>Level</th>
<th>Degree above Tunnel</th>
<th>Run time (seconds)</th>
<th>Idle time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2°F (-16.7°C)</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>5°F(-15°C)</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>8°F(-13.3°C)</td>
<td>20</td>
<td>5-7</td>
</tr>
</tbody>
</table>

3.4  Statistical Analysis

Previous data collected at the University of Arkansas from 1995-2005 were analyzed as a Randomized Complete Block Design. SAS version 9.4 was used, and significance was indicated with P ≤ 0.05.

3.5  Results

3.5.1  Arkansas growout 1995-2005 data

The recent analysis of the early Arkansas experimental research data showed a significant (P=0.003) 84.25% reduction in cooling water usage by the by the sprinkler house as seen in Figure 3.6. Mean sprinkler cooling water usage was 5,169 gal/flock vs. 32,806 gal/flock for cool cell cooling. The average daily mortality for flocks reared from 1995 to 2005 was also significant (P=0.035), with less mortality observed in houses utilizing sprinkler systems when compared to
houses using cool cell systems (Figure 3.7). Mean sprinkler systems daily mortality was 19 birds/day vs. 28 birds/day for the conventional evaporative cool cell system. Sprinkler systems also illustrated a trend (P=0.064) of increased mean grower pay per pound of 4.42 cents/lb. vs. 4.16 cents/lb. for the cool cell system (Figure 3.8). No other significant differences or trends were observed for water intake, FCR, or average weight (P>0.05).

Figure 3.1  Cooling water results of sprinkler data analysis from University of Arkansas, 1995-2005
Figure 3.2  Average daily mortality results, D35-harvest, of sprinkler data analysis from University of Arkansas, 1995-2005
This data suggests that when we postpone cool cells and utilize sprinklers for most of the cooling, 63-day old broilers can maintain adequate performance at 90°F(32.2°C) temperatures and ~65% house humidity. It was also determined that cooling water usage was reduced by as much as 50% or more. It is likely that sprinkler cooling usage can create an environment where temperatures routinely reach 90°F(32.2°C) with reductions in relative humidity of 20%, and in turn making it easier for broilers to cool themselves through respiratory evaporation, therefore maintaining performance.

All these results were compared and analyzed in order to provide guidance for the study conducted in chapter 3. This data was utilized to provide preliminary findings to support the utilization of cool cell pads with sprinkler system combinations. Due to little research conducted in this area, this research provided a foundation to support the concept and begin future studies.
Future research could also be performed to determine if using only sprinklers to cool broilers could be effective and still maintain flock performance. House environments should also be observed in relation to sprinklers effect on temperature, humidity, windspeeds, litter moisture, as well as flock welfare and water conservation.

### 3.5.2 Preliminary data for sprinkler systems settings

In regard to the preliminary study to determine the optimum sprinkler system setpoint, Figures 3.1, 3.2 and 3.3 depict the water usage in regard to drinking, sprinklers, and cool cells for 2018 at 86°F(30°C) and 2019 at 86°F(30°C) and 90°F(32.2°C), respectively. Tables 3.1 and 3.2 both have cool cell set points of 86°F, but they also exhibit the authors learning curve as how to successfully implement a combination sprinkler system cool cell cooling regimen. For the 2018 86°F(30°C) degree flock the cool cells were allowed first and later the sprinklers were worked in before cool cell cooling. The author wasn’t comfortable allowing sprinkler cooling at a younger age sue to floor coverage. For the 2019 86°F(30°C) flock the author was more comfortable with the operation where the sprinklers were utilized earlier at day 34 and cool cells were held off until day 47. These data concludes that the higher temperature was not detrimental for the flock and less water was utilized for the grow-out phase. Therefore, it was determined that for the following study the higher temperature would be utilized.
Figure 3.4  Drinking water and cooling water use by SS and CC for 63-day-old flock from July-September 2018 with CC set point at 86°F(30°C)

Figure 3.5  Drinking water and cooling water use by SS and CC for 63-day-old flock from March-May 2019 with CC set point at 86°F(30°C)
3.6 Drinking water and cooling water use by SS and CC for 63-day-old flock from June-August 2019 with CC set point at 90°F(32.2°C)

3.5.3 **Data from Mississippi State University summertime flock**

Data collected from the summertime flock were for observational use only due to no control unit being utilized. Both houses utilized the combination of cool cell pads with sprinkler systems, with a cool cell setpoint of 90°F(32.2°C). Figure 3.4 illustrates the house and ambient temperatures along with Figure 3.5 demonstrating the minimum and maximum humidity levels.
Figure 3.7  House and ambient minimum and maximum temperatures for 63-day-old flock from June-August 2019
Upon completion of this grow-out phase, reports were viewed to determine the ranking of the farms flock performance. Table 3.3 shows the average weight, feed conversion ratio, points from average on cost, grower pay and ranking for the week for the grow out.

<table>
<thead>
<tr>
<th>House #</th>
<th>Live Weight</th>
<th>FCR</th>
<th>Pay Cents/lb (Cents/kg)</th>
<th>Points from average</th>
<th>Ranking out of 11 farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.92 lb (4.5 kg)</td>
<td>1.968</td>
<td>6.39 (2.88)</td>
<td>-.10</td>
<td>#8</td>
</tr>
<tr>
<td>2</td>
<td>9.48 (4.3 kg)</td>
<td>1.937</td>
<td>6.54 (2.94)</td>
<td>+.04</td>
<td>#6</td>
</tr>
</tbody>
</table>

It was determined that utilizing the sprinkler system at 90°F (32.2°C) did not have any negative effects on flock performance and with further research could prove to be an effective method with less water usage during a grow-out period.
3.6 Discussion

With the compilation of Arkansas data collected over ten years (17 flocks) and the study completed in this chapter we can conclude that a sprinkler system utilized as a secondary cooling system coupled with cool cell pads could be beneficial at reducing water usage without having negative effects on flock performance.
CHAPTER IV
THE EFFECT OF SPRINKLER COOLING ON WATER CONSERVATION, HOUSE ENVIRONMENT, AND BROILER PERFORMANCE

4.1 Abstract

Sustainability and water conservation are critical to a poultry industry faced with global production challenges that include an increased demand for high-quality, affordable animal protein and greater environmental pressures resulting from climate change, heat stress, and limits on water availability. 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 conservation, broiler performance, and in-house environments. Environmental and Production data were calculated and recorded throughout the flocks. The combination house exhibited a 3°F increase in average temperature, numerically lower average humidity, with a 64% (16,389 gals/flk) 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 difference at several time points between and across flocks. Findings are similar to previous reported research and offer additional confirmation that sprinklers in conjunction with cool cells maintain broiler performance and reduce cooling water usage, thus improving sustainability. Future research should investigate optimum flock age and house temperature to begin sprinkler and CC cooling.

Key Words: Water conservation, Sustainability, relative humidity, sprinkler, broiler cooling
4.2 Introduction

Commercial broiler chickens are raised in specially designed houses capable of maintaining an environment that allows for optimum production performance even during long periods of high environmental temperatures. Additionally, in recent years, consumers and the poultry industry have been in a quest of raising chickens in a more sustainable manner. Besides an emphasis in reducing environmental concerns associated with reducing carbon footprint in response to consumer demands, water conservation is now a major emphasis for the poultry industry.

Climate change and heat stress are challenges to sustainable poultry production. Evaporative cooling pad systems are found on most modern poultry houses and are used when mechanical ventilation (cooling fans) alone cannot provide adequate cooling in hot environments (Czarich et al., 2014). 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. This requires large volumes of water, and negatively affect the ability for broilers to dissipate heat 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 relative humidity level is also 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).

Sprinkler systems that target cooling demand of the growing broilers by partially wetting the birds periodically with intermittent applications of large coarse water droplets at water low
pressure, offer water conservation while maintaining production 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; Liang et al., 2020). Although the studies previously mentioned were conducted in broilers marketed at a lighter final body weight, 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 during a hot southern U.S. summer.

4.3 Materials and Methods

4.3.1 Housing

Research was conducted at Mississippi State Universities Poultry Research farm during two consecutive summer flocks (May-July and August-October 2020). Two commercial sized solid-wall broiler houses, measuring 42 x 400 ft (12.2 x 121.9 m) and equipped with three lines of pan type feeders and four lines of nipple-type drinkers were utilized. Each of the houses were equipped with both a commercial recirculating evaporative cool cell (CC) system and a commercial (Weeden Environments, Woodstock, Ontario, Canada) sprinkler system (SS). Both houses were ventilated with 10 BDR48 Acme Engineering and Manufacturing Corp slant wall fans.
4.3.2 Cool Cell system

The cool cell systems were comprised of 55’ of 5’ x 6”x 1’ cool cell on each side of the house. These pads were installed on dog houses and cool cell doors were utilized. The entire cool cell system was replaced in 2019 with an inground sump system utilizing one pump per side.

4.3.3 Sprinkler system

The sprinkler system consisted of two overhead sprinkler lines mounted to the ceiling, 10’ from each sidewall and positioned above the outside feed lines. The sprinklers were spaced evenly 20’ apart directly across from each other and suspended 7’ above the litter. The sprinkler system was divided into two zones, front and back of the house, with one temperature probe (at bird height) per zone, located in the center of each zone. Zone #1 was the West/brood end where the cool cells were located. Zone #2 was the East/off end where the tunnel fans were located. Each zone was comprised of 20 sprinkler spinning heads, for a total of 40 in each house. Low pressure water was delivered to the sprinkler heads by way of a ¾ in PVC supply line. The sprinkler system was operated by an independent Weeden Environments controller located in the control room of each house and separate from the main house controller (no communication between the two). The sprinkler controller intermittently applied controlled volumes of coarse water droplets directly to the surface of the birds in the form of three cooling levels. The controller monitored and controlled each zone independently with the use of the temperature probes and solenoid valves assigned to each zone. That being said, it is possible for the two zones to be in different cooling levels at the same time depending on the temperature differentiation from zone to zone. For this research the sprinkler system was run at higher setpoints than the previous trial, closer to the manufacturer recommendation (Table 4.1). In the
previous study the sprinklers run temperature was taken down to 70°F(21.1°C) but for the current study the sprinkler run temperature was stopped at 78°F, see SS Level 1 (Table 4.1).

Table 4.1  Set point temperatures in the sprinkler system/cool cell house

<table>
<thead>
<tr>
<th>Day</th>
<th>Set Temp</th>
<th>Tunnel Temp</th>
<th>SS Level 1</th>
<th>SS Level 2</th>
<th>SS Level 3</th>
<th>CC on-temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>***</td>
<td>***</td>
<td>+6°F</td>
<td>+10°F</td>
<td>+3°F</td>
<td>+3°F</td>
<td>+14°F</td>
</tr>
<tr>
<td>56</td>
<td>62°F (16.7°C)</td>
<td>68°F (20°C)</td>
<td>78°F (25.6°C)</td>
<td>81°F (27.2°C)</td>
<td>84°F (28.9°C)</td>
<td>90°F (32.2°C)</td>
</tr>
</tbody>
</table>

Each of the three cooling levels of the Weeden controller were designed to perform different jobs. The manufacturer had specific settings for each of the three levels and are as follows: Cooling level #1 is set to operate at 2°F (-1.7°C) above the temperature setting at which the house goes into tunnel ventilation and will operate for 10 seconds every 30 minutes during daylight cooling hours. The main purpose of cooling level one was to stimulate the birds and get them up on their feet more often in order to release captured heat trapped under their bodies. Very little if any cooling from wind chill is accomplished during level one cooling.

Cooling level #2 was set to operate at 5°F above the temperature setting at which the house goes into tunnel ventilation and would operate for 20 seconds every 15 minutes. This level also removed the trapped body heat when the birds stand but also utilized the wind chill from added fans to help evaporate the added sprinkler droplets from the head and feathers of the bird.

Cooling level #3 was set to operate at 8°F above the temperature setting at which the house went into tunnel ventilation and would operate for 20 seconds every 5-7 minutes, which was adjusted depending on ambient weather conditions (Table 4.2). This level utilized max wind speeds of 500+ ft/min and shorter idle times between sprinklings to achieve optimal wind chill cooling as
the water droplets fell off the surface of the birds. The idea of this level is to allow the sprinklers to operate, and the droplets evaporate just before they operate again to have this cooling as near continuous as possible.

Table 4.2  Weeden Environments suggested temperature and run time settings

<table>
<thead>
<tr>
<th>Level</th>
<th>Degree above tunnel</th>
<th>Run time (seconds)</th>
<th>Idle time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2°F (-16.7°C)</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>5°F(-15°C)</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>8°F(-13.3°C)</td>
<td>20</td>
<td>5-7</td>
</tr>
</tbody>
</table>

For these trials a Commercial SS was used in combination with a CC system (SSCC) and was evaluated against a CC only system. The combination house was set up to run 8 fans before allowing sprinkler level #1 to operate, level #2 was allowed with 9 fans, and level #3 was allowed with 10 fans running. With the way that the fans were staged in and allowed to operate, sprinkler cooling levels two and three were withheld until fans #9 and #10 were added respectively. Level #3’s idle time was adjusted depending on the rate at which the birds fully dried after water was applied. The cool cell systems set on temperature was delayed to 90°F and was set to shut off with a 1 degree drop in temp, most of the time the cool cells would typically not run over 19 seconds each time. The Cool Cell only house was set to run cool cells at 82°F (27.8°C) degrees and shut off with a 2°F (-16.7°C) drop in temp was achieved. The max allowable run time was 150 seconds out of 300 seconds. Treatments were switched from one house to the other during the second study to eliminate any house effect. For the first flock the combination house was allowed to run sprinklers from day 37 and cool cells from day 53 until harvest at 61 days. For the second flock both the sprinklers and cool cells in the combination house and the cool cells in the cool cell only house were allowed to operate from day 27 until
harvest at 60 days. During both Summer flock’s sprinkler system and cool cell cooling was restricted to operate during daytime hours only, 9:00 am to 9:00 pm.

4.3.4 Measurements

Environmental and performance data was monitored, calculated and recorded throughout, and at the end of each trial. In-house temperature and in-house humidity were recorded every 15 minutes through the flock by using an Intelia data collection system (Intelia Technologies Inc., Quebec, Canada). Drinking water consumption, and cooling water utilization of both the evaporative cool cell systems and sprinkler systems was calculated, recorded and compared throughout the flock. Water consumption and cooling water usage was monitored with 1 pulse = 1 gal electrical output water meters and recorded in the Chore-Time Chore-Tronics-3 controllers in each house. At harvest the records from the processor were obtained for feed conversion ratio (FCR), live market weight, mortality, and paw quality data.

Litter moisture data was obtained at weeks 5, 7, and 9. To determine the litter moisture there were multiple subsamples taken from the top 1-2 cm of the litter surface with a round tipped shovel. These subsamples were obtained from various locations in a diagonal pattern across the house (8 samples) and back across (8 samples), totaling 16 subsamples. These 16 subsamples were combined and mixed to produce one 946 ml composite sample (Figure 4.1)
This technique was used to produce one sample for each end of the house, cool cell and fan end, and repeated for the other house. These samples were then taken to the Mississippi State University Chemical Laboratory for moisture content analyzation.

4.3.5 Core body Temperatures

Thermochron iButton Temperature Data Loggers were used in attempts to obtain core body temperatures in the days leading up to catch. The houses were broken into four quadrants with the use of migration fences. Quadrant 1 was the cool cell end of the house and quadrant 4 was the fan end with 2 and 3 being those quadrants found in the middle of the house. 5 birds in each quadrant were caught, weighed, tagged, force fed data loggers, marked with different color animal marking paint, and returned to the proper quadrant. Both males and females were used in each of the four quadrants. In quadrant #1 3 males and 2 females were used, and 2 males and 3
females were used in quadrant #2. This was repeated in quadrants #3 and #4 respectively. The data loggers were placed three days prior to catch for the first flock and four days prior to catch for the second flock. On the day of catch the birds in each quadrant were located, caught, weighed, euthanized, and the data recorders were recovered. The location of the data recorders was noted upon collection. Prior to feeding these data recorders to the birds a practice session was held to simulate the placement of the data recorders. Slices of squash neck were cut to the proper thickness of the data loggers and a sharpened piece of PVC pipe was used to punch out disk similar in diameter to the data loggers. These squash disks were then fed by hand to the birds. The bird’s beak was opened, and the disk were placed in, and a finger was used to start the process. Once in, the disk were worked down by hand from the outside of the throat.

4.4 Statistical Analysis

Data were analyzed as a Randomized Complete Block Design using SAS 9.4 with significance indicated by $P \leq 0.10$. Due to the limited amount of replication a P value of $P \leq 0.10$ were utilized to determine significance. Although there were limited replications due to the use of whole house treatments the study was conducted twice and a crossover design was utilized to eliminate house effect. Core body temperature data were analyzed using One-Way ANOVA according to Randomized Complete Block Design with significance indicated by $P \leq 0.05$.

Results of this study are similar to those reported previously (Liang et al., 2014; Moon et al., 2020; Dunlop and McAuley, 2021).

4.5 Results

After analyzing these data there some significant differences were found. When looking at cooling days only, there was a 3° F significant ($P=0.08$) difference in average house
temperature shown in. The combination house temperature averaged 87.8°F (31°C) vs. 84.8°F (29.3°C) in the cool cell house see Figure 4.2.

Figure 4.2  Average in house temperature 2020 summer, two flock avg
There was also a 3.8% significant (P=0.054) difference in in house humidity. The combination house humidity averaged 73.6% vs. 77.4% in the cool cell house (Figure 4.3).

Figure 4.3  Average in house humidity 2020 summer, two flock avg
Grower earnings for the two treatments showed a .155 cent per pound significant (P=0.021) difference. The combination house grower pay averaged 7.74 cents/lb. vs. 7.56 cents/lb. in the cool cell house (Figure 4.4).

![Figure 4.4](image)

Figure 4.4  Average grower earnings 2020 summer, two flock avg

Although deemed not statistically significant there were substantial numerical cooling water usage differences seen between the combination cooling system and the cool cell only system for both flocks. On average there was a 64% reduction in cooling water usage for the combination system (8,946 gal) vs the cool cell only system (25,335 gal) (Figure 4.5). Over the course of the two summer flocks the Combination house saved 32,779 gallons of cooling water when compared to the cool cell only house. For the first flock the combination house used 13,279 gallons cooling water vs. 38,956 gallons in the cool cell only house. For the second flock
the combination house used 4,612 gallons cooling water vs. 11,714 gallons in the cool cell only house, see (Figure 4.6) for a further breakdown by type of cooling by house for each flock.

Figure 4.5 Average grower earnings 2020 summer, two flock avg
Although there were no significant litter moisture differences found, there were numerical differences noted. The combination house mean litter moisture % tended to be slightly less for most points with both flocks in all three weeks of sampling (Table 4.3). The largest moisture differences were seen for week seven. Week five shows similar differences between treatments which is assumed to be due to this being close to the start of secondary cooling. The litter moisture values at week nine again are similar between treatments and it is assumed that this is due to the increase in broiler body size which limits the air movement to the floor, hindering evaporation of moisture from the litter.
## Table 4.3  Effect of cooling system on litter moisture (weeks 5, 7 and 9)

<table>
<thead>
<tr>
<th>Cooling system</th>
<th>Weeks</th>
<th>Location - cool cell end % litter moisture</th>
<th>Location – fan end % litter moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCC</td>
<td>5</td>
<td>20.05</td>
<td>19.7</td>
</tr>
<tr>
<td>CC</td>
<td>5</td>
<td>20.05</td>
<td>20.65</td>
</tr>
<tr>
<td>SCC</td>
<td>7</td>
<td>20.95</td>
<td>24.15</td>
</tr>
<tr>
<td>CC</td>
<td>7</td>
<td>27.85</td>
<td>31.9</td>
</tr>
<tr>
<td>SCC</td>
<td>9</td>
<td>26.9</td>
<td>29.95</td>
</tr>
<tr>
<td>CC</td>
<td>9</td>
<td>28.95</td>
<td>29.4</td>
</tr>
</tbody>
</table>

SSCC = sprinkler/cool cell combination  
CC = cool cell only

Although there were issues with compromised iButton Temperature Data Loggers with reporting useable core temperatures, statistical analysis was still completed on those data that was obtained. Regardless of sex, quadrant, and house there was significant (P=0.0004) difference in core body temperature Table 4.4.

## Table 4.4  Mean body temp, regardless of sex, quadrant, and house

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Average body temp (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination</td>
<td>107.16°F (41.8°C)</td>
</tr>
<tr>
<td>Cool Cell</td>
<td>107.04°F (41.7°C)</td>
</tr>
</tbody>
</table>

P-value 0.0004

Overall, the flocks preformed fairly well. The first flock May-July, the combination house outperformed the cool cell house. The combination house average live weight was 9.37lb (4.25 kg), 1.901 FCR, 7.90 cents/pound (3.56 cents/kg), and its cost was 1.05 better than the average weekly cost VS. the cool cell house. The cool cell house performance was a live weight of 9.27lb, (4.25 kg) 1.954 FCR, 7.75 cents/pound (3.52 cents/kg), and its cost was 0.60 better
than the average weekly cost. Both houses finished #1 and #2 respectively for the week out of seven total growers contracted with the company (Table 4.5).

Table 4.5 May-July flock summer 2020 settlement results

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Live Weight</th>
<th>FCR</th>
<th>Pay Cents/lb (Cents /kg)</th>
<th>Points from average</th>
<th>Ranking out of 7 farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination</td>
<td>9.37 lb (4.25 kg)</td>
<td>1.901</td>
<td>7.90 (3.56)</td>
<td>+1.05</td>
<td>#1</td>
</tr>
<tr>
<td>Cool cell</td>
<td>9.27 lb (4.25 kg)</td>
<td>1.954</td>
<td>7.75 (3.52)</td>
<td>+0.60</td>
<td>#2</td>
</tr>
</tbody>
</table>

In the second flock (August-October), the combination house outperformed the cool cell house. The combination house average live weight was 10.23 lb (4.64 kg), 1.826 FCR, 7.53 cents/pound (3.39 cents /kg), and its cost was .43 better than the average weekly cost VS. the cool cell house being 10.24 lb (4.64 kg), 1.846 FCR, 7.37 cents/pound (3.3 cents /kg), and its cost of 0.27 being better than the average weekly cost. The houses finished #2 and #4 respectively for the week out of seven total growers Table 4.6.

Table 4.6 August-October flock summer 2020 settlement results

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Live Weight</th>
<th>FCR</th>
<th>Pay Cents/lb (Cents /kg)</th>
<th>Points from average</th>
<th>Ranking out of 7 farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination</td>
<td>10.23 lb (4.64 kg)</td>
<td>1.826</td>
<td>7.53 (3.39)</td>
<td>+.43</td>
<td>#2</td>
</tr>
<tr>
<td>Cool cell</td>
<td>10.24 lb (4.64 kg)</td>
<td>1.846</td>
<td>7.37 (3.3)</td>
<td>+.27</td>
<td>#4</td>
</tr>
</tbody>
</table>

Although not deemed significant and there were no data run thermal imaging shows a before and after visual representation of the cooling effect sprinklers create on the surface of the bird (Figure 4.7)
Figure 4.7   Thermal image of birds immediately A) prior to and B) after sprinkling
4.6 Discussion

To successfully manage a sprinkler cooling system, one should first understand what is going on with the environment inside the chicken house and what is actually being cooled. When utilizing a sprinkler system in combination with an evaporative cool cell system one needs to adjust the point at which the cool cell operates. As the setpoint at which the cool cells come on is raised, (i.e. 82°F (27.8°C) to 90°F(32.2°C)) average house temperature will be substantially hotter. This explains the significantly higher house temperatures observed in the combination house over the cool cell house. This increase in house temperature also explains why we see a significant decrease in the humidity level in the combination house over the cool cell house, and further explains how we could see numerically lower litter moisture readings at some points over time. As the temperature rises the air becomes drier because cool cells are not being used as frequently. This warmer, drier environment does two things: 1, it creates a situation where the bird can cool itself more efficiently through respiratory evaporation. 2, it creates a situation where the large water droplets from the sprinkler system can be removed from the surface of the bird through evaporation more efficiently. All this together allows us to more easily cool the bird over the environment, which in turn allows the combination house to rely less on the inefficient cool cell system. This reduction in cool cell usage will produce the cooling water reductions we see allowing large amounts of water to be conserved. Also, when birds were stimulated and brought to their feet it was noted that many birds would migrate to feed and water before sitting back down. Even though broilers were grown in a hotter environment and a significant increase in average body temp in the combination house of .12 °F (-17.7°C) was observed over the cool cell only house, a significant increase in grower pay was observed which insinuated performance was maintained at a higher level.
4.7 **Overall Conclusions**

This data illustrates that broilers can be reared at much higher in-house temperatures than previously thought. When properly managed, a commercial sprinkler system used in conjunction with an evaporative cool cell system can be successful in numerous areas. The in-house temperature will run warmer because the cool cells have been pushed to a higher temperature setpoint. As the temperature in the house increases and the cool cells run less, the air becomes less humid. This decline of the inhouse humidity makes it easier for birds to cool themselves naturally through respiratory evaporation, and it also creates the ideal environment to evaporate sprinkler water droplets off the surface of the bird, thus in turn cooling them in the process.

When using sprinkler cooling in conjunction with a cool cell system we can effectively cool broilers, maintain efficient production gains, and save considerable amounts of cooling water over a cool cell only system. The water conserving ability of sprinkler cooling improves sustainability which is very important to the poultry industry today. Adoption of sprinkler cooling technology has been somewhat limited, due to the fact that it goes against what has been preached for years, which is to never introduce water inside the broiler house. Water scarcity and the importance of sustainability has companies focusing on water conservation and they are assembling teams to focus on such topics. Sprinkler technology when used to cool broilers can save tons of cooling water making it more sustainable. As companies become more interested in saving water on the farm level sprinklers may become more common. When this happens, it may be necessary for state extension agencies to work with integrators to help train then average grower on how to implement sprinkler systems in conjunction with evaporative cool cells.
REFERENCES


Cahaner, A., & Leenstra, F. (1992). Effects of high temperature on growth and efficiency of male and female broilers from lines selected for high weight gain, favorable feed conversion, and high or low fat content. *Poultry science, 71*(8), 1237-1250.


Campbell, J., Donald, J., Simpson, G., & Macklin, K. 2009. AVOIDING HOT WEATHER PROBLEMS. Newsletter of the National Poultry Technology Center, Auburn University. Issue No 60.


Fairchild, B. D. (2005). Basic introduction to broiler housing environmental control. University of Georgia's College of Agricultural and Environmental Sciences, Cooperative Extension service, Georgia, USA.


