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Water Consumption Behavior in Broilers

A thesis submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in Poultry Science

by

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California State Polytechnic University
Bachelor of Science in Animal Science, 1992

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This dissertation is approved for recommendation to the Graduate Council.

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Abstract

A series of trials were conducted to analyze broiler water consumption behaviors under commercial conditions. The first trial was to quantify the number of broilers drinking at times of peak water demand. Birds were evaluated at time intervals of 5, 10, 15, 30, 45, and 60 minutes from the start of the light period to establish the percentage birds having consumed water by that point in time. Significant differences were found by bird age in the 5, 10, and 15 minute intervals, however there were no significant differences in the percentage of birds having consumed water in the 30, 45, and 60 minute intervals.

A second trial was conducted to evaluate the percentage of birds drinking while on pre-slaughter feed withdrawal. Birds were evaluated at four, hourly intervals after feed had been withdrawn. It was found that there was no significant difference between the percentage of birds drinking during each hour of feed withdrawal when compared to birds that had not had feed withdrawn. Additionally, water utilization rates of liters/100 birds in the first, second, and third hour of feed withdrawal were established.

A third trial evaluated the daily water to feed intake ratios on a commercial broiler farm and investigated the changes in this ratio by season. It was demonstrated that water to feed intake ratios become smaller as the birds age, ranging from 1.931:1 at 11 days of age to 1.715:1 at 46 days of age. Also, it was found that significant differences exist in daily water to feed ratios by season.

A fourth and final trial was conducted to evaluate the relationship between changes in lighting and changes in water intake. Daily records of lighting changes and water consumption were collected from six farms in two different integrator complexes.   These records were

analyzed and no statistically significant effect (P>0.0554) of changing lighting intensity or duration on daily water consumption by broilers.

Acknowledgments

First and foremost, my thanks to God for leading me to this place and time. This all would not have been possible without the support of my wife, Jenny and my children, Casey and Callie. Truth be told, this was all Callie's idea. I would like to thank Dr. Susan Watkins who has been my boss, mentor, advisor, and friend. Thank you also to each member of my committee: Dr. Craig Coon, Dr. Karen Christensen, Dr. John Halley and Dr. Andrew Sharpley.

I would like to thank all the students who worked with me on the farm. I have been fortunate to be surrounded by a lot of great people and my work would not have been possible without them. Of these students, I would especially like to thank Dr. Chance Williams.

Finally, I would like to thank Rusty Sikes, who taught and continues to teach me most of what I know about broiler production.

Dedication

To Tom, from Huck with greatest appreciation.

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Introduction

Water has long been recognized as the most critical nutrient in livestock production. While animals might survive for long periods of time without food, without water they would soon die. Water makes about 70% of a chicken's total weight and is the highest single constituent of the body. It is the major component of the cell as well as the extra cellular environment and contributes to the regulation of cellular homeostasis. Water plays a vital role in multiple metabolic and physiological processes that occur throughout the body. Water aids in the transportation of nutrients; glucose, amino acids, vitamins and minerals. It conducts gases, in particular oxygen and carbon dioxide. Water carries waste products to the liver and kidneys for elimination. It is responsible for maintaining mineral homeostasis. Water aids in the transportation of hormones from their source to the target organ. It is responsible for the adjustment of body temperature. Finally, it aids in the excretion of end products of digestion (particularly urea), anti-nutritional factors ingested with the diet, drugs and drug residues.

The animal obtains water from three sources; drinking water, water in feed and metabolic water. Drinking water typically comes from a well, surface water or some type of community supply. Due to the variations in water sources, there can be variations in water content and quality. Additionally, mineral content of the water should also be considered. With the exceptions of oil and synthetic vitamins, all feeds contain some water. A meal type feed ingredient is typically as low as 12 % moisture where grasses and fruits might be as high as 75%. About 70% of metabolic water is located in the cells, with the remaining 30% making up the extracellular space and the blood. The water content of the body is related to its protein content.

As an animal ages, it’s body fat percentage increases and protein content decreases. As this occurs, the body water content, as a percentage of body weight, decreases.

Water loss occurs in four ways. Water is expired during respiration. Water is lost from the skin through perspirations and insensible water loss. Additional water loss occurs through feces and urine.

Water Intake

Patrick and Ferrise (1962) concluded that the water requirement of broilers up to 9 weeks of age were approximately 1.5 kilograms of water per kilograms of feed consumed. More recently, it has been shown that normal water consumption for chickens ranges from 1.6 to 2.0 times that of feed intake (Fairchild and Ritz, 2009). Drinking behavior is closely associated with feed intake, such that factors affecting feed consumption will indirectly influence water intake. Water intake can also be influenced by several other factors, such as age, sex, and environment. Due to this, daily water consumption makes an excellent litmus test for the overall health and condition of a flock (Dozier *et al.*, 2002, Manning *et al.*, 2007). Decreases in water consumption can be an indication of health problems (Butcher *et al.*, 1999) or environmental issues. Inadequate consumption of water will result in decreased growth rates. Increased consumption is associated with higher feed conversions.

Differences in strain and breed can influence water intake. This is most likely due to differences in metabolism, growth rates, body weight and body fat content. Marks (1980) showed that water and feed intake levels were higher in strains that were selected for rapid growth compared to the intake levels of a non-selected line.

Age is another factor influencing water intake in chickens. Adult animals maintain a constant water balance through the control of liquid intake and output. A positive water balance is found in growing animals to facilitate growth. As young animals grow, water intake increases but, as a percentage of body weight, water intake decreases. Pesti *et al.*, (1985) demonstrated that broiler water consumption was a linear function of age and could be predicted as 5.28 grams x age (days). In a more recent study, Williams *et al.*, (2013) analyzed water consumption in birds grown in 1991, 2000-2001, and 2010-2011. It was demonstrated that, over the course of time, daily water consumption has increased. Each flock of birds grown in 2010-2011 averaged 190.48 liters of water consumed per 1000 head. This was significantly different ($P<0.048$) than average daily water consumption of birds grown in 2000-2001 which averaged 160.54 liters/1000 head. The water intake of the birds grown in 2000-2001 was found to be significantly different ($P<0.042$) than water consumption rates of birds grown in 1991 which averaged 140.33 liters/1000 head. Williams found the 2010-2011 flocks had a greater water to feed ratio than the 2000-2001 and 1991 flocks (2.02 vs. 1.98 and 1.90 respectively).

The sex of the bird plays a role in levels of water and feed consumption. Most of these differences are a result of differences in body weight. Marks (1985) showed that the divergence of the difference in weights between males and females began immediately post hatch but were not significantly different until four days of age. These weight differences were shown to result in differing levels of water consumption.

Stage and type of production as well as growth rate influence water intake levels. Differences in water consumption can be seen on different days in the sexually mature female.

Daily intake is higher on days when there is an egg in the oviduct. This is related to the circulating estrogen levels associated with the egg laying process (Savoy, 1978).

Possibly, the factor with the greatest ability to affect water consumption in birds is ambient temperature. Water consumption increases when the ambient temperature exceeds 21^{o}C (Benton and Warren, 1933; and Wilson, 1948). Wilson also showed that water consumption at 35^{o}C was double that at 21^{o}C. Donkoh (1989) raised broilers under four constant ambient temperatures: 20^{o}, 25^{o}, 30^{o}, and 35^{o}C. Birds raised at 30^{o} and 35^{o}C showed a significant increase in water consumption. Lott (1991) demonstrated that heat energy produced from digestion contributed to the increase of water consumption in broilers during heat stress. Birds that did not eat in the hour prior to heat stress, consumed less water. May *et al.*, (2000) showed that broilers exposed to high air velocity during times of potential heat stress consumed less water and more feed, gained more weight and had an improved feed: gain ratio.

Feed content and intake both affect the rate of water consumption. Glista and Scott (1949) noted that as the level of soybean oil meal in the diet increased, water consumption rose. Allemand and Leclerq (1997) found that chickens fed a low protein diet versus a control diet in varying temperatures consistently consumed less water than the birds fed the higher protein control diet. The increase in water consumption relative to higher dietary protein levels could arise from the reduction of metabolic water produced due to the higher protein content. Also, the increased demand for nitrogen excretion due to the higher protein content could cause the higher demand for water for uric acid removal.

The mineral content of both feed and water can influence the amount of water consumed by chickens. High sodium and chloride levels in the feed can cause an increase in subsequent water intake. When found in the water, sodium and chloride are in a useful form for the chick. Without adjusting the level of sodium and chloride in the diet, problems with loose droppings, wet litter and increased feed conversions can occur. High levels of nutritional salt have been shown to increase water consumption with varying influences on feed consumption (Darden and Markes, 1985). Watkins *et al* (2005) investigated the relationship between sodium and chloride levels in drinking water and feed supplied to broilers. They found that water sources of sodium and chloride could be used to supply part or all of the chicks needs for these minerals. This indicates that feed levels of sodium and chloride must be decreased when these minerals are present in the drinking water.

Stocking density also plays a role on water utilization in broilers. Feddes *et al.*, (2002) raised birds at four different stocking densities. It was demonstrated that, as stocking density increases, water intake per bird increases.

The lighting program can also affect bird water consumption. In operations using lighting programs, two definitive peaks in water consumption can be observed. The initial peak can be seen just after the lights come on (dawn), and the second peak just prior to the darkening of the lights (dusk). Water consumption will peak about an hour prior to darkness, indicating that the birds actually anticipate the coming dark period.

Due to the high importance of water in the physiology of broilers and layers, multiple types of water drinkers have been developed to maximize water utilization. Bruno *et al* (2011) explored the water volume intake and behavior of birds when given choice between nipple and bell drinkers with separate groups raised at different environmental temperatures (25 and 34^{o}C). Birds were found to visit the bell drinkers less often while consuming a higher total water intake per visit. However, in commercial conditions, bell drinkers are typically associated with greater water wastage and damp litter with ensuing footpad burns and leg problems.

Water temperature may also affect consumption and bird performance, particularly during times of heat stress. Several studies have investigated the effects of water temperature during heat stress and in most cases found that when cool water is provided, performance was enhanced for broilers and layers. Water temperature below the body temperature of the bird is beneficial for the dissipation body heat and has an effect on the bird's desire to consume water (Fairchild & Ritz, 2009). The temperature of the water can also affect other parameters. It can influence the solubility of gases, amplify tastes and odors and change the speed of chemical reactions (Patience, 1988).

Water Utilization

In addition to the bird's consumption for physiological purposes, water is used within the poultry house for cooling purposes. This can be through the use of cool cells, sprinklers or fogger systems. Czarick and Fairchild (2009) illustrated the use of water for cooling purposes over the course of two years. They concluded that evaporative cooling accounted for a 20% increase in the amount of water used. This is significant in that it could result in less water being available for bird consumption. More recent research suggests that air speed alone may be more beneficial to bird welfare and production. This would make the 20% available for bird intake.

Water Quality

The quality of water supplied to chickens has a direct bearing on their overall performance. Extremes in pH, bacteria level, nitrogen levels, and excessively high naturally occurring elements adversely affect water quality. As the universal solvent, water can contain many compounds and minerals. Pure water is not necessary for poultry drinking water, but heavily contaminated water can be detrimental to poultry digestion and performance as well as create equipment problems. These equipment troubles can lead to restricted water flow and availability for consumption as well as for evaporative, misting and fogger cooling systems. The consequences of highly contaminated water can have repercussions on both growth and reproduction (Vodela *et al.*, 1997; and Fairchild & Ruiz, 2009).

The pH of water can influence the overall quality in two ways. First, it has a noticeable effect on the efficacy of disinfectants such as chlorine. If pH is above 8.0, the chlorine is present as chloric ions which add very little sanitizing quality. Chlorine is most effect in water with a pH of 6.0 to 7.0. This pH level creates a greater percentage of hypochlorous ions that have strong sanitizing qualities. Secondly, pH below 6.5 may precipitate some antibacterial water treatments (Patience, 1988). Waggoner *et al.* (1984) found detriments to poultry performance when the water supply had a pH of 6.0 to 6.3. At pH levels of less than 6.0, there were definite adverse effects on broiler performance and egg quality in breeders. Water with a pH level above 6.4 showed no adverse effects.

Another factor to consider when determining water quality is the oxidation-reduction potential (ORP) value of the water. Oxidation-reduction potential is a measure of the cleanliness of the water and its ability to break down organic contaminants. It can be viewed as a measure of bacterial activity in the water. ORP sensors measure the dissolved oxygen in the water. Lower dissolved oxygen levels are the result of the consumption of oxygen by the organic contaminants. Strong oxidizers, like chlorine, degrade any bacteria, virus or other organic material in the water, leaving the water safe. An ORP value in the range of 650 mV or greater is indicative of good quality water. However, lower values indicate heavy organic load that will most likely overwhelm the chlorine's ability to properly disinfect.

As was stated previously, water is the universal solvent. As such, it has the ability to easily pick up and suspend impurities. Water always contains some impurities and no supply of water exists in nature that is chemically pure. Total dissolved solids (TDS) comprise the inorganic salts and some small amounts of organic matter that are dissolved in water. The inorganic salts are primarily calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates. Some dissolved solids come from organic sources such as leaves, silt, plankton or sewage. Runoff from urban areas, road salts used in the winter, fertilizers and pesticides can all contribute to TDS. Naturally occurring inorganic sources include sodium bicarbonate, sulfur and iron phosphorus. Copper and lead may be picked up as water travels through pipes. High levels of TDS are the most common contaminants found in poultry drinking water and can have adverse effects on chick performance and production. The most harmful effects of high TDS levels in drinking water include loose stools, increased feed conversions, decreased weights and possibly higher mortality.

Water hardness is a measure of the amount of dissolved minerals, specifically calcium and magnesium found in ground water. This occurs as water travels through rocks, limestone deposits and soil. The farther water travels, the greater opportunity it has for minerals to become suspended. This accounts for the differences in water hardness in various areas. Mineral content of water alters the effectiveness of soaps and disinfectants while also interfering with some medication administrations (Fairchild & Ruiz, 2009). The considered maximum acceptable level for hardness is 110 ppm but the individual maximum levels of calcium and magnesium salts in poultry drinking water are 500 ppm and 125 ppm, respectively. Waggoner (1984) found that magnesium present at 50 ppm is detrimental to production if sulfate is also present.

Brackish or briny water is water that has more salinity than fresh water, but not as much as seawater. This salt content ranges from 0.5 to 30gL^{-1} water (approximately 500-30,000 ppm). It may result from mixing seawater with fresh water, as in estuaries, or may occur in brackish fossil aquifers. Ilian and colleagues (1981) demonstrated that broilers and replacement pullets could be raised on brackish water of 3,000 ppm without adverse effects on weight gain, feed consumption, water intake, and water to feed intake ratios. Additionally, there were no abnormalities in the internal organs of the birds found when the birds were processed. Examination of the livers for fat accumulation and of the blood for concentrations of major cations and anions did not reveal any significant differences to birds raised on soft water. It has been suggested by the National Research Council (1974) that water with 1,000 to 3,000 ppm range may cause loose droppings but should not affect health or performance.

Another problem influencing water quality is the buildup of nitrates and nitrites. Nitrates are produced during the final stages of decomposition of organic matter. Consequently, nitrates in the water are an indication of runoff from animal or human wastes, nitrogen fertilizer, crop residues and industrial wastes. Because nitrates are soluble, they may travel considerable distances in the soil. Nitrites are produced during the intermediate stages of the decomposition of organic compounds. Since nitrites are ten times more toxic than nitrates and bacteria in the gut can convert nitrates to nitrites, both must be minimized in the water supply. Grizzle and colleagues (1997) demonstrated coliform bacteria in the presence of nitrate nitrogen in the drinking water caused reduced weights at 4 and 6 weeks of age. Additionally, it was shown that the presence of the bacteria and nitrates did not affect water or feed consumption at the tested levels. Reduced weights were not shown in birds supplied with water that contained nitrates or bacteria, but not both. The same group ran a similar test (1997) in broiler breeders. Hens received water containing nitrate nitrogen, *Escherichia coli*, or both. Hen day egg production was not affected by treatment with either nitrate or bacteria alone. The combination of nitrates and bacteria were shown to significantly decrease egg production. Waggoner (1984) found that nitrate levels above 20 ppm were detrimental to production. He suspected that levels at low as 3 ppm may cause adverse effects.

Iron (Fe) has not been shown to influence broiler performance up to 660 ppm (Fairchild et al., 2005) even though the recommended maximum level is only 0.03 ppm. Iron contaminants pose a greater problem with water equipment and bacterial growth. Iron in the water can form particulates such as iron oxide, which can lead to leaky nipples and blocked fogging nozzles or sprinklers. Although Fe levels do not directly affect poultry health and performance, the subsequent problems with water equipment may prove detrimental to broiler performance. Additionally, several species of bacteria require iron for cellular functions. If high Fe levels are present in the drinking water, these types of bacteria are more likely to thrive, which can result in a biofilm buildup. Iron can be successfully removed with a sand filter and/or chlorination (Waggoner, 1984)

A biofilm is a tiny, diverse community of living organisms bound in a matrix. These were first described by Anton van Leeuwenhoek in the 17th century while studying his own dental plaque. These colonies form when single microorganisms attach to a hydrated surface forming an adhesive matrix. Costerton *et al.,* (1979) suggested, in most natural environments, growth as a biofilm is the prevailing microbial lifestyle. Some sources state that the cells irreversibly attach meaning that they cannot be removed by gentle rinsing. In the case of poultry watering systems, this would indicate that routine flushing is not enough to remove biofilms. Poor water line sanitation can lead to biofilm slime and cause health problems flock after flock.

Marin *et al.,* (2009) investigated the risk factors associated with the contamination of *Salmonella* with broiler and layer houses. Additionally, they addressed the biofilm development capacity of the strains of *Salmonella* that could be isolated. The found *Salmonella enteritidis* to be the most common serotype to be isolated from each risk factor and, irrespective of the origin of different serotypes, around 50% were able to form biofilms. These biofilms were tested for resistance to common water disinfectants. It was found that the biofilms produced were resistant to glutaraldehyde, formaldehyde, and peroxygen use at concentration of 1.0%. The resistance was irrespective of serotype, the biofilm development capacity, and the disinfectant contact time.

In a study of the effect of water quality on the broiler performance criteria of body weight, feed conversion, livability and condemnation, Barton (1994) showed that nitrates in the water resulted in a detrimental effect on overall performance. Calcium was shown to decrease feed conversions while magnesium had a negative effect on feed conversion. Dissolved oxygen, bicarbonate, hardness, calcium and magnesium were all positively correlated with adjusted weight while nitrate had a negative correlation with adjusted weight. Calcium and potassium were negatively correlated with livability but calcium and nitrate were positively correlated with condemnation.

A similar study was conducted by Zimmerman (1995). He used the tests developed by Barton to compare water quality to broiler production in Washington State. He found that water having high concentrations of sulfate and copper was associated with poor feed conversion. Additionally, he found that water having high levels of potassium, chloride, and calcium reduced mortality. No water inclusions in this study were found that were significantly related to body weight or condemnation.

When comparing the results of these two studies, one from Arkansas and the other from Washington State, it is interesting to find that they have little in common. In Arkansas, high levels of potassium and calcium in the water were shown by Barton to be correlated with increased mortality. The same elements in the Zimmerman study were correlated with decreased mortality. There are differences in the water quality parameters between the two states. Arkansas water was found to be harder. Washington water is less acidic and contains more phosphate and potassium. This suggests that the relationship between water quality parameters can cause great and varying effects in production. This leads one to wonder if the perfect water for poultry production could be identified and produced similar to Ideal Amino Acid standards developed for swine and poultry.

Perhaps the greatest challenge to poultry production via the drinking water supply is bacterial contamination. The Environmental Protection Agency allows 5,000 coliforms per 100 ml. of potable water. Waggoner (1984) states that any level of bacterial contamination in poultry drinking water is unacceptable. This contamination can usually be solved through chlorination of the water of the water at 1 ppm chlorine. He goes on to state that water quality should never be ruled out as a production challenge. His research included finding pseudomonas in public water supply as well as unacceptable levels of sodium and chloride.

Water quality can be affected by both the source and method of supply. Water supplied from surface storage such as ponds will have higher levels of organic matter in the water. This is especially true of bacteria levels. The manner in which water is supplied to the birds can influence contaminant levels and the effectiveness of chlorination. Poppe *et al.,* (1985) demonstrated that chlorination of water was effective at maintaining lower levels of bacteria in the drinking water throughout the grow out period. However, they also showed that salmonellae could not be kept out of the bird through chlorination of the water due to the contaminated environment of the chicken house. As part of the same experiment, they were able to demonstrate that nipple type drinker systems were more effective at maintaining water quality than trough and swish cup drinkers. This was thought to be a function of the closed nature of the nipple drinker system where the water is not exposed to the organic matter contained in the chicken house.

Lighting

As was mentioned earlier, lighting has an effect on water intake of poultry. Light plays a critical part in the control and function of the bird’s physiological and behavioral activities. Manser (1996) demonstrated that light is integral to sight, both in visual acuity and color determination. Light plays a role in synchronizing many essential functions including body temperature and the various metabolic steps that control feeding and digestion. Light influences the secretion of several hormones which contribute to growth, maturation, and reproduction.

There are three aspects of lighting which are important to consider in poultry production; intensity, duration and wavelength. Light intensity or luminous flux is the measure of the perceived power of light by the human eye. It differs from radiant flux, which includes infrared and ultraviolet light. The International System of Units (SI) measurement for light intensity is lux (lx). One lux is equal to one lumen per square meter of space. Therefore, for a given amount of light, as area for that light increases, the intensity decreases. Duration refers to the ratio between the dark and light periods in which the birds may be grown. This can range from continuous lighting 24 hours per day to a ratio of light and dark. Additionally, intermittent lighting may be used. In this case, there are two or more dark periods per day. Wavelength, also known as spectral density, refers to the spectrum of visible colors within the light.

Light intensity has a strong effect on broilers. Generally, broilers will be more active in brighter conditions. Lights can be dimmed to decrease activity, decrease feed conversion and limit aggressive behaviors. Buyse *et al*, (1996) demonstrated decreased incidences of fighting, feather pecking and cannibalism as well as decreased walking and standing of birds raised at lower light intensities. It has also been shown that birds raised at higher light intensities will have decreased body weights and increased feed conversions compared to birds raised at lower light intensities of less than 5 lux. However, the birds raised at lighting levels in excess of 5 lux have been shown to have a decreased incidence of skeletal disorders. Berk (1995) showed that chicks under 28 days of age generally prefer brighter light. Prayitno *et al*, (1997) concluded that broilers prefer blue or green light over red or white light.

Light duration, or photoperiod may also alter broiler performance. Much of the research in broiler lighting has investigated different lighting regimes. Most of these different regimes have been shown to improve broiler welfare as compared to near continuous lighting (Gordon, 1994). In the example lighting program (Figure 1), it can be seen that the length of the rest or dark period is related to age. As birds age, the rest period can be decreased.

The rest period or hours of dark has been shown to be as important to the broiler as the hours of light. Buckland et al (1976) grew broilers under four different lighting regimes. These lighting regimes were: 1.) continuous light (5 to 10 lux), 2.) intermittent lighting consisting of 1 hour of light (5-10 lux) and three hours of dark, 3.) as in regime 2 but the 3 hours of darkness was interrupted with 13 hours of light at the same intensity, and 4) as in regime three but the 13 hours of light was at an intensity of less than 1 lux. They found that regimes 1 and 2 were significantly heavier than regimes 3 and 4. Lighting regime had no significant effect on feed conversion, percent crooked toes or mortality. The birds that were grown in regime 1., continuous light, had significantly more leg abnormalities than birds grown in any of the intermittent regimes. Classen *et al*., (2004) found that longer periods of darkness prevent regular access to feed. This results in lower feed intake and lighter weights at early ages. They also demonstrated that from days 14 to 35, average daily gain as well as the final weight were not affected by lighting programs. In this study, feed conversions were found to be higher on a schedule of 12 hours of light and 12 hours of dark or two 6 hour light and 6 hour dark periods than they were on birds raised with 12 (1 hour light, 1 hour dark) periods.

In the Buckland study mentioned previously, it was shown that raising birds in continuous lighting resulted in a higher rate of leg abnormalities. Other studies have found similar results. One method of quantifying leg abnormalities is through gait scoring (Santora *et al.*, 2002). In general, using a lighting regime that includes light and dark periods results in

Age in Days	**Hours of Dark**
0	0
1	1
100-160 grams	9
22	8
23	7
24	6
Five days before kill	5
Four days before kill	4
Three days before kill	3
Two days before kill	2
One day before kill	1

Figure 1. Cobb Vantress Standard Lighting Program, slaughter weight: 2.5-3.0 kg

lower mortality and improved gait scores, indicating improved animal welfare. Birds provided with sufficient dark periods have been shown to have fewer health problems than those maintained in continuous light (Appledoorn *et al*,. 1999: Moore and Slopes, 2000). This included sudden death syndrome, spiking mortality and leg problems. Improvements in livability, body weight, feed conversion and condemnation were also shown (Classen *et al*., 1991). Reduced stress levels have been reported in birds provided with dark periods (Buckland et al., 1974: Zulkifli et al., 1998: Puvadolpirod and Thaxton, 2000).

Color of light can also contribute to the performance of broilers. Birds sense light through the retinal receptors in their eyes as well as through the extra retinal photoreceptor cells in the brain. Blue light has been found to have a calming effect on birds. Red light has been shown to enhance feather pecking and cannibalism. Blue-green light stimulates growth in chickens and orange-red light stimulates reproduction (Rozenboim *et al.*, 1999, 2004). Lewis and Moore (2000) showed that lights of different wavelength have different effects on the retina and can affect growth and development.

It was mentioned in the introduction that water is recognized as the most critical nutrient. Water can also be the forgotten or taken for granted nutrient. The thought that water is water and some is enough has been prevalent. The discussions above demonstrate the water quality, amount, temperature are all important in broiler production. The following experiments were conducted to investigate the relationship between broilers and water with goals of improved welfare, production and food safety.

Analysis of Water Consumption During Periods of Peak Demand in Broilers

Abstract

A trial was conducted to quantify the number of broilers drinking at times of peak water demand. To establish this, 80,000 Cobb 500 x Cobb 500 chicks were obtained on day of hatch and placed into two commercial broiler houses. At three days of age, 528 straight run chicks were randomly selected and 22 were placed in each of 24, 1.49 square meter mini-pens (14.77 birds/m^2), twelve pens in each house. The birds were fed commercial diets throughout the trial. Birds were on full light for the first 7 days. From day 8 until the end of the trial, the birds were on a lighting program of 18 hours of light and 6 hours of dark per day. On days 12, 19, 26, 33, and 40, dye was injected into the water line prior to the onset of the light period. Each pen was randomly assigned a time interval of 5, 10, 15, 30, 45, and 60 minutes after the advent of the light period. At the assigned time, four pens of birds were evaluated for percentage of birds consuming water. This was repeated for each time interval. It was found that the percentage of birds drinking continues to increase for the first hour reaching a mean of 68.55% after 60 minutes. The percentage of birds drinking within the first hour were: 5 minutes, 23.62% of birds had consumed water, 10 minutes - 36.40%, 15 minutes - 45.77%, 30 minutes - 53.96%, and 45 minutes - 62.43%. Significant differences were found with each check time category ($P<.0001$). The 5 minute group was significantly different than the 15, 30, 45, and 60 minutes groups. The 10 minute group was found to be significantly different than the 30 and 60 minute groups. There were significant differences between the 15 and 60 minute groups. Significant differences were found by age in the 5 ($P<0.0036$), 10 ($P<0.0116$), and 15 ($P<0.0017$) minute intervals, however

there were no significant differences by age in the percentage of birds having consumed water in the 30, 45, and 60 minute intervals.

Introduction

Many factors can influence water utilization in broilers. Patrick and Ferrise (1962) concluded that the water requirements of broilers up to 9 weeks of age were approximately 1.5 pounds of water per pound of feed consumed. More recently, it has been shown that normal water consumption for chickens ranges from 1.6 to 2.0 times that of feed intake (Fairchild and Ritz, 2009). Drinking behavior is closely associated with feed intake, such that factors affecting feed consumption will indirectly influence water intake. Water intake can also be influenced by other factors, such as age, sex, and environment. Therefore, daily water consumption makes an excellent litmus test for the overall health and condition of a flock (Dozier *et al.*, 2002, Manning *et al.*, 2007). Decreases in water consumption can be an indication of health problems (Butcher *et al.*, 1999) or environmental issues. It is believed that inadequate consumption of water will result in decreased growth rates. Increased consumption is associated with water wastage as well as higher feed conversions.

Differences in strain and breed can influence water intake. This is most likely due to differences in metabolism, growth rates, body weight and body fat content. Marks (1980) showed that water and feed intake levels were higher in strains that were selected for rapid growth compared to the intake levels of a non-selected line.

Age is another factor influencing water intake in chickens. Adult animals maintain a constant water balance through the control of liquid intake and output. A positive water balance is found in growing animals to facilitate growth. As young animals grow, water intake increases yet, as a percentage of body weight, water intake decreases. Pesti *et al.,* (1985) demonstrated that broiler water consumption was a linear function of age and could be predicted by multiplying 5.28g of water times the broiler age in days. He further specified that 5.1 g could be used for birds grown in the cooler months or 5.7 for those grown in warmer months. In a more recent study, In a more recent study, Williams *et al.,* (2013) analyzed water consumption in birds grown in 1991, 2000-2001, and 2010-2011. It was demonstrated that, over the course of time, daily water consumption has increased. Each flock of birds grown in 2010-2011 averaged 190.48 liters of water consumed per 1000 head. This was significantly different ($P<0.048$) than average daily water consumption of birds grown in 2000-2001 which averaged 160.54 liters/1000 head. The water intake of the birds grown in 2000-2001 was found to be significantly different ($P<0.042$) than water consumption rates of birds grown in 1991 which averaged 140.33 liters/1000 head. Williams found the 2010-2011 flocks had a greater water to feed ratio than the 2000-2001 and 1991 flocks (2.02 vs. 1.98 and 1.90, respectively).

The sex of the bird plays a role in levels of water and feed consumption. Most of these differences are a result of differences in body weight. Marks (1985) showed that the increased rate of growth seen in male chicks begins at hatching. From this point, the males are larger but the difference is not significant until four days of age. These weight differences were shown to result in differing levels of water consumption.

Possibly, the factor with the greatest ability to affect water consumption in birds is ambient temperature. Water consumption increases when the ambient temperature exceeds 21^{o}C (Benton and Warren, 1933; and Wilson, 1948). Wilson also showed that water consumption at 35^{o}C was double that at 21^{o}C. Donkoh (1989) raised broilers under four constant ambient temperatures: 20°, 25°, 30°, and 35°C. Birds raised at 30° and 35°C showed a significant increase in water consumption. Lott (1991) demonstrated that heat energy produced from digestion contributed to the increase of water consumption in broilers during heat stress. Birds that did not eat in the hour prior to heat stress, consumed less water. May *et al.*, (2000) showed that broilers exposed to high air velocity during times of potential heat stress consumed less water and more feed, gained more weight and had an improved feed: gain ratio.

Feed content and intake both affect the rate of water consumption. Glista and Scott (1949) noted that as the level of soybean oil meal in the diet increased, water consumption rose. Allemand and Leclerq (1997) found that chickens fed a low protein diet versus a control diet in varying temperatures consistently consumed less water than the birds fed the higher protein control diet. The increase in water consumption relative to higher dietary protein levels could arise from the reduction of metabolic water produced due to the higher protein content. Also, the increased demand for nitrogen excretion due to the higher protein content could cause a higher demand for water for uric acid removal.

The mineral content of both feed and water can influence the amount of water consumed by chickens. High sodium and chloride levels in the feed can cause an increase in subsequent water intake. When found in the water, sodium and chloride are in a useful form for the chick. Without adjusting the level of sodium and chloride in the diet, problems with loose droppings, wet litter and increased feed conversions can occur. High levels of nutritional salt have been shown to increase water consumption with varying influences on feed consumption (Darden & Markes, 1985). Watkins *et al* (2005) investigated the relationship between sodium and chloride levels in drinking water and feed supplied to broilers. They found that water sources of sodium and chloride could be used to supply part or all of the chicks needs for these minerals. This indicates that feed levels of sodium and chloride must be decreased when these minerals are present in the drinking water.

Stocking density also plays a role on water utilization in broilers. Feddes *et al.,* (2002) raised birds at four different stocking densities. It was demonstrated that, as stocking density increases, water intake per bird increases.

The lighting program can also affect bird water consumption. In operations using lighting programs, two definitive peaks in water consumption can be observed. The initial peak can be seen just after the lights come on (dawn), and the second peak just prior to the darkening of the lights (dusk). Water consumption will start to drop off about an hour prior to darkness, indicating that the birds actually anticipate the coming dark period.

Due to the high importance of water in the physiology of broilers and layers, multiple types of water drinkers have been developed to maximize water utilization. Bruno and associates (2011) explored the water volume intake and behavior of birds when given choice between nipple and bell drinkers with separate groups raised at different environmental temperatures (25 and 34^{o}C). Birds were found to visit the bell drinkers less often while consuming a higher total water intake per visit. However, in commercial conditions, bell drinkers are typically associated with greater water wastage and damp litter with ensuing footpad burns and leg problems.

Water temperature may also affect consumption and bird performance, particularly during times of heat stress. Several studies have investigated the effects of water temperature during heat stress and in most cases found that when cool water is provided performance was enhanced for broilers and layers. Water temperature below the body temperature of the bird is beneficial for the dissipation body heat and has an effect on the bird's desire to consume water (Fairchild & Ritz, 2009). The temperature of the water can also affect other parameters. It can influence the solubility of gases, amplify tastes and odors and change the speed of chemical reactions (Patience, 1988).

It has been recognized by poultry production professionals that optimal consumption during peak water demand could be a limiting factor to feed and water intake in broilers. If feed and water intake are limited, a decrease in growth rate and final bird weight should be expected. The primary occurrence of peak water demand occurs when the rest period ends as the lights come on. It can be observed that activity at the drinker and feeder are very high at this time. The goal of this trial was to document the water consumption/usage pattern of broilers and establish the percentage of birds drinking in the first hour following the rest period.

Materials and Methods

This trial was performed at the University of Arkansas' Applied Broiler Research Farm. A total of 40,000 Cobb 500 x Cobb 500 straight run chicks were obtained from a commercial hatchery and placed in two, 12 meter by 122 meter tunnel ventilated, commercial broilers hours. The water system is a complete closed system with Choretime Steadi-flow drinkers provided at one drinker per 13 birds. Feed is provided with an automated system using Choretime Liberty feeders at a ratio of 65.79 birds per feeder. At three days of age, 528 straight run chicks were randomly selected and 22 were placed in each of 24, 1.49 square meter mini-pens (14.77 birds/m^2), twelve pens in each house. The pens were placed in groups of two down the center of the house with approximately 7.5 meters between groups. Pen location and spacing was consistent between the two houses. Water was supplied to each pen from the same watering system with two drinkers provided per pen. Feed was supplied by one Choretime hanging feeder with a 14 kg hopper per pen and a supplemental feeder was used for the first 8 days. The birds were fed a five phase commercial diet as used in the balance of the house and feed and water were available *ad libitum.* The birds were raised in the pens through the end of the trial.

The lighting program for this flock was utilized according to the commercial integrator. Light emitting diode (LED) and compact fluorescent (CFL) bulbs were used in each house on full brightness, 24 hours/day during the first seven days of the grow out period. After seven days, the CFL lights were turned off and the LED lights remained at full intensity. A dark period was added so that the birds received 18 hours of light and 6 hours of dark. This remained in effect for the rest of the flock. On day 15, lights were dimmed to 3.0 lux on the outside water line, half way between light bulbs. Thereafter, lights were dimmed based on bird activity levels throughout the flock.

A stock solution was produced by mixing 0.5 liters of Sentient Green dye with 4 liters of water. On days 12, 19, 26, 33, and 40, the stock solution of dye was injected into the drinking water at a ratio of 1 part stock solution to 128 part water, during the birds rest period. The pen drinking line was flushed until full of dyed water as visible at the flush line exit. Each pen was randomly assigned a time after the end of the rest period for evaluation. Two pens per house were assigned to each of the following evaluation times: 5 minutes, 10 minutes, 15 minutes, 30 minutes, 45 minutes and 60 minutes after the end of the rest period. At the assigned time, the mouth of each bird in the pen was visually inspected for evidence of dye. This was used to calculate a percentage of birds drinking between the end of the rest period and the assigned time frame.

Statistical analysis was performed by Oneway Analysis of Variance (ANOVA) using JMP Pro 11. Comparisons of the means was conducted using Tukey-Kramer HSD and all means that were significant at the $P<0.05$ were separated. The alpha value for all analyses was 0.05.

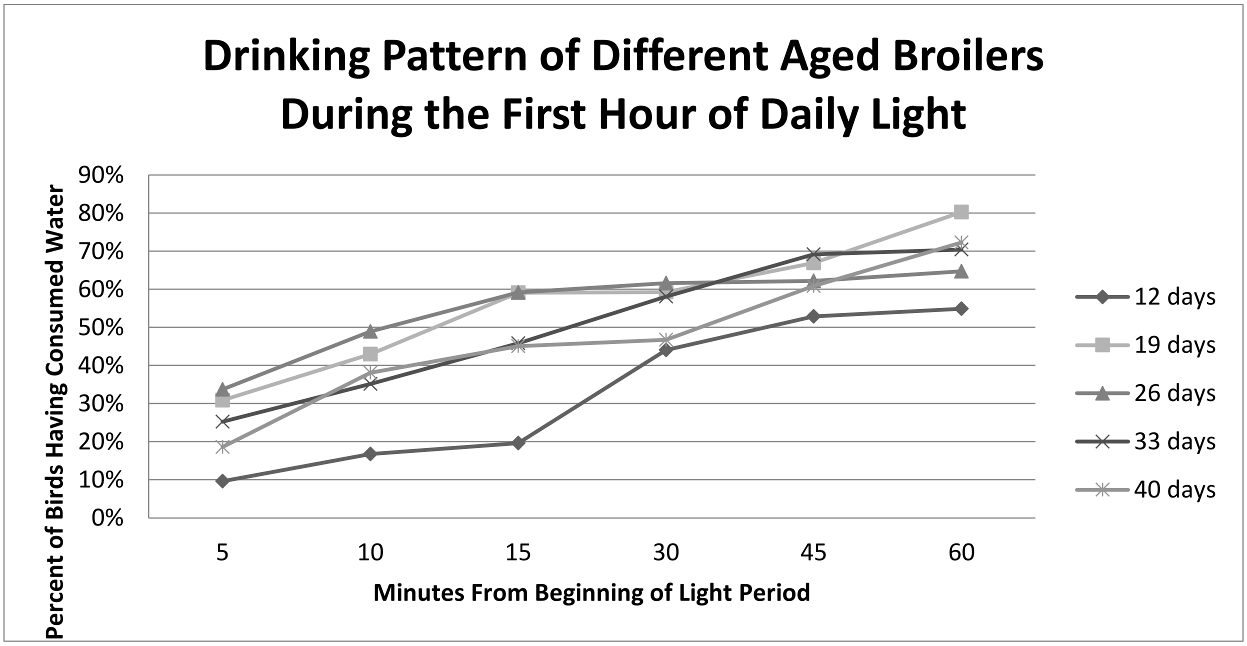

Figure 2. Drinking pattern of different aged broilers during the first hour of daily light

Results

An evaluation of the birds drinking at each of the check times demonstrated that the percentage of birds drinking during the hour after the lights came on each week increased as time progressed. Looking at consumption pattern over time for all ages combined, it was found that in the first 5 minutes after the end of the rest period, 23.62% of the birds had consumed water. After 10 minutes, 36.40 percent had consumed water. At 15 minutes, the percentage had increased to 45.77%. The percentage increased to 53.96%, 62.42%, and 68.55% at 30, 45, and 60 minutes post rest period, respectively (Figure 3).

When the data was analyzed to determine how each of the ages compared in their drinking pattern for each of the times evaluated (Figure 4), significant differences were found in the variations of birds consuming water in the first five minutes by age (P>0.0036). The number of twelve day old birds who had consumed water was significantly lower than the balance of the age groups. Additionally, a significantly higher percentage of birds in the 19 and 26 day age groups drank than in the other groups. A similar trend was found in the age groups of other time

Time After Rest Period **minutes**	**Samples (n)**	**Birds Having Consumed Water** **mean percent**[1]
5	20	23.62 ± 3.16^{e}
10	20	36.40 ± 3.16^{d,e}
15	20	45.77 ± 3.16^{c,d}
30	20	53.96 ± 3.16^{b,c}
45	20	62.42 ± 3.16^{a,b}
60	20	68.55 ± 3.16^{a}

[a]means with no common superscript differ significantly (P>0.0001)

[1]values are mean ± SE

Figure 3. The percentage of birds consuming water in time intervals after the end of the rest period

intervals. At ten minutes past the advent of the light period, the percentage of birds having consumed water was again significantly higher ($P<0.0116$) in the 19 and 26 day age groups. There were no significant differences between the other groups. After fifteen minutes of light, the 12 day group was found to be significantly lower than the other birds and the 19, 26, and 33 day groups were found to be significantly higher than the other birds ($P>0.0017$). While the variance within the 30 minute group was found to be significant ($P>0.0407$), there was no significant differences between the means of the percent of birds having consumed water at different ages. There were no significant differences found in the 45 and 60 minute groups ($P>0.4282$, $P>0.2225$, respectively).

Bird Age (days)	**Samples (n)**	**Birds Having Consumed Water mean percent[1]**
12	24	33.00 ± 3.91^{b}
19	24	56.57 ± 3.91^{a}
26	24	55.08 ± 3.91^{a}
33	24	50.68 ± 3.91^{a}
40	24	$46.96 \pm 3.91^{a,b}$

[a] means with no common superscript differ significantly ($P<0.05$)

[1] values are mean ± SE

Figure 4. The percentage of birds consuming water by age after the end of the rest period

	12 days	19 days	26 days	33 days	40 days	Prob > F	SEM
5 Minutes	$9.65\%^{b}$	$30.89\%^{a}$	$33.70\%^{a}$	$25.29\%^{ab}$	$18.60\%^{ab}$	0.0036	3.88
10 Minutes	$16.80\%^{d}$	$43.01\%^{c}$	$48.96\%^{c}$	$35.18\%^{cd}$	$38.07\%^{cd}$	0.0116	5.60
15 Minutes	19.60^{f}	59.09^{e}	59.22^{e}	45.85^{e}	45.10^{ef}	0.0017	5.94
30 Minutes	44.10^{g}	59.24^{g}	61.61^{g}	58.06^{g}	45.78^{g}	0.0407	4.39
45 Minutes	52.90^{h}	66.88^{h}	62.24^{h}	69.20^{h}	60.90^{h}	0.4282	6.24
60 Minutes	54.94^{i}	80.27^{i}	64.77^{i}	70.48^{i}	72.3^{i}	0.2225	7.42

^{a}means with no common superscript differ significantly ($P<0.05$)

Figure 5. The percentage of birds having drank in time intervals, by age after the end of the rest period

Discussion

The goal of this experiment was to quantify the number of birds drinking during the time period each day which is considered to be the period of peak water demand. The results showed a steady increase in the percentage of the birds having consumed water over the first hour of the light period. While this is to be expected, it is important to note that for all ages evaluated, never did 100% of the birds consume water during the first hour of the day. This would indicate that it may take longer than an hour for the flock to eat and drink. In designing the experiment, it was expected that one hour would be sufficient. Further repetitions of this trial should extend the monitoring period past one hour and establish the amount of time for the entire sample population to drink.

Pesti *et al.*, (1985) demonstrated that broiler water consumption was a linear function of age. It was seen in this trial that peak water consumption activity occurred in the 19 day old and 26 day old groups. The number of birds having drank in the first hour of the light period showed a marked decrease after 26 days declining to an average of 46.96% in the 40 day old group. This would appear to indicate that birds are not as aggressive to water past these ages. This may be related to the increase in fat production in relationship to protein, resulting in increased metabolic water and a decreased drinking water intake.

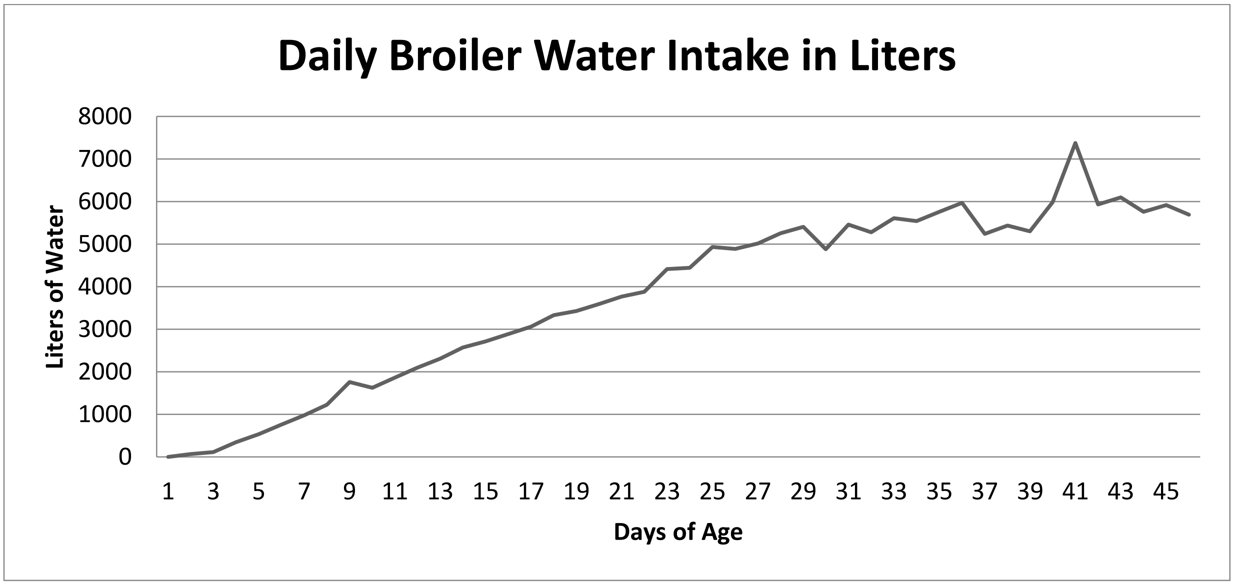

Figure 6. Daily broiler water intake in liters

It has been speculated by growers and production personnel that there is some relationship between the availability of water at times of peak demands and the fluctuations in water intake frequently seen at the end of a flock. A graph of the water consumption for one of the two houses used for this experiment (Figure 5) shows there is a steady increase in daily water consumption until the birds are 27 days of age. At this point, the daily water intake does not increase at the same rate. In fact, a trend line from day 27 to the end of the flock would be almost flat. The experiment results suggest that during the first hour after lights come on, birds were most aggressive to water at 19 and 26 days. This was especially evident in the first half hour after the end of the rest period. This indicates a possible relationship between drinking behavior at times of peak demand and daily water intake. A daily evaluation of the behavior compared to total daily water consumed is needed to investigate the relationship.

When the lights come on at the end of the rest period in a broiler house, the space under the drinkers is quickly filled with birds seeking water. With this level of demand, the amount of water available per bird is decreased. The question arises as to whether the bird drinks less at this time or spends an increased amount of time getting enough to drink. If the bird drinks less at this time, is that a lost opportunity or is water intake increased later in the day? Due to the high correlation between water and feed intake, decreased water intake would result in a reduction in feed intake leading to less than optimum weight gains. Commercial water systems capable of increasing the flow rate of water during times of peak demand may be advantageous in improving overall water intake. Further research is called for to investigate water consumption when flow rate is increased during times of peak demand.

The decrease in the percentage of birds drinking later in the flock may be a reflection on the stocking density of the house, size of the birds, and the number of available drinkers and feeders. It is possible that birds over 26 days of age have reached a large enough size that access to feed and water is inhibited. Decreased access would result in a lower percentage of birds drinking at one time and increase the length of time for all birds to drink. The ratios of birds per drinker and birds per feeder, as well as the distances between drinkers or feeders, have remained basically unchanged for many years. In the meantime, the growth rate and body style of broilers has changed dramatically. It is possible that these ratios and distances may need to be reevaluated to fit the modern bird.

An Evaluation of Water Consumption Behavior in Broilers During Pre-Slaughter Feed Withdrawal

Abstract

A trial was conducted to quantify the percentage of birds drinking during pre-slaughter feed withdrawal and the amount of water consumed. To establish this, 80,000 Cobb 500 x Cobb 500 straight run chicks were obtained on day of hatch and placed into four commercial broiler houses. At three days of age, 220 chicks per house were randomly selected and placed into 10 pens per house for a total of 40 pens. Each pen was 1.486 m^2 and replicated the house density. All birds were fed the same commercial diets throughout the trial. In the pen portion of the trial, five pens per house were randomly assigned as withdrawal pens and the balance served as control pens. Feed was withdrawn by raising the feeders in the pens assigned as the withdrawal treatment pens. The houses were randomly assigned one, two, three, or four hours of feed withdrawal and a water dye solution was injected into the drinking water one hour prior to the end of the assigned feed withdrawal time. The pen drinking lines were flushed until they were full of dyed water as visible at the flush line exit. At the assigned withdrawal time (1,2,3, or 4 hours after feed had been withdrawn), the mouth of each bird was inspected for evidence of dye.

In the whole house portion of the trial, each house was randomly assigned as either control or 1, 2, or 3 hours of feed withdrawal. Feed was withdrawn from the each house for the assigned time periods and water meter readings were recorded at the time of withdrawal and hourly thereafter to establish water consumed per 100 birds for each house in the assigned time frame. The house assigned as control did not have feed withdrawn but water meter readings were recorded at 1, 2, and 3 hours post withdrawal to match the test houses.

In the pen trial, it was found that there was no significant difference between birds on feed withdrawal and birds still on feed in the percentage of birds drinking over the course of four hours of withdrawal. The whole house portion of the trial demonstrated no significant difference in water consumption rate in the first two hours of feed withdrawal. A significant decrease in the rate of water consumption of birds from whom feed had been withdrawn was found in the third hour of withdrawal.

Introduction

At the end of a commercial broiler flock, feed is withdrawn from the birds several hours prior to slaughter. May and Lott (1990) demonstrated that this allows for gastrointestinal tract clearance and aids in reducing fecal contamination of the carcasses during processing. Ramirez *et al.*, (1997) found that pre-slaughter feed withdrawal resulted in an increase in the number of *Salmonella* isolated from crops of experimentally and naturally infected broilers. Byrd and colleagues (1998) showed that feed withdrawal increased the incidence of *Campylobacter* in the crops of commercial broilers.

These studies show that, while feed withdrawal must be completed to avoid fecal contamination during processing, it is complicated by the additional risks due to the increase of *Salmonella* and *Campylobacter*. Byrd and colleagues (2001) showed that this risk could be mitigated with the use of an acidifier in the drinking water of the birds while on pre-slaughter feed withdrawal. They found that the addition of 0.5% lactic or 0.5% formic acids in the drinking water during feed withdrawal resulted in a significant decrease in the incidence of *Salmonella* contaminated crops. Additionally, they demonstrated that lactic acid (0.4%) provided in the drinking water during pre-slaughter withdrawal resulted in significantly lower incidences of *Salmonella* culture-positive, pre-chill carcass rinsate and *Campylobacter* culture-positive crops and in pre-chill carcass rinsates when compared to untreated controls.

Drinking behavior is closely associated with feed intake, such that factors affecting feed consumption will directly influence water intake. It is understood that, in the absence of feed, birds drink less water but the actual drinking behavior of the birds in not fully understood. This trial will seek to understand the drinking behavior by establishing a percentage of birds drinking during pre-slaughter feed withdrawal.

Materials and Methods

To establish percentage of birds drinking during pre-slaughter feed withdrawal, 80,000 Cobb 500 x Cobb 500 straight run chicks were obtained on day of hatch from a commercial hatchery and placed in four 12 meter by 122 meter tunnel ventilated, commercial broilers hours located on the University of Arkansas' Applied Broiler Research Farm. The water system is a complete closed system with Choretime Steadi-flow drinkers provided at one drinker per 13 birds. Feed is provided in two houses with an automated system using Choretime Liberty feeders at a ratio of 65.79 birds per feeder. The other two houses have Choretime FF Revolution feeders at the same ratio of birds per feeder. At three days of age, 220 chicks per house were randomly selected and placed into 10 pens per house for a total of 40 pens. Each pen was 1.486 m^2 and replicated the house density. The pens were placed in groups of two down the center of the house with approximately 7.5 meters between groups and the positioning of the pens was consistent between the houses. Water was supplied to each pen from the same watering system with two drinkers provided per pen. Feed was supplied by one Choretime hanging feeder with a 14 kg hopper in each pen and a supplemental chick feeder was used for the first 8 days. The birds were fed a five phase commercial diet as used in the balance of the house and both feed and water were available *ad libitum.* The birds were raised in the pens through the end of the trial.

The lighting program for this flock was utilized according to the commercial integrator's guidelines. Light emitting diode (LED) and compact fluorescent (CFL) bulbs were used in each house on full brightness, 24 hours/day during the first seven days of the growout period. After seven days, the CFL lights were turned off and the LED lights remained at full intensity. A dark period was added so that the birds received 18 hours of light and 6 hours of dark. This remained in effect for the rest of the flock. On day 15, lights were dimmed to 3.0 lux on the outside water line, halfway between light bulbs. Thereafter, lights were dimmed based on bird activity levels.

. The water dye solution was produced by mixing 0.5 liters of Sentient Green dye with 4 liters of water. This was used as a stock solution which was injected by medicator into the drinking water lines at ratio of 1 part stock solution to 128 parts drinking water.

Pen Trial – In the pen portion of the trial, five pens per house were randomly assigned as withdrawal pens and the balance served as control pens. Feed was withdrawn by raising the feeders in the pens assigned as the withdrawal treatment pens. Each house was randomly assigned one, two, three, or four hours of feed withdrawal. One hour prior to the end of the assigned withdrawal time, the solution of water dye was injected into the drinking water and the pen drinking line was flushed until dyed water was visible at the flush line exit. In this manner, the one hour house had dye injected at the time of feed withdrawal. The two hour house had dye injected after one hour of feed withdrawal. The three hour house had dye injected after two hours of feed withdrawal. The four hour house was injected after three hours (Figure 6). At the end of assigned withdrawal time (1,2,3, or 4 hours after feed had been withdrawn), the mouth of each bird was inspected for evidence of dye. This process was replicated three times. Houses and pens were re-randomized for each replication.

Whole House Trial - Pre-slaughter feed withdrawal was simulated in three of the four houses with the fourth serving as the control. Each house was randomly assigned as either control or 1,

House	Hours of Feed Withdrawal	Feeders Raised	Dye Flushed Into Water Lines	Mouths Checks
3	1	9:00	9:00	10:00
1	2	9:00	10:00	11:00
4	3	9:00	11:00	12:00
2	4	9:00	12:00	1:00

Figure 7. Example of pen trial feed withdrawal schedule

2, or 3 hours of feed withdrawal. Water meter readings were recorded at the beginning of the withdrawal period and hourly thereafter to establish water consumed per 100 birds for each house in the assigned time frame.

Statistical analysis was performed by Oneway Analysis of Variance (ANOVA) using JMP Pro 11. Comparisons of the means was conducted using Tukey-Kramer HSD and all means that were significant at the $P<0.05$ were separated. The alpha value for all analyses was 0.05.

Results

Pen Trial – In the first hour of feed withdrawal, the control pens averaged 54.46% of the birds having consumed water while the test pens averaged 54.82%. There was no significant difference between the test and control pens ($P>0.9622$). In the second hour of feed withdrawal, 48.63% of the control pen birds and 47.88% of the test pen birds had consumed water. This was not significantly different ($P>0.8749$). In the third hour of withdrawal, 59.65% the control pen birds and 52.15% of the test pen birds had consumed water. While this was the greatest difference found in the pen trial, it was not shown to be of statistical significance (P>0.1013). The fourth and final hour of withdrawal found the control pens with an average of 57.53% of birds consuming water. The test pens had an average of 51.01% having consumed water in that hour. This difference was not found to be statistically significant (P>0.2162).

Whole House Trial – In the first hour, the birds under feed withdrawal consumed 0.1505 liters of water per 100 head. The control group consumed 0.1499 liters/100 head in the same time period. The difference in water consumption was not found to be significant (P>0.9799).

In the second hour of withdrawal, the birds under feed withdrawal consumed 0.0988 liters of water per 100 birds during the second hour. The control birds consumed 0.1492 liters/100 birds. While the P value was very low (P>0.0530), it failed to meet the standard for significance.

	1st Hour	**2nd Hour**	**3rd Hour**
Withdrawal	54.82%	47.88%	52.15%
Control	54.46%	48.63%	59.65%
SE	5.35	3.35	3.16
Prob>F	0.9622	0.8749	0.1013

Figure 8. Percentage of birds' drinking water during the hourly phases of feed withdrawal – Pen Trial

The third hour of feed withdrawal yielded significant differences in the amount of water consumed. The withdrawal birds consumed 0.0626 liters of water/100 birds during this time, while the control birds consumed 0.1536 liters/100 birds. This was found to be a significant difference (P>0.0009).

Water Consumption (liters/100 hd)			
	1st Hour	2nd Hour	3rd Hour
Withdrawal	.1505	.1492	0.0626
Control	.1499	.0989	0.1536
SEM	.0167	.0131	0.072
Prob>F	0.9799	0.0530	0.0009

Figure 9. Water consumption rates during three hours of feed withdrawal

Discussion

In the pen portion of the trial, no significant differences were found in the drinking behavior between birds on feed withdrawal and control birds, which were provided access to feed. This indicates that the presence or absence of feed within the first four hours after feed has been removed does not appear to be correlated to the number of birds drinking.

The primary goal of the whole house portion of the experiment was to establish drinking water consumption rates during pre-slaughter feed withdrawal. The rate of water consumption in the first hour of feed withdrawal was not found to be significantly different between the withdrawal and control groups. The second hour results were also found not to be statistically significant but, due to the low P value, it can be said that there is a trend towards a difference in the second hour with the birds becoming less interested in drinking as the length of time feed is removed increases. The third hour's water consumption rates were significantly different with the birds on feed withdrawal drinking less than their control counterparts. Taken as a whole, this indicates that while the withdrawal of feed does not immediately affect the intake of water, it does appear to impact it the longer birds are without feed. In this case, a decrease in water consumption took place over the course of the three hours.

As birds eat, they also drink to solubilize feed and help move it through the digestive system. As feed is removed, it is to be expected that water intake should decrease. The results support this but indicate that a similar number of birds will consume water whether in the presence or absence of feed. This suggests that drinking water could be used as a carrier for some interventions for a broiler flock during preslaughter feed withdrawal.

Acidification of the water to lower the pH of the crop and decrease levels of *Salmonella* and *Campylobacter* during pre-slaughter feed withdrawal presents challenges. First, the amount of water consumed in the third hour of feed withdrawal may not be enough to maintain the lower pH of the crop. If the pH of the crop rises, increased levels of *Salmonella* and *Campylobacter* would be expected. Additional research will be necessary to explore the dosage rates of an acidifier to attain decreased levels of *Salmonella* and *Campylobacter* at the plant.

Daily Water to Feed Ratios with Seasonality in Broilers

Abstract

An evaluation was made of fifteen successive broiler flocks, grown from 2012 to 2014 in four commercial houses, to establish daily water to feed intake ratios over the course of a flock. In addition, the flock data was separated by season to establish the seasonal effect on these ratios. It was demonstrated that over the course of the flock, water to feed ratios decline from an average of 1.931:1 on day 11 to 1.715:1 on day 46. The flock mean water to feed ratio over this period was 1.778:1. When evaluated for seasonality, winter was found to have the lowest mean water to feed ratio at 1.724:1. The ratios ranged from 2.129 at 11 days to 1.370:1 at 44 days. The fall season had a mean ratio of 1.732:1. Fall water to feed ratios were found to vary from 1.774:1 on day 11 to 1.715:1 on day 46. Spring saw an overall increase in the water to feed ratios with a mean of 1.837:1. Birds at day 11 averaged 1.951:1 while birds at day 41 averaged 1.750:1. Summer water to feed ratios average 1.838:1. This ranged from 1.956:1 at 11 days to 1.744:1 at 41 days.

Introduction

Water had long been recognized as the most critical nutrient in livestock production. While animals might survive for long periods of time without food, without water they would soon die. Water makes up about 70% of a chicken's total weight and is the highest single constituent of the body. The animal obtains water from three sources; drinking water, water in feed and metabolic water. Water losses occur in four ways. Water is expired during respiration. Water is lost from the skin through perspirations and insensible water loss. Additional water loss occurs through feces and urine.

Patrick and Ferrise (1962) concluded that the water requirements of broilers up to 9 weeks of age was approximately 1.5 pounds of water per pound of feed consumed. More recently, it has been shown that normal water consumption for chickens ranges from 1.6 to 2.0 times that of feed intake (Fairchild and Ritz, 2009). Drinking behavior is closed associated with feed intake, such that factors affecting feed consumption will indirectly influence water intake. Water intake can also be influenced by several other factors, such as age, sex, and environment. Due to this, daily water consumption makes an excellent litmus test for the overall health and condition of a flock (Dozier *et al.*, 2002, Manning *et al.*, 2007). Decreases in water consumption can be an indication of health problems (Butcher *et al.*, 1999) or environmental issues. Inadequate consumption of water will result in decreased growth rates. Overconsumption is associated with higher feed conversions.

Age is another factor influencing water intake in chickens. Adult animals maintain a constant water balance through the control of liquid intake and output. A positive water balance is found in growing animals to facilitate growth. As young animals grow, water intake increases but, as a percentage of body weight, water intake decreases. Pesti *et al.,* (1985) demonstrated that broiler water consumption was a linear function of age and could be predicted as 5.28g times the broiler age in days. In a more recent study, Williams *et al.,* (2013) looked at water consumption in birds grown in 1991, 2000-2001, and 2010-2011. It was demonstrated that, over the course of time, daily water consumption has steadily increased resulting in increased water to feed ratios. Williams found the 2010-2011 flocks had a greater water to feed ratio than the 2000-2001 and 1991 flocks (2.02 vs. 1.98 and 1.90, respectively).

Stage and type of production as well as growth rate influence water intake levels. Differences in water consumption can be seen on different days in the sexually mature female. Daily intake is higher on days when there is an egg in the oviduct. This is related to the circulating estrogen levels associated with the egg laying process (Savoy, 1978).

Possibly, the factor with the greatest ability to affect water consumption in birds is ambient temperature. Water consumption increases when the ambient temperature exceeds $21^{o}C$ (Benton and Warren, 1933; and Wilson, 1948). Wilson also showed that water consumption at $35^{o}C$ was double that at $21^{o}C$. Donkoh (1989) raised broilers under four constant ambient temperatures: 20^{o}, 25^{o}, 30^{o}, and $35^{o}C$. Birds raised at 30^{o} and $35^{o}C$ showed a significant increase in water consumption. Lott (1991) demonstrated that heat energy produced from digestion contributed to the increase of water consumption in broilers during heat stress. Birds that did not eat in the hour prior to heat stress, consumed less water. May *et al.,* (2000) showed that broilers exposed to high air velocity during times of potential heat stress consumed less water and more feed, gained more weight and had an improved feed: gain ratio.

Feed content and intake both affect the rate of water consumption. Glista and Scott (1949) noted that as the level of soybean oil meal in the diet increased, water consumption rose. Allemand and Leclerq (1997) found that chickens fed a low protein diet versus a control diet in varying temperatures consistently consumed less water than the birds fed the higher protein control diet. The increase in water consumption relative to higher dietary protein levels could arise from the reduction of metabolic water produced due to the higher protein content. Also, the increased demand for nitrogen excretion due to the higher protein content could cause the higher demand for water for uric acid removal.

The mineral content of both feed and water can influence the amount of water consumed by chickens. High sodium and chloride levels in the feed can cause an increase in subsequent water intake. When found in the water, sodium and chloride are in a useful form for the chick. Without adjusting the level of sodium and chloride in the diet, problems with loose droppings, wet litter and increased feed conversions can occur. High levels of nutritional salt have been shown to increase water consumption with varying influences on feed consumption (Darden & Markes, 1985). Watkins et al., (2005) investigated the relationship between sodium and chloride levels in drinking water and feed supplied to broilers. They found that water sources of sodium and chloride could be used to supply part or all of the chicks needs for these minerals. This indicates that feed levels of sodium and chloride must be decreased when these minerals are present in the drinking water.

Stocking density also plays a role on water utilization in broilers. Feddes *et al.*, (2002) raised birds at four different stocking densities. It was demonstrated that, as stocking density increases, water intake per bird increases.

The lighting program can also affect bird water consumption. In operations using lighting programs, two definitive peaks in water consumption can be observed. The initial peak can be seen just after the lights come on (dawn), and the second peak just prior to the darkening of the lights (dusk). Water consumption will peak about an hour prior to darkness, indicating that the birds actually anticipate the coming dark period.

Water temperature may also affect consumption and bird performance, particularly during times of heat stress. Several studies have investigated the effects of water temperature during heat stress and in most cases found that when cool water is provided performance was enhanced for broilers and layers. Water temperature below the body temperature of the bird is beneficial for the dissipation body heat and has an effect on the bird’s desire to consume water (Fairchild and Ritz, 2009). The temperature of the water can also affect other parameters. It can influence the solubility of gases, amplify tastes and odors and change the speed of chemical reactions (Patience, 1988).

Materials and Methods

Daily production records were collected for fifteen successive broiler flocks at the University of Arkansas’ Applied Broiler Research Farm. This farm has four 12 meter by 122 meter tunnel ventilated, commercial broilers hours. The water system is a complete closed system with Choretime Steadi-flow drinkers provided at one drinker per 13 birds. Feed is provided in two houses with an automated system using Choretime Liberty feeders at a ratio of 65.79 birds per feeder. The other two houses have Choretime FF Revolution feeders at the same ratio of birds per feeder.

Daily mortality was counted and deducted to establish the live inventory. Daily water and feed intake were standardized to intakes per 1000 head based on daily live inventories. Water volumes were converted to weight to establish the water to feed ratio. Data from the first ten days of each flock was not used. This was done due to the differences in daily feed utilization of hand feeding during the brood period. Data from days with unusual occurrences such as broken water lines, out of water or out of feed were also excluded as were days on which the water lines were flushed. The final day of the flock was excluded as it was incomplete and included pre-slaughter feed withdrawal. Flocks were separated by season.

Season was selected using these dates:

Spring	March 21-June 20
Summer	June 21 – September 20
Fall	September 21- December 20
Winter	December 21- March 20

Majority of days in one season was used to determine seasonality of flocks which overlapped the listed dates. Of the fifteen flocks, five overlapped seasons; one flock from spring to summer, two from summer to fall, and two from fall to winter. Bird placement averaged 20,298 birds per house with a range of 19,500-21,375 and an average stocking density of 13.66 birds/meter^2. Average grow out was 43.40 days with a range of 41-47 days. The four spring flocks averaged a 43.0 day grow out period which ranged 42-45 days. There were three summer flocks which averaged 42.33 days with a range of 42-43 days. The four fall flocks averaged 44.75 days and had a range of 42 to 47 days of grow out. The four winter flocks averaged 43.25 days of grow out with a range of 41 to 45 days.

Statistical analysis was performed by Oneway Analysis of Variance (ANOVA) using JMP Pro 11. Comparisons of the means was conducted using Tukey-Kramer HSD and all means that were significant at the $P<0.05$ were separated. The alpha value for all analyses was 0.05.

Results

Water to feed ratios showed a marked decrease over the course of each flock (Figure 9). Results ranged from 1.9301:1 at 11 days of age to 1.715:1 at 46 days of age, with a mean ratio of 1.778:1 over the course of the fifteen flocks. When viewed by season, spring and summer were found to have higher ratios than fall and winter (Figure 10). Evaluation by season showed a significant difference ($P<0.0001$) in the water to feed ratios per season. The variation between the seasonal water to feed ratios was analyzed using the Tukey-Kramer HSD method ($\alpha=0.05$).

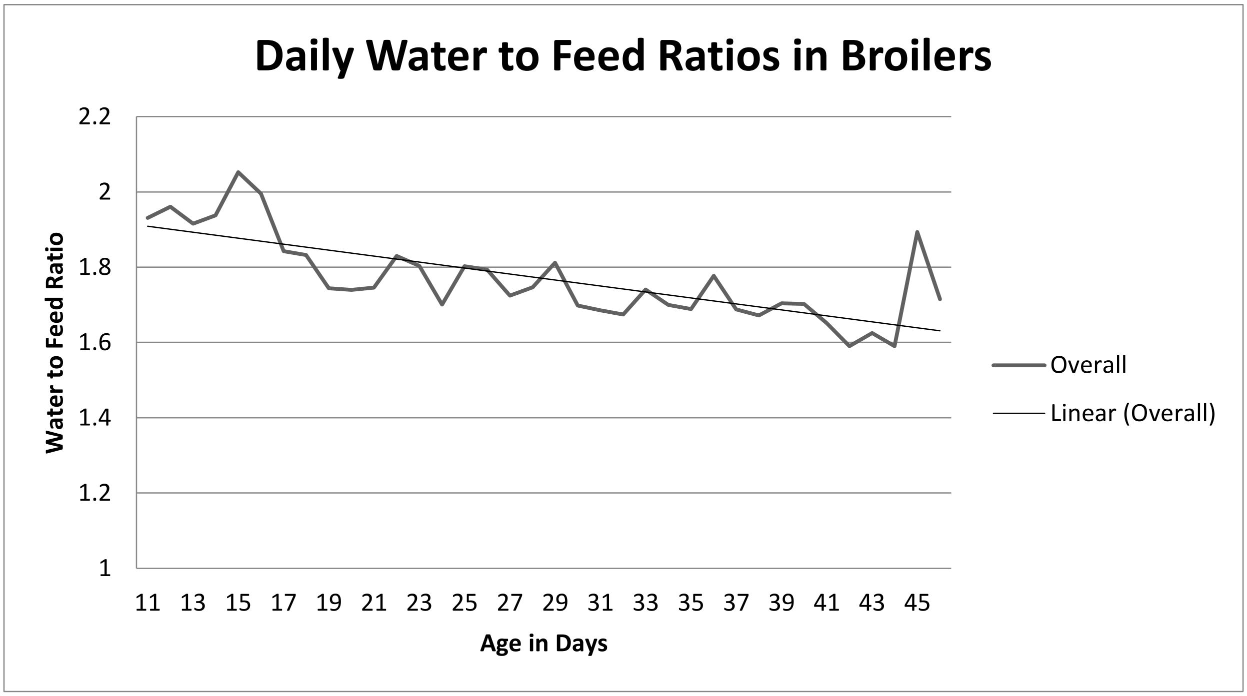

Figure 10. Overall daily water to feed ratios in broilers

Spring and summer were both found to be significantly different than fall and winter. There were no significant differences found between spring and summer or fall and winter.

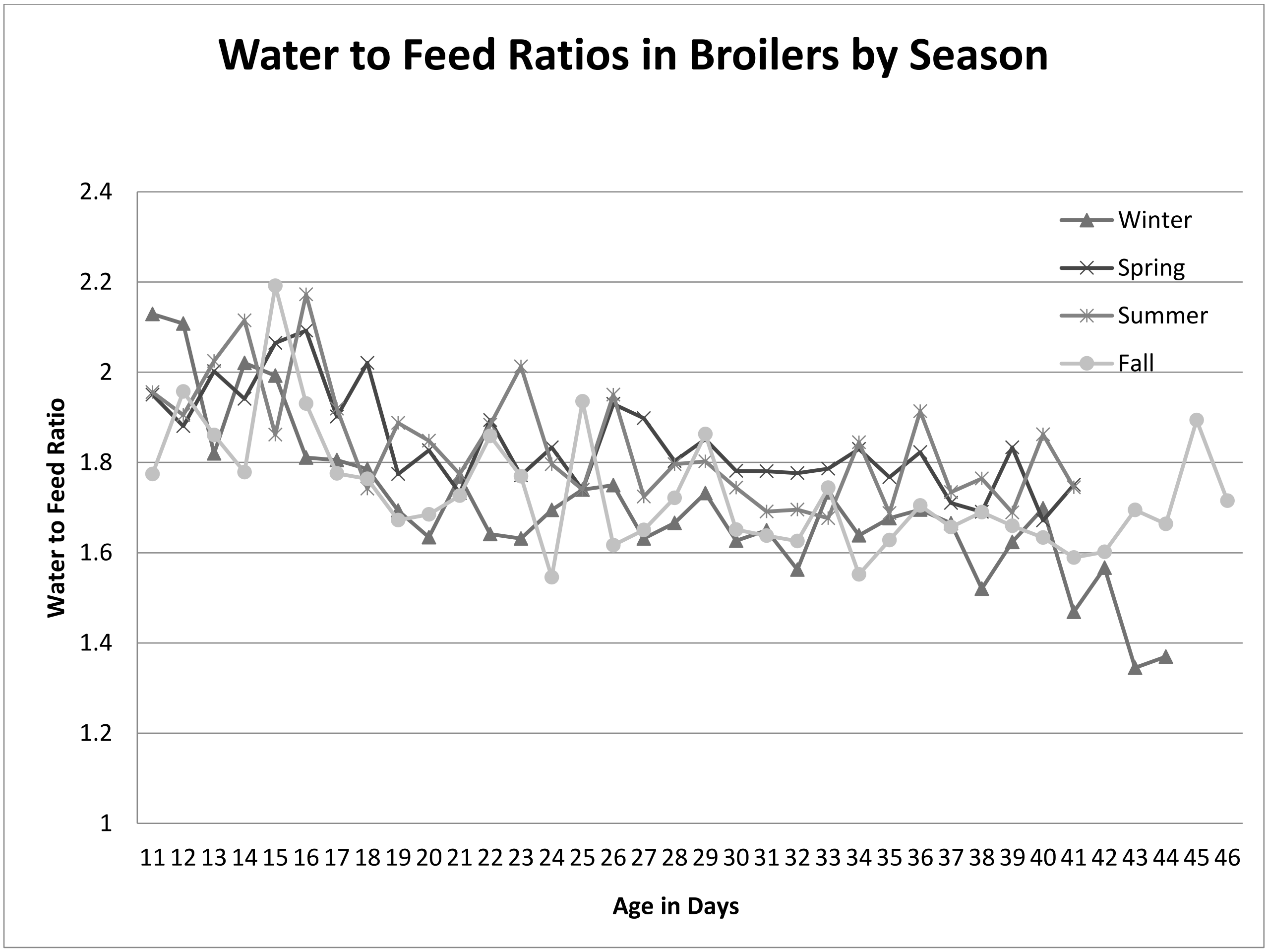

Figure 11. Water to feed ratios in broilers by season

Winter water to feed ratios (Figure 11) were found to be the lowest with a mean of 1.725:1. At eleven days, the ratio was 2.129:1 and dropped to 1.370:1 at 44 days of age.

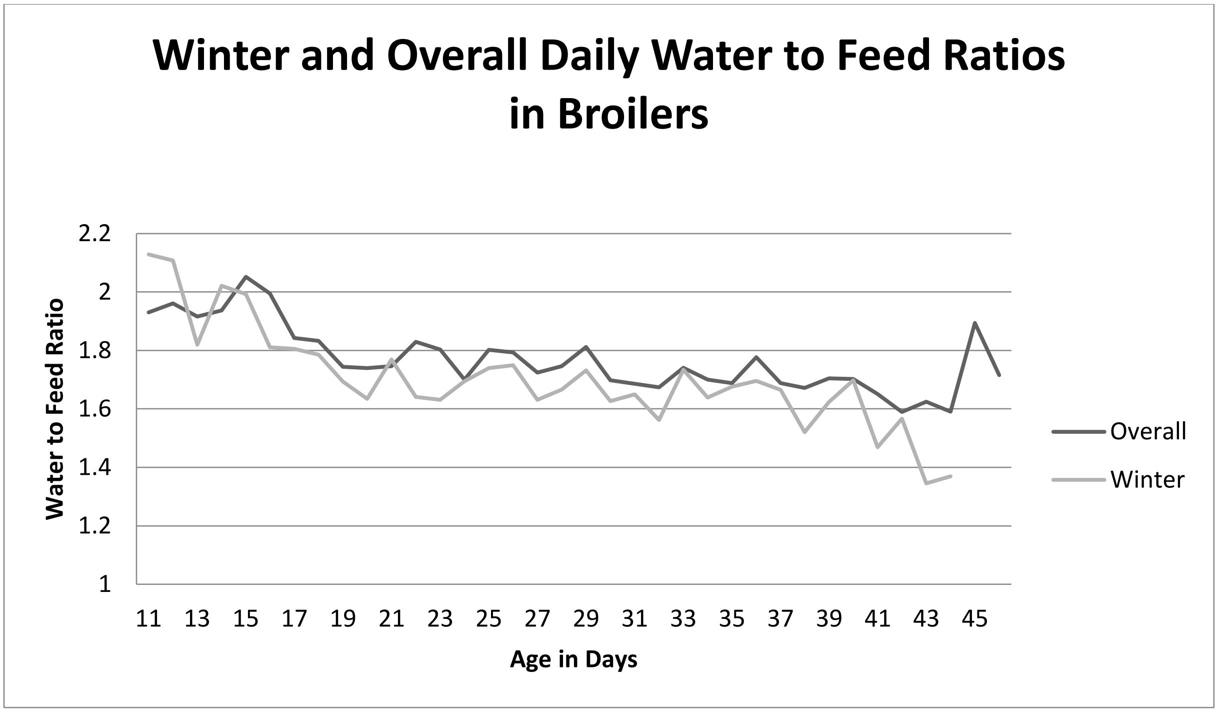

Figure 12. Winter and overall water to feed ratios in broilers

The fall season (Figure 12) had a mean water to feed ratio of 1.732:1. This included the range of 1.774 at 11 days to 1.715 at 46 days.

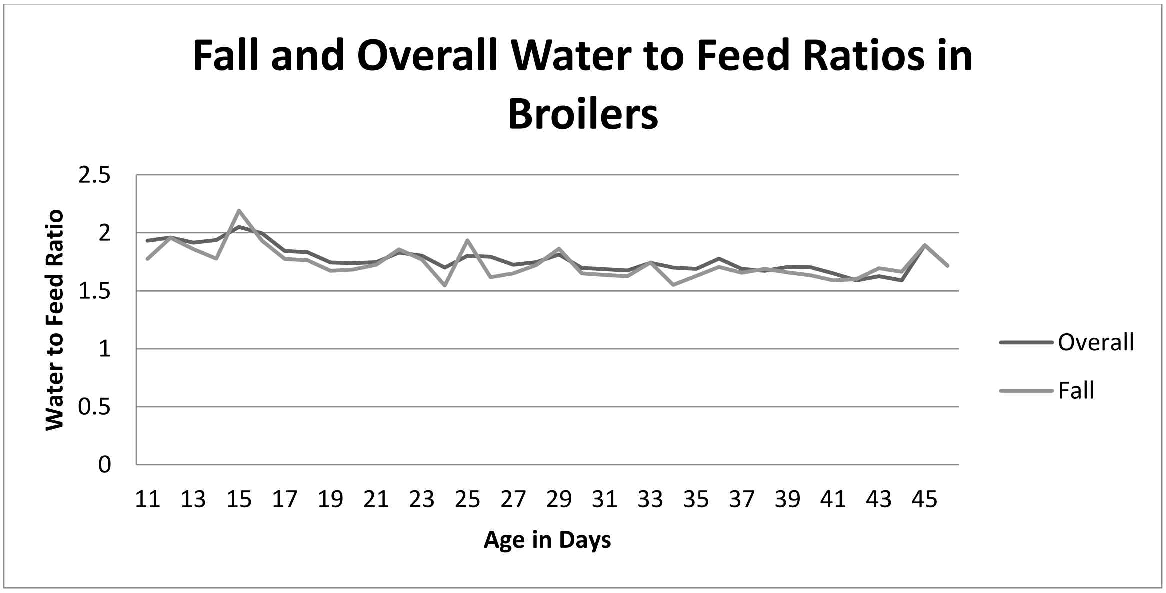

Figure 13. Fall and overall water to feed ratios in broilers

Spring (Figure 13) had a mean response of 1.837:1. The four flocks averaged 1.951 at 11 days of age. This decreased to 1.750 at 41 days.

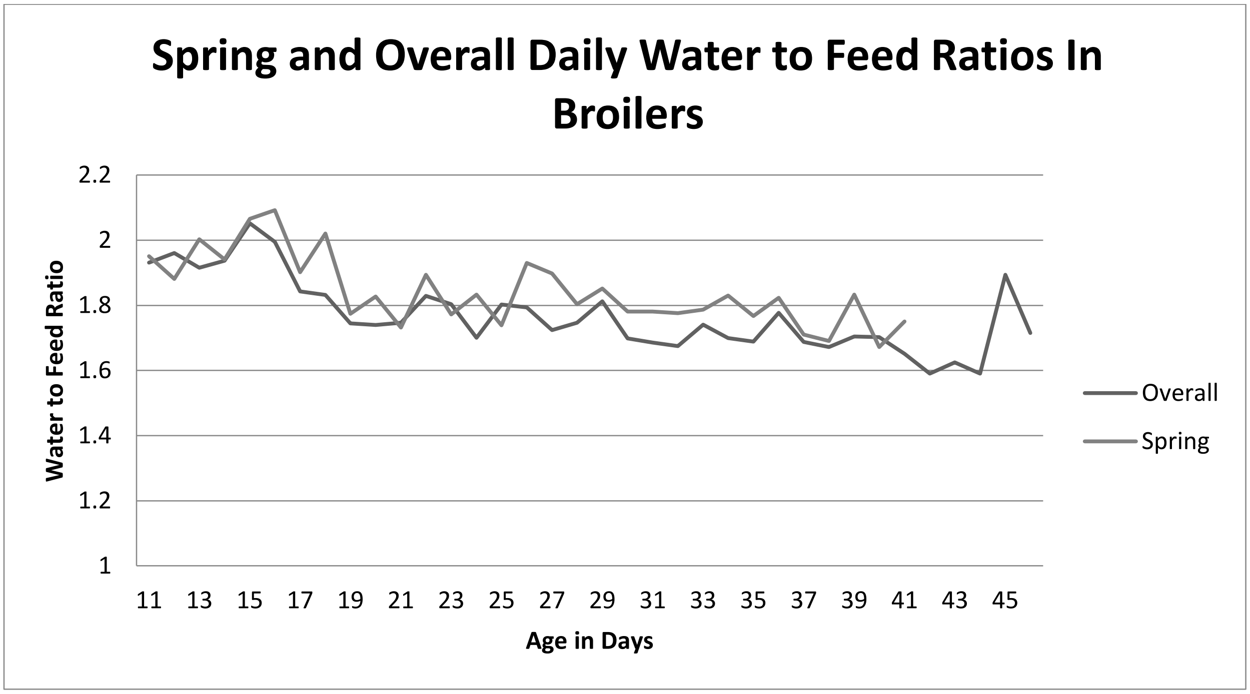

Figure 14. Spring and overall daily water to feed ratios in broilers

Finally, the three summer flocks (Figure 14) had a mean water to feed ratio of 1.838:1. The summer flocks averaged 1.956:1 at 11 days of age and decreased to 1.744 at 41 days of age.

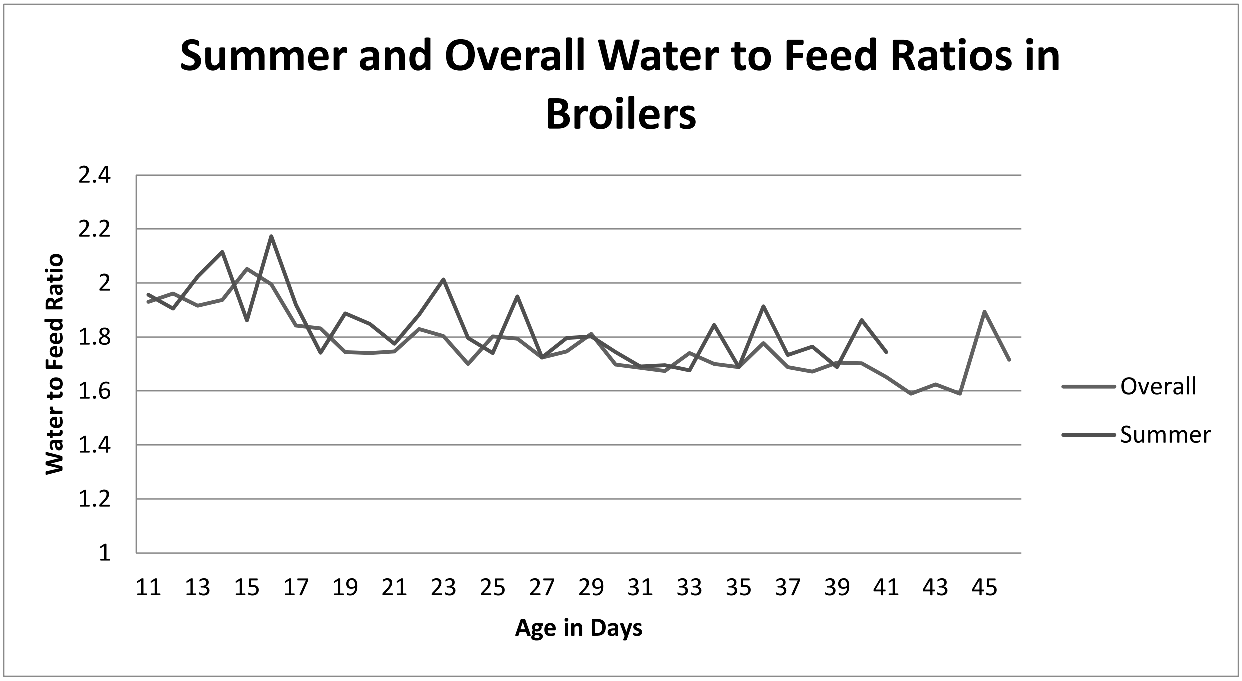

Figure 15. Summer and overall water to feed ratios in broilers

Discussion

It has been understood that, as broilers grow, their water intake decreases on a water by body weight basis. This trial demonstrated that daily water intake also decreases over the course of the flock in relationship to daily feed intake (Figure 9). There are several places on the charted line where the ratio appears to spike. There is a strong increase from 14 days of age (1.937:1) to the next day (2.0521:1). On each of the fifteen flocks, lights were dimmed from full light to 3.0 lux on the outside waterline at this time. The controllers were set so that the change was made during the rest period. When the rest period ended on day 15 (birds are 14 days old, but it is the 15th day of production), the lights were at the lower setting. Feed intake for the period of 13 through 17 days of age showed daily increases which were found to be significantly different ($P<0.0001$). The difference between the daily levels was tested using the Tukey-

Krammer HSD method. Each day was found to be significantly different than each of the others. Water intake was similarly evaluated. A significant difference was found in the water intakes over the course of the five days (P<0.0001). When the pairwise evaluations were conducted, no significant difference was found between days 13 and 14 or between days 15 through 18. The significant differences were found between those two groups, i.e. water intakes on days 13-14 are significantly different that those of days 15-18. This suggests that the change in water to feed ratio is due to the change in lighting.

There are variations in the overall curve that may be related to diet changes. As these were commercial flocks, there are not exact times and days of diet changes. In general, the flocks were budgeted similarly and feed changes occur approximately as follows:

Age in Days	**Water Intake (kg)**	**Feed Intake (kg)**
13	2374.62	1231.23
14	2535.98	1320.77
15	2963.65	1458.57
16	3293.38	1541.75
17	3184.52	1729.13

Figure 16. Daily intakes of feed and water at ages 13-17

Prestarter to starter - day 7-9

Starter to grower – day 16 – 18

Grower to Withdrawal I – day 29-31

Withdrawal I to Withdrawal II – day 34-36

It appears that there may be a relationship between the changes in diet and the changes in water to feed ratio. Certainly, additional detailed study is called for.

The last two days of the overall curve has a two day spike in water to feed ratio. Only one flock was this length of time, therefore, this data is based on only four houses of information. A review of that individual flock did not add to an understanding of the higher water to feed ratio.

The seasonal differences in water to feed ratios fell into two groups with significant differences. Summer and spring were not significantly different from one another but were different from fall and winter. Fall and winter were not significantly different from one another. There are seasonal differences in the curves that previous research suggests might be related to increased ambient temperatures results in increased water intake and feed conversions and decreased feed intakes. This is demonstrated in the winter and summer water to feed ratio chart. In the cooler portion of the year, it can be seen that the curve declines below the overall mean throughout the flock (Figure 11). The opposite relationship is evident in the summer months.

The Relationship Between Lighting Changes and Water Intake in Broilers

Abstract

An experiment was conducted to evaluate the relationship between changes in lighting and water consumption in broilers. Data was collected from six commercial broiler houses. The farms used were in three integrator complexes located in three different states. The growers recorded daily water intake, daily mortality, the volume from water line flushes and any changes in lighting. Daily water utilization was used to calculate a daily change in water consumption. Daily mortality was removed from the inventory and daily water changes per 1000 head was calculated. Daily water consumption changes per 1000 head were compared to changes in made to the lighting program. There was no significant difference in daily changes in water consumption due to changes in lighting although the P value was found to be very low (P>0.0554) indicating a possible relationship between lighting changes and water intake in broilers.

Introduction

Many producers make significant lighting changes such as turning off brood lights following the rest or dark period so birds wake up to the new light intensity. More subtle changes such as reduction in grow light intensity are typically implemented any time throughout the day. For example, while walking through a house, a grower may decide that the birds are too active and reduce the light intensity. However, little is understood about how these types of light intensity changes occurring during peak bird activity, may influence water consumption patterns. The objective of this investigation was to determine whether these changes affect water intake and consequently feed intake thus influencing overall flock performance.

During broiler grow out, the lighting program can affect bird water consumption. In operations using lighting programs with rest periods, two definitive peaks in water consumption can be observed. The initial peak can be seen just after the lights come on (dawn), and the second peak prior to the darkening of the lights (dusk). Water consumption will peak about an hour prior to darkness, indicating that the birds actually anticipate the coming dark period.

There are three aspects of lighting which are important to consider in poultry production; intensity, duration and wavelength. Light intensity or luminous flux is the measure of the perceived power of light by the human eye. It differs from radiant flux, which includes infrared and ultraviolet light. The International System of Units (SI) measurement for light intensity is lux (lx). One lux is equal to one lumen per square meter of space. Therefore, for a given amount of light, as area for that light increases, the intensity decreases. Duration refers to the ratio between the dark and light periods in which the birds may be grown. This can range from continuous lighting 24 hours per day to a ratio of light and dark. Additionally, intermittent lighting may be used. In this case, there is two or more dark periods per day. Wavelength, also known as spectral density, refers to the spectrum of visible colors within the light.

Light intensity has a strong effect on broilers. Generally, broilers will be more active in brighter conditions. Lights can be dimmed to decrease activity, improve feed conversion and limit aggressive behaviors. Buyse *et al.*, (1996) demonstrated decreased incidences of fighting, feather pecking and cannibalism as well as decreased walking and standing in birds raised at lower light intensities. It has also been shown that birds raised at higher light intensities will have decreased body weights and higher feed conversions than birds raised at lower light intensities of less than 5 lux. However, the birds raised at lighting levels in excess of 5 lux have been shown to have a decreased incidence of skeletal disorders. Berk (1995) showed that chicks under 28 days of age generally prefer brighter light. Prayitno *et al.,* (1997) concluded that broilers prefer blue or green light over red or white light.

Light duration, or photoperiod may also alter broiler performance. Much of the research in broiler lighting has investigated different lighting regimes. Most of these different regimes have been shown to improve broiler welfare as compared to near continuous lighting (Gordon, 1994). In the example lighting program (Figure 16), it can be seen that the length of the rest or dark period is related to age. As birds age, the rest period can be decreased.

The rest period or hours of dark has been shown to be as important to the broiler as the hours of light. Buckland *et al.,* (1976) grew broilers under four different lighting regimes. These lighting regimes were: 1.) Continuous light (5 to 10 lux), 2.) Intermittent lighting consisting of 1 hour of light (5-10 lux) and three hours of dark, 3.) As in regime 2 but the 3 hours of darkness

Age in Days	**Hours of Dark**
0	0
1	1
100-160 grams	9
22	8
23	7
24	6
Five days before kill	5
Four days before kill	4
Three days before kill	3
Two days before kill	2
One day before kill	1

Figure 17. Cobb Vantress Standard Lighting Program, slaughter weight: 2.5-3.0 kg

was interrupted with 13 hours of light at the same intensity, and 4). As in regime two but the 13 hours of light was at an intensity of less than 1 lux. They found that regimes 1 and 2 were significantly heavier than regimes 3 and 4. Lighting regime had no significant effect on feed conversion, percent crooked toes or mortality. The birds that were grown in regime 1, continuous light, had significantly more leg abnormalities than birds grown in any of the intermittent regimes. Classen *et al*., (2004) found that longer periods of darkness prevent regular access to feed. This results in lower feed intake and lighter weights at early ages. They also demonstrated that from days 14 to 35, averaged daily gain as well as the final weight were not affected by lighting programs. In this study, feed conversions were found to higher on a schedule of 12 hours of light (L) and 12 hours of dark (D) or two 6L:6D periods than they were on birds raised with 12 (1L:1D).

Color of light can also contribute to the performance of broilers. Birds sense light through the retinal receptors in their eyes as well as through the extra retinal photoreceptor cells in the brain. Blue light has been found to have a calming effect on birds. Red light has been shown to enhance feather pecking and cannibalism. Blue-green light stimulates growth in chickens and orange-red light stimulates reproduction (Rozenboim *et al.,*1999, 2004). Lewis and Moore (2000) showed that lights of different wavelength have different effects on the retina and can affect growth and development.

Materials and Methods

Broiler growers were selected from three different integrator complexes in three different states. All flocks were begun in a two week time frame beginning the week of January 5, 2015. For the entire flock, each grower recorded:

- daily water usage or meter readings
- mortality
- water line flushing dates and volumes
- all lighting changes

Six houses were used for the study. Of these:

- all were solid sided houses capable of tunnel ventilation
- all used a Precision PLS-7200 dimmer
- 5 had ceiling vent boards
- 1 had side wall vent boards

Mortality was tracked and deducted from the number of chicks placed to quantify daily inventories. Flush volumes were deducted from the daily water utilization total to establish an adjusted daily volume. The adjusted daily volumes were then reduced to volumes per 1000 head based on daily inventories. This was used to calculate the daily change in water intake volume. Changes in lighting, both in intensity or duration, were documented on the day the change took place. Changes in water intake on days that lighting changes occurred were measured using the day of the change and the following day. Days that the lighting program changed were labeled "Yes" and assigned the value 1. Days without lighting changes were labeled 'No" and assigned the value 0.

Statistical analysis was performed by Oneway Analysis of Variance (ANOVA) using JMP Pro 11. Comparisons of the means was conducted using Tukey-Kramer HSD and all means that were significant at the $P<0.05$ were separated. The alpha value for all analyses was 0.05.

Results

Among the six farms, there were 71 total changes in lighting. Of these, 39 were in the amount of light, 30 where changes in light intensity and two were changes in both at the same time. There were 232 days with no changes in lighting. Changes in lighting yielded a mean change of 4.5273 liters/day/1000 head (Figure 17). No change in lighting resulted in a mean daily increase of 7.9744 liters/day/1000 head. While this was not found to be statistically significant ($P>0.0587$), the low P value indicates some interaction between changes in lighting program and water consumption.

	Daily Change in Water Intake/1000 head - liters	
Changes in Lighting	**Mean**	**Std Error**
No Change	7.9745	0.9672
Changes Made	4.5273	1.3257

Figure 18. Daily change in water intake per 1000 birds, in liters

Figure 18 demonstrates the relationship between the mean daily water intake changes on each farm of days with and without lighting changes. The blue line connects the means for each farm. It can be seen that there is some variation between the farms. The variations were not found to be statistically significant (P>0.9946). No significant difference was found in daily change in water intake between farms. Individual farm analysis is listed in figure 19. When no lighting changes were made, the mean change in daily water intake ranged from 6.7210 to 9.4189 liters per 1000 head per day. On days the lighting changes were made, the change in water intake between that day and the next ranged from 2.6620 to 7.3758 liter per 1000 head per day.

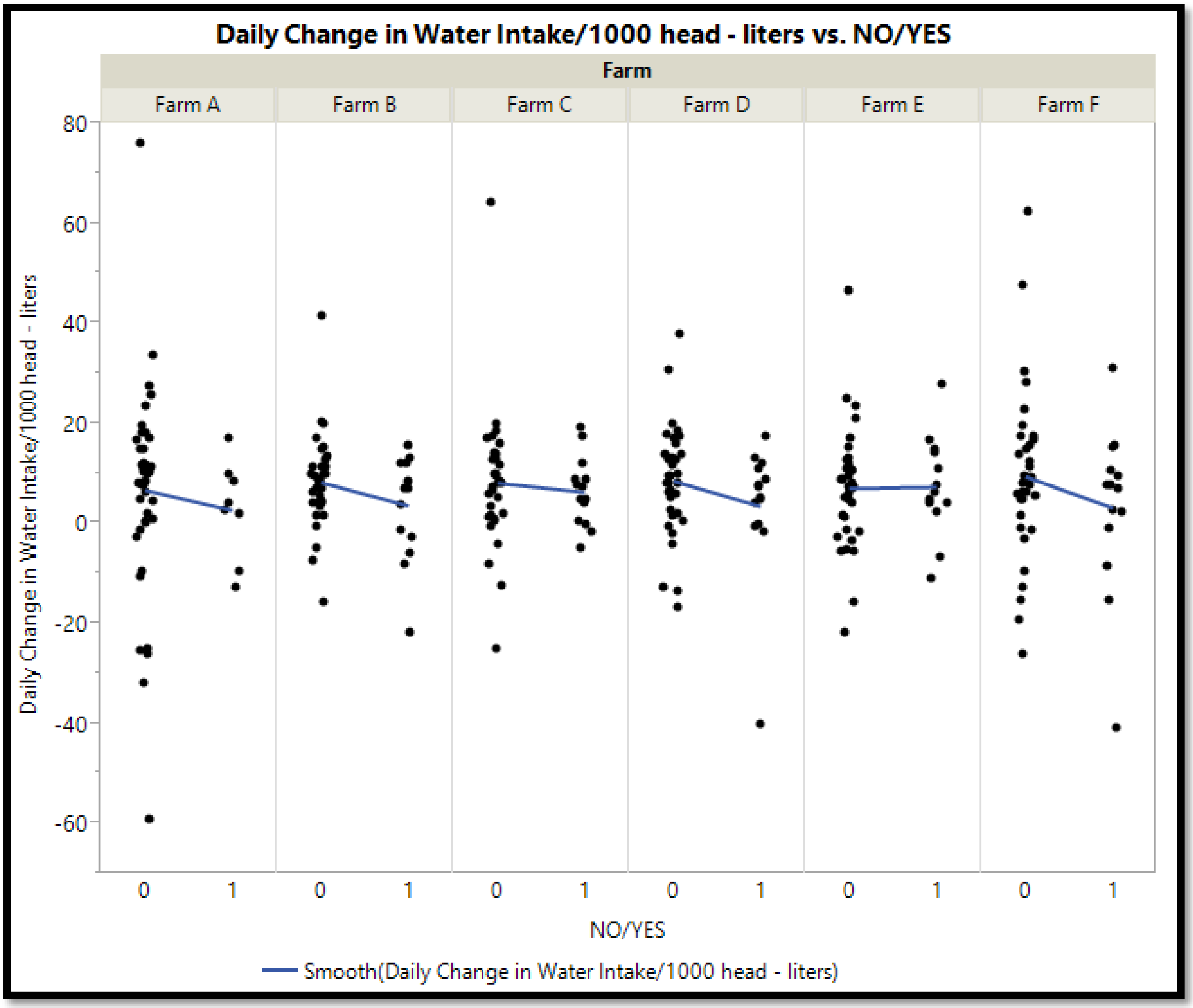

Figure 19. Daily change in water intake per farm

Discussion

The interaction between changes in lighting and water intake in broilers did not meet the α value required for statistical significance. As the P value of 0.0587 was just above the 0.05 requirement, suggests that there is a trend for lighting changes to affect water consumption in broilers. In Figure 19, it can be seen that Farm E shows an increase of 0.2908 liters/1000 head when lighting changes occur. All other farms showed decreases in water intake ranging from

1.8566 to 6.2558 liters/1000 head under the same circumstances. A review of the farm documentation offered no reason for this difference.

Daily Change in Water Intake By Farm				
	No Lighting Changes Made		**Lighting Changes Made**	
Farm	**Mean**	**Std Error**	**Mean**	**Std Error**
Farm A	**6.7210**	**2.691**	**2.6620**	**3.4803**
Farm B	**8.2812**	**1.5642**	**3.5946**	**2.8074**
Farm C	**8.1703**	**2.2563**	**6.3137**	**1.8188**
Farm D	**8.5541**	**1.8759**	**3.4589**	**3.6614**
Farm E	**7.0850**	**1.9767**	**7.3758**	**2.7846**
Farm F	**9.4189**	**2.8633**	**3.1631**	**4.5021**

Figure 20. Daily change in water in water intake per 1000 head per farm in liters

Fluctuations in water intake in broiler houses are commonly seen. Figure 20 is the daily water consumption of one house used in the trial, chosen at random. It can be seen that past day 27, water consumption not only ceases to increase, it declines on some days. Feed and water intake are highly correlated. Therefore, if water consumption is not being optimized it can be assumed that neither is feed. This would result in lower finished weights than might be obtained. This experiment sought to identify one of the contributing factors to these phenomena.

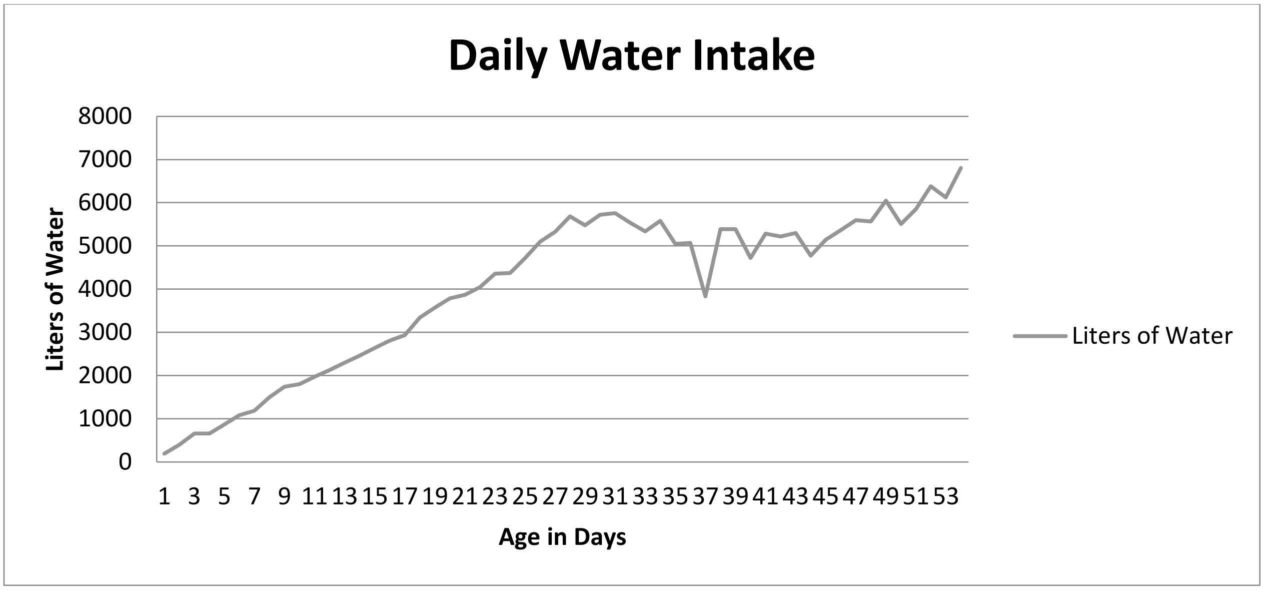

Figure 21. Water intake by days of age in broilers

The implications of the effects of lighting changes on water intake are as varied as the lighting programs used. Additionally, practices such as turning the lights back to full intensity while picking up dead may be influencing the performance of the flock. If changes in lighting cause a decrease in water consumption, lighting changes within a flock are best limited to as few as possible. In commercial broiler production, negative results are rarely the result of a single cause. More typically, it is a combination of events or practices that result in decreased performance. In the case of lighting changes and their effect on water consumption, it is probable that there are other factors at play other than lighting. The results seen in this trial indicate that further, more controlled study is required to understand the relationship between lighting changes and water intake.

Conclusion

These experiments were conducted to obtain a clearer understanding of the water consumption by broilers. The varied functions of water in the broiler serve to highlight the importance of its role in commercial broiler production. Water makes up 70-75% of the broilers weight and is the major component of the cell and the extra cellular space. In its role as the universal solvent, water carries nutrients, waste products, gases and hormones through the body. It aides in the excretion of end products, ant-nutritional factors, drugs and drug residues. Water plays a key role in the maintenance of body temperature, especially during periods of heat stress. The roles explain why water is referred to as the most important nutrient.

Previous research has established the importance of both water quantity and quality in broiler production. The research reported here adds to that understanding. The investigation into water consumption during peak water demand quantified the number of birds drinking in the first hour of the light period. While the number of birds consuming water increases over that first hour, never did 100% of the birds consume water during the first hour of the day, indicating that it may take longer than an hour for the whole flock to eat and drink. This experiment also suggested part of a possible solution to the fluctuation in water intake seen at the end of many flocks.

The investigation into broiler water consumption during pre-slaughter feed withdrawal provides documentation of the changes in both percentage of birds drinking and amount of water consumed during feed withdrawal. This information could prove valuable for intervention strategies using water as a carrier prior to slaughter.

The third experiment quantified the daily relationship between water and feed intake in broilers over the course of three years. This information may serve to make water consumption more predictable. If used with feed consumption tables provided by primary breeders, expected water utilization rates can be calculated. This information can be used to estimate production parameters such as growth rate and as an overall indication of flock health.

The investigation into the effect of lighting changes on water consumption suggests that changes in lighting affect the water intake rates in broilers. Further study in a more controlled environment is required to complete this evaluation.

The importance of water in commercial broiler production cannot be underestimated. The evolution of nipple drinker systems and the increasing importance of water quality are two examples of the ongoing changes within the industry. It can be expected that the current understanding of water in broiler production will continue to evolve and change resulting in improved performance and animal wellbeing.

Agricultural water use faces many challenges today. Recent severe droughts in California and Texas and a growing urban population and food demand are a couple of examples. As more and more demands are placed on water available for agricultural use, efficiency in its use will become critical to success. Water utilization in poultry production and processing will be key to the continued growth of this industry.

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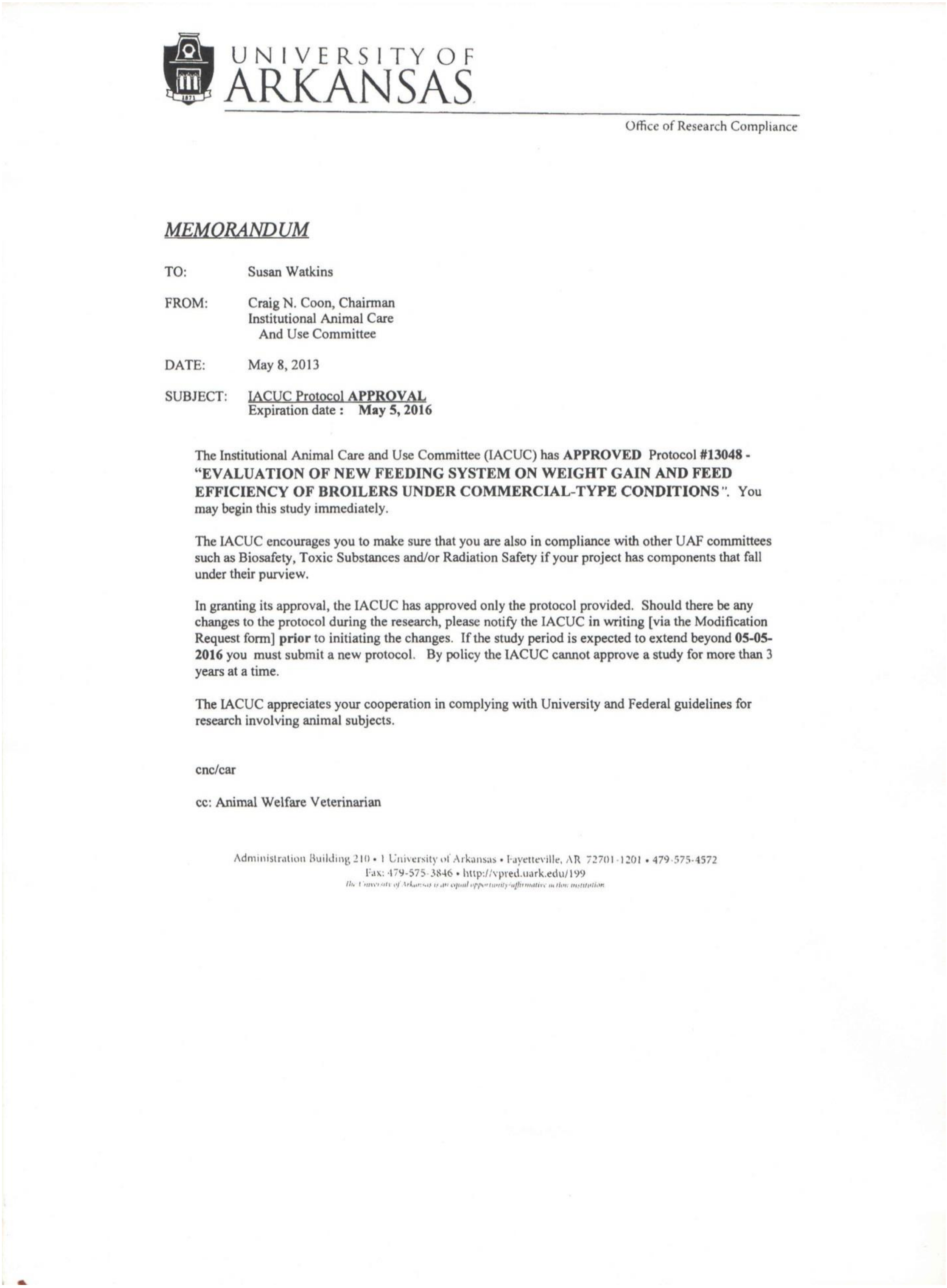
Appendix



UNIVERSITY OF
ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: Susan Watkins

FROM: Craig N. Coon, Chairman
Institutional Animal Care
And Use Committee

DATE: May 8, 2013

SUBJECT: IACUC Protocol **APPROVAL**
Expiration date : **May 5, 2016**

The Institutional Animal Care and Use Committee (IACUC) has **APPROVED** Protocol **#13048 - "EVALUATION OF NEW FEEDING SYSTEM ON WEIGHT GAIN AND FEED EFFICIENCY OF BROILERS UNDER COMMERCIAL-TYPE CONDITIONS"**. You may begin this study immediately.

The IACUC encourages you to make sure that you are also in compliance with other UAF committees such as Biosafety, Toxic Substances and/or Radiation Safety if your project has components that fall under their purview.

In granting its approval, the IACUC has approved only the protocol provided. Should there be any changes to the protocol during the research, please notify the IACUC in writing [via the Modification Request form] **prior** to initiating the changes. If the study period is expected to extend beyond **05-05-2016** you must submit a new protocol. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines for research involving animal subjects.

cnc/car

cc: Animal Welfare Veterinarian

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