THE EFFECT OF PEN SIZE ON WATER TO FEED RATIO OF BROILER CHICKENS

by

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(Under the Direction of Brian D. Fairchild)

ABSTRACT

Two trials were conducted where the same numbers of Cobb male chicks were assigned to floor pens of three different sizes (20, 30, and 40 $ft^2$). Each pen contained 33 chicks and each size of pen was replicated 6 times. In Trial 1, week 4 and 5 water:feed ratio (WFR) increased as pen size decreased ($P<0.05$) with the 20 $ft^2$ pens having a higher WFR than 40 $ft^2$. Week 28 WFR of 20, 30, and 40 $ft^2$ pen sizes was 1.98, 1.91, and 1.88 respectively while Week 5 WFR of 1.91, 1.86, and 1.81 respectively. The variable results in Trial 1 being used and it was decided that new nipples and regulators caused an evaluation of drinker systems. No significant difference in WFR was observed during Trial 2. These data suggest that pen size does not influence WFR and thus may not be an issue for consideration in broiler research.

INDEX WORDS: pen size, water usage, feed consumption

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# CHAPTER 1

# LITERATURE REVIEW

## Importance of water usage on broiler chickens

Water is a critical nutrient for poultry and represents 70-80% of the bird's body mass (Romanoff and Romanoff 1949). It is vital to feed movement, temperature balance, organ and joint lubrication. Broilers cannot live without it for more than a few days (Brommage 2003; Medway and Kare 1959; Kellerup et al. 1965; Annual Report. 1992). Because of its crucial nature, all of the factors that affect water intake in broilers must be taken into account. Those factors affecting water intake include water availability, water quality, environmental temperature and humidity, lighting program, gender, feed availability, genetic selection, management, and diet composition (Fairchild and Czarick 2006; Romijn and Lokhorst 1966; Fussell 1990). In general, it is important to monitor water consumption because it can be an indicator of growth and health. One of the most important reasons to monitor water intake is because of the correlation between it and feed consumption (Hemel and Meyer 1969; Zeigler et al. 1972; Marks 1981). Water consumption strongly reflects broiler performance, thus producers need to have an accurate idea of water intake in order to monitor the productivity of their flocks. Water usage increases as broilers grow. Pesti et al. (1985) stated that consumption might be estimated by multiplying a bird's age in days times 5.28 grams. Water usage was later measured by Brake et al. (1992) and was found to be twice that of Pesti et al.

$$\text{Water consumption} = 9.73 + 6.142x$$
$$x = \text{bird age (day)}$$

Daily water intake is an important indicator for many reasons, such as the bird's health, welfare, feed digestion, livability, performance and metabolism (Kellerup et al. 1965; Lepkovsky et al. 1960; Williams 2013). The absence of water impairs the digestion rate in broilers (Kellerup et al. 1965), and this impairment leads to slow growth, poor feed conversion, and eventually death (Kellerup 1965; Lepkovsky et al. 1960). Furthermore, high mortality and dehydrated shanks have been reported due to low water availability (Marble and Jeffrey 1955). Marks (1981) and Ferket and Gernat (2006) found that water restriction had greater negative effects than feed restriction on feed conversion. The relationship between feed and water is strong, and thus any impact on water consumption almost invariably impacts feed consumption. Many studies have shown that when healthy birds consume more water, feed consumption also increases (Brake 1992; Dozier et al. 2002; Balogun 2013). Growers typically monitor daily water intake using water meters, so feed consumption and performance of a flock can be easily predicted (Czarick and Lacy, 2001). Xin et al. (1994) demonstrated the relationship between a bird's age and water intake by using this equation:

$$\text{Water consumption} = (-2.79 + 4.70D + 0.128D^2 - 0.00217D^3) \times 0.26$$
$$D = \text{bird age (day)}$$

The relationship between water and feed intake has been reported to be 1.8 lb. of water to 1 lb. of feed (Czarick and Lacy, 2001; Fairchild and Ritz, 2012). Others have reported broiler water consumption at least twice the amount of feed consumption (Hoerr, 2001; Lacy, 2002; Ferket and Gernat 2006). The water usage of chickens is sensitive to different factors, including environment (Fairchild 2006; Ferket and Gernat 2006; Belay and Teeter 1993), feed composition (Belay and Teeter 1993), and water quality (Barton 1996).

**Nutritional factors affect water usage**

Diet composition can have a significant effect on water consumption. According to Ferket and Gernat (2006), feed that is excessively high in dietary salt will stimulate increased water consumption while reducing feed intake. This increased water consumption occurs because the increase in dietary salt and other osmotically active minerals requires additional water to flush excess minerals from the body through the kidneys (Marks 1987 and Ziaei et al. 2008). A 2.4% addition of salt to the feed significantly increases water consumption (Marks and Washburn 1983; Darden and Marks 1985; Gomes et al. 2008). Similarly, increasing the dietary crude protein in feed causes a corollary increase in water consumption and in water to feed ratios (Marks and Pesti 1984). The energy content (calories) in feed also affects water intake (Leeson et al., 1996).

**Nutritional factors affect feed consumption**

Feed composition has a significant effect on chickens' consumption of feed and water. A dry feed with a high salt level may decrease feed consumption while increasing water intake. According to Darden and Marks (1985), the dietary salt level has varying effects on feed consumption; in some birds, high dietary salt (3.2%) did not have an effect on feed consumption, whereas in other birds it had a negative effect on feed consumption and body weight. High levels of dietary mineral levels in feed will reduce feed consumption in broilers. In contrast, mineral deficiencies in feed will not affect chickens' appetite levels unless the deficiencies continue for a prolonged period (Ferket and Gernat 2006). Dietary energy content exercises the most predictable effect on meat birds' feed intake. Feed intake will increase in inverse proportion to dietary energy content until intake is limited by either gut fill or other physiological limitations (Ferket and Gernat 2006). Dietary protein and amino acid content also have an impact on feed intake, but these are more indirect effects than that caused by changes in energy content (Boorman 1979 and Hurwitz et al. 1980).

**Nutritional factors affect water to feed ratio**

Water to feed ratio has also been reported to affect abdominal fat in chickens. Studies have shown that birds with lower water to feed ratios have more abdominal fat than birds with higher water to feed ratios. Therefore, the amount of abdominal fat is inversely related to water to feed ratio, as seen in two commercial broiler stocks that were fed with high salt diets to increase the water to feed ratio (Marks and Baik 1994; Marks and Washburn 1983). Similarly, high protein diets have also been shown to reduce abdominal fat levels and increase water to feed ratio (Marks and Pesti 1984).

A higher amount of dietary soybean oil also increases the water to feed ratio (Glista and Scott 1949). Higher soybean oil concentration increases the water consumption in birds, which leads to a higher water to feed ratio. Dietary proteins tend to have similar effects on water to feed ratio in birds as soybean oil. High protein diets increase water to feed ratio in chickens by increasing water usage.

In addition to dietary ingredients, the physical properties of feed also affect the water consumption. It has been reported that when chickens are fed crumbled feed, they have higher feed and water consumption compared to when they are fed with mashed diet. However, the water to feed ratio remains the same whether they eat pelleted feed or crumbled feed (Marks and Pesti 1984).

**Water quality factors affect broiler performance**

Water quality is also critical for chickens, and they should be clean, and fresh, and water (Donald et al., 2000; Fairchild 2008). The quality and cleanliness of water impacts broiler's health and growth with both direct and indirect effects. It could have direct impact on the digestive system and bird performance. The indirect effect on bird performance can be through the drinker system. Poor water quality could cause increases water leakage from the drinker lines, which would cause increased ammonia levels due to wet litter (Fairchild et al., 2006). The high ammonia levels decrease bird performance (Bell, 2002; Miles et al. 2004). Water pH less than 7.0 helps to decrease bacteria proliferation (Oviedo, 2006). In fact, slightly decreasing pH is acceptable for poultry drinking water (Dozier et al. 2002; Kare, 1970; Tabler et al., 2013). Electrolytes such as magnesium (Mg), sodium (Na), calcium (Ca), potassium (K), and chlorine (Cl) are important for nerve and muscle functions. However, improper levels of these electrolytes may affect water lines and bird performance (Bell, 2002). Water taste may impact water and feed intake (Kare and Pick 1960).

**Health effects on water usage, feed consumption, and water to feed ratio**

Bird health is also one of the factors affecting water to feed ratio, but there are conflicting reports on its effects. It has been observed that even when a bird is suffering from coccidiosis its water consumption does not decrease whereas feed consumption does (North 1984; Jones 1957). However, other studies have shown that when a chicken is sick, both water and feed consumption decrease but the water to feed ratio itself remains the same (Reid and Pitois 1965).

**Environmental factors affect water usage, feed consumption, and water to feed ratio**

Environmental factors such as temperature has significant influence on the bird's water consumption patterns. Water usage increases approximately 7% for each one degree Fahrenheit increase above the bird thermoneutral temperature (NRC, 1994). In addition to the environmental temperature, water temperature can also influence broiler water intake. Birds will drink water that has a temperature close to freezing and will suffer from extreme thirst rather than drink water that is a degree or two above their body temperature. The relative humidity also influences broilers' water intake (Ferket and Gernat 2006).

Temperature is an important factor for broiler production. Chickens' body temperatures increase with high ambient temperatures. This increase results in decreased feed intake (Payne, 1967). Generally, for every pound of feed eaten, a bird drinks 1.8 pounds of water (Fairchild and Czarick 2006). This value slightly changes during warm weather because birds drink more water to keep their body cool. Therefore, water to feed ratio for birds varies from around 1.5:1 in winter to 1.77:1 in summer (Czarick et al., 2001). Feed consumption in healthy chickens decreases when the temperature is higher than 20°C. However, water consumption does not increase until temperatures reach 25°C (Romijn and Lokhorst 1966; Fussell 1990). Barott and Pringle (1947, 1949, 1950) altered the temperature in a series of experiments on Rhode Island Red chicks from 1-32 days old, beginning with a temperature of 35°C and ending with a temperature of 18°C. Their study showed that in Rhode Island Red chicks, the water to feed ratio is not constant from 1 to 32 days of age, and the water to feed ratio value ranges between 1.56 and 1.76. In the case of Rhode Island Red chicks, there was no correlation of water to feed ratio with age, temperature or humidity (Barott and Pringle 1947, 1949, 1950).

**Lighting program factors affect water usage**

Light exposure has an effect on water usage. During dark periods, bird water consumption and activity stop (Classen, 2004a; Fairchild and Czarick 2006). Prior to enclosed housing and modern production practices, chickens received natural light from the sun, behaviorally; the activity of chickens and their water demand increase at sunrise and before sunset (Classen, 2004a). Today, birds raised with a controlled artificial lighting program behave like those exposed to natural lighting. Birds learn and respond quickly to lighting patterns and any changes of the light schedule may result in a change in the birds' pattern of water intake (Czarick 2002; Ferket and Gernat 2006; Tabler et al., 2012). Simply stated, water usage increases when birds are active (Simmons, 1982; Simmons and Haye, 1985).

**Lighting program factors affect feed consumption**

In broiler houses, the consumption of feed and water spikes before and after photoperiodic cycles (Ferket and Gernat 2006; Fairchild and Czarick 2006). Light has three different aspects: intensity, duration, and wavelength. The intensity, color, and photoperiodicity of light affect broiler chickens' physical activity and feed consumption (Lewis and Morris 1998). In fact, short photoperiods in early life reduce chickens' feed intake and limit their growth (Classen 2004a; Gordon 1994).

**Management factors affect water usage and water to feed ratio**

**Drinker lines**

Water line height, water pressure, drinker design, drinker placement, drinker maintenance, and stocking density all can affect water usage (Fairchild and Czarick 2006; Ferket and Gernat 2006). Uneven water lines and as well as dirty filters may impact water pressure. High water pressure may increase wastage and may lead to poor litter quality. A change in bird water usage can be a good indicator of a management issue (Fairchild and Czarick 2006). It may be preliminary indicator that producers may observe before chickens experience health issues, low production, and mortality.

Recent studies have shown that water to feed ratio also varies between the farms where the broilers are raised. Different aspects of the farm, such as drinker type, breed, water availability, site management and housing environment vary between farms and these variations also play a role in total water intake (Balogun 2013; Manning et al. 2007). It has been reported that the water to feed ratios vary among nipple drinkers without cups, nipple drinkers with cups and bell drinkers with ratios of between 1.6:1, 1.7:1 and 1.8:1 respectively (Ross Breeders, 1999). According to Williams et al. (2013), the water to feed ratio was 2.01 and 1.98 in 2001 and 1991, respectively. The water to feed ratio could also be different between the farms because of the size of the birds grown, their breed, density, and other environmental factors.

**Feed availability**

Feed availability plays a role in broiler performance. Giving chicks access to water three hours prior to feed when placed in the house is helpful in preventing or diminishing dehydration (North 1984). Knobloch and Siegel (1970) found that chickens given water before feed gained more weight than those that had access to feed and water at the same time. In addition, if chicks were given feed first, they gained less than those given a choice of water first or both (Twining 1978). Marks (1985) also found that the differences in the growth rate are affected by water and feed intake.

**Stocking density affects feed consumption**

Stocking density affects feed intake. High stocking density may result in low feed intake because of the high competition of feeder space, which lowers the time available for chickens to consume feed as needed. Shanwany (1988) suggested that physical access to feed and water is impeded when stocking density is too great, resulting in low feed intake. Fairchild 2002 found similar performance issues associated with high stocking density. If birds have to travel farther to access the feeder, or if space at the feeders is limited, feed intake will likely be negatively affected (Feddes et al. 2002). High stocking density decreases body weight gain, feed intake and feed conversion ratio (Dozier et al. 2006; Estevez 2007; Asaniyan 2014).

Although higher water to feed ratio in birds with higher stocking density could be due to lower feed consumption, water to feed ratio is still higher in those chickens (Feedes et al. 2002 and Dozier et al. 2006). The water to feed ratio of birds in high stocking density conditions has been shown to be around 1.93, whereas birds in low stocking density conditions have a water to feed ratio of 1.83 (Balogun et al., 1997).

**Water restriction affects water usage**

Water to feed ratio is affected by many factors, but it is likely that water restriction is not among them. When chicks were restricted from water consumption for certain periods in a day, they compensated for the lack of water consumption by drinking more water when they again had access to it, resulting in no overall difference in water to feed ratio compared to the controls with unlimited access to drinking water (Kellurup et al. 1965).

**Genetics affect water usage and feed consumption**

Water consumption in broilers has increased over the past 20 years and genetic selection is considered to be the major cause of this increase. Commercial broilers now gain more weight and have improved feed efficiency because they have been selected for fast growth (Williams et al. 2013). Genetic improvement has changed birds' appetites and feed efficiency (Lepore 1965). Body weight selection has a relationship with feed intake and appetite (Siegel and Wisman 1966). A genetic correlation of 0.71 has been reported for weight gain and feed conversion in broilers (Pym and Nichols 1979).

**Strain affects water to feed ratio**

Different breeds have different water to feed ratios. For example, the water to feed consumption ratio is estimated to be around 1.54 for young Rhode Island Red chicks (Barott and Pringle 1949) while the estimated ratio for White Leghorn females 1 to 16 weeks of age is 2.4

(Medway and Kare 1959). The water to feed ratio has changed over time even within strains. In the case of commercial broiler stocks, it was estimated that the water to feed consumption ratio ranged from 1.6 to 2.6 among randomly bred broiler stocks in the 1950s, whereas the ratio ranges from 1.8 to 2.34 among commercial broilers (Marks 1981).

To conclude, the volume of water consumed by birds is dependent on many different and cumulative factors. The water to feed ratio is the result of the interaction of all those factors acting on the chicken such as genetics, nutrition, drinker design and management.

# CHAPTER 2

## OBJECTIVE

Water and feed consumption are strongly related to each other, and understanding this relationship helps poultry producers and researchers to better manage bird performance. Water to feed ratio factors have been reviewed and current information on the effect of pen size effect on broiler water to feed ratio on broiler is limited. Therefore, the primary goal of this study was to investigate the effect of different pen sizes on water to feed ratio in broiler chickens.

# CHAPTER 3

# MATERIALS AND METHODS

**Chicks and housing management**

Three different pen sizes of 20, 30, and 40 $ft^2$ were utilized with each pen containing 33 birds. The bird density was 0.6, .91, and 1.2 $ft^2$/bird for the 20, 30 and 40 $ft^2$ pens respectively. There were six replicates for each pen size. The three pen sizes were distributed in the room and chicks were placed in each pen. In both trials, the room size was 45 by 32 feet. The house had sidewall inlets and three exhaust fans (two 24", and one 36"). In addition, four circulation fans were running during both trials to provide continuous circulation air. No evaporative cooling system was used. Overhead lighting was provided by 4 rows of 24 incandescent lights spaced 9 feet from each other. A Chore-Tronics-Model 16 controller was used to control the temperature and lighting program.

Chicks were Cobb 500 by-product males. Chicks used in Trial 1 were from a 39 wk old breeder flock. Chicks used in Trial 2 were from a 37 wk old breeder flock. Trial 1 ended at 32d, and Trial 2 ended at 35 d.

Each pen was equipped with a single Ziggity TLMax3 drinker line with 3 nipples/pen (Ziggity Systems, Inc., Middlebury, IN). A hanging tube feeder was placed in each pen with one supplemental feed tray, which was removed at day 7. The space between the drinker and feeder in each pen was two feet. Feed and water were provided *ad libitum* throughout the study. Birds were fed a crumbled starter feed from day 0 to 14. A pelleted grower diet was fed for the remainder of the study. Diets were standard broiler diets with the starter feed consisting of 22% protein and 3050 kcal/kg energy and the grower having 20.5% protein and 3150 kcal/kg energy

(Table 1).

Water was supplied to each pen drinker line by a 6-gallon carboy attached to a plastic water tube with quick-disconnect couplets (Koolance, Auburn, WA). Each carboy was elevated five feet from the ground to generate sufficient water pressure (2-6' wc) to supply the drinkers. Drinker pressure and height were adjusted according to the manufacturer's guidelines. All pens had the same water pressure and height throughout the experiment. Water and feed consumption were weighed daily.

In Trial 1, pen weights and feed conversions were measured on days 1, 7, 14, 21, 28, and 32. In Trial 2, pen weights and feed conversions were measured on days 1, 7, 14, 21, 28, and 35. Pens were checked daily for bird mortality and the weight of dead birds was used to calculate the adjusted feed conversion. Individual birds were weighed in three pens from each treatment at the end of Trial 2.

Nipple static flow rate was measured (Lott et al., 2003) at the end of Trial 1 by activating the nipples for a minute (mL/min). This indicated a high variation in water flow from individual nipples within and between pens. In Trial 2, new Ziggity nipples and regulators were installed to provide a uniform nipple flow rate.

The lighting program was maintained according to the Cobb Broiler Management Guidelines (Cobb-Vantress, 2013). The first two days, the birds received 24 hours of light at an intensity of 30 lux. From Day 3-6 the birds received 22 hours of light and 2 hours dark, from Day 7 through the end of the study, the birds received 20 hours light and 4 hours of darkness. On Day 10 light intensity was decreased to 5 lux and was held at this level for the rest of the study. A light intensity meter (General Digital Light Meter, model UA-002-64) was used at the beginning of each trial to measure the light intensity at floor level inside the pens.

The house temperature was maintained according to the primary breeder (Cobb-Vantress, 2013). Brooding temperature started at 93°F and was decreased 1°F each day until 70°F was reached 28 days of age. Temperature was retained at this level until the end of the study. Temperature/relative humidity data loggers (HOBO Pendant model UX90-004M) were placed in the front and back seven feet from either wall of the house end recorded data every 15 minutes. The data were downloaded from the data logger twice a week.

**Data analysis**

The water usage (ml/bird/day), feed intake (g/bird/day), water to feed ratio (WFR), bird body weight gain (g/bird/week), and feed conversion ratios (FCR) were analyzed weekly using analysis of variance. The treatment means of variables that were significant were separated using Tukey's test (JMP PRO 11, 2013). Significance was based at $P \leq 0.05$. Coefficients of variation were calculated to determine bird uniformity only at the end of the Trial 2. Data were then analyzed adding NFR as an independent variable (Tables 2, 3, and 4). No significant differences in water usage, feed consumption, FCR, and BW were observed throughout the study (Tables 2, 3, and 4). In Trial 1, two models of analysis used for BW, FC, FCR, WU, and WFR. Model 1 in Table 2 and 3 represents only the treatment (pen size) as a variable, while Model 2 use treatment and nipple flow rate (NFR) as the main effects. The correlation between WFR and NFR was analyzed using JMP.

Table 1. Composition of starter and growing diets in Trial 1 and 2 (%, as fed)

| Ingredient | Starter (1 to 14 d) | Grower (14 to 35 d) |
|---|---|---|
| Corn | 56.07 | 60.74 |
| Soybean meal | 37.47 | 32.59 |
| Poultry fat | 3.07 | 3.43 |
| Salt | 0.29 | 0.32 |
| Limestone | 0.73 | 0.78 |
| Dical Phos. | 0.00 | 0.00 |
| Def. Phos. | 1.75 | 1.56 |
| Trace mineral | 0.07 | 0.07 |
| Vitamin | 0.25 | 0.25 |
| DL-Meth. | 0.20 | 0.17 |
| Coban 60 | 0.07 | 0.07 |
| BMD 50 | 0.01 | 0.01 |
| Total | 100 | 100 |
| **Calculated analysis** | | |
| ME, (kcal/kg) | 3050 | 3117 |
| Crude Protein (%) | 23 | 21 |
| Lys (%) | 1.25 | 1.12 |
| Met (%) | 0.55 | 0.49 |
| Cys (%) | 0.37 | 0.34 |
| TSAA (%) | 0.92 | 0.84 |
| Threonine (%) | 0.90 | 0.82 |
| Available Phosphorus (%) | 0.15 | 0.14 |
| Calcium (%) | 0.95 | 0.90 |

CHAPTER 4

RESULTS AND DISCUSSION

**Temperature and relative humidity data**

The 15-minute temperature data for both Trials were graphed from each logger to compare their readings (Figure 1, 2). Both temperature loggers in each Trial were analyzed for correlation. The data showed no significant differences ($p<0.001$) between two loggers with a correlation of (0.99), indicative of no differences in temperature within the house. An average daily temperature and RH were graphed for both Trials (Figure 3).

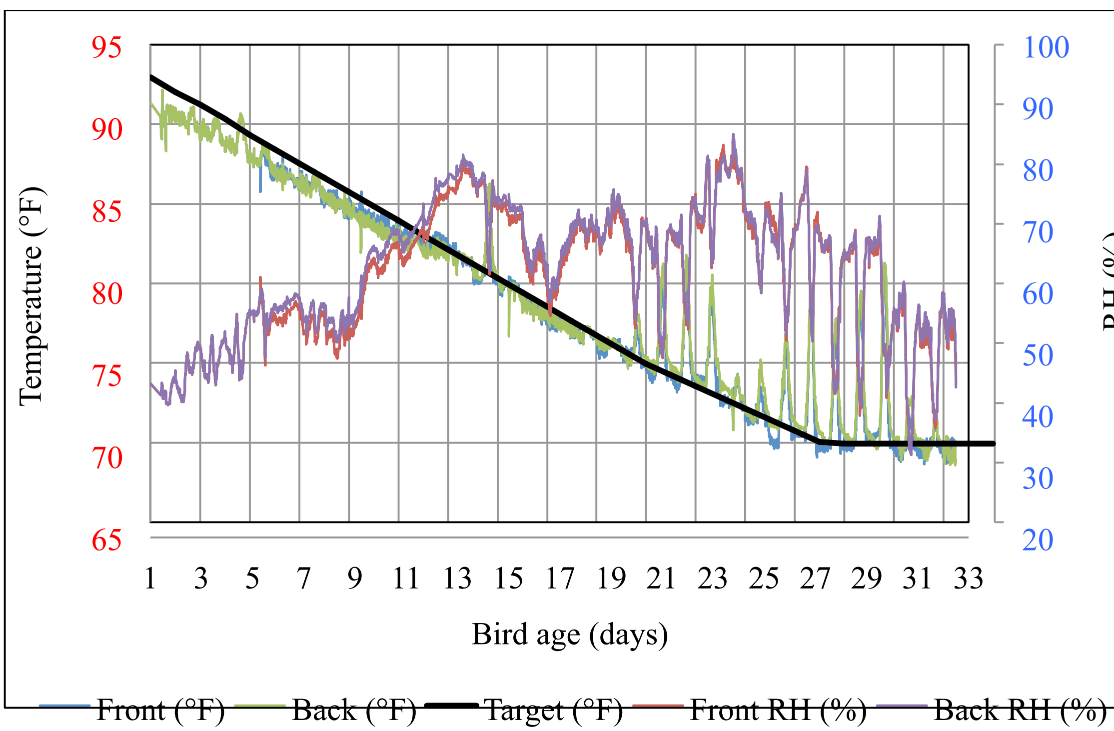


Figure 1. Trial 1 Temperature Front-Back (°F) and relative humidity (%) (15 min.)

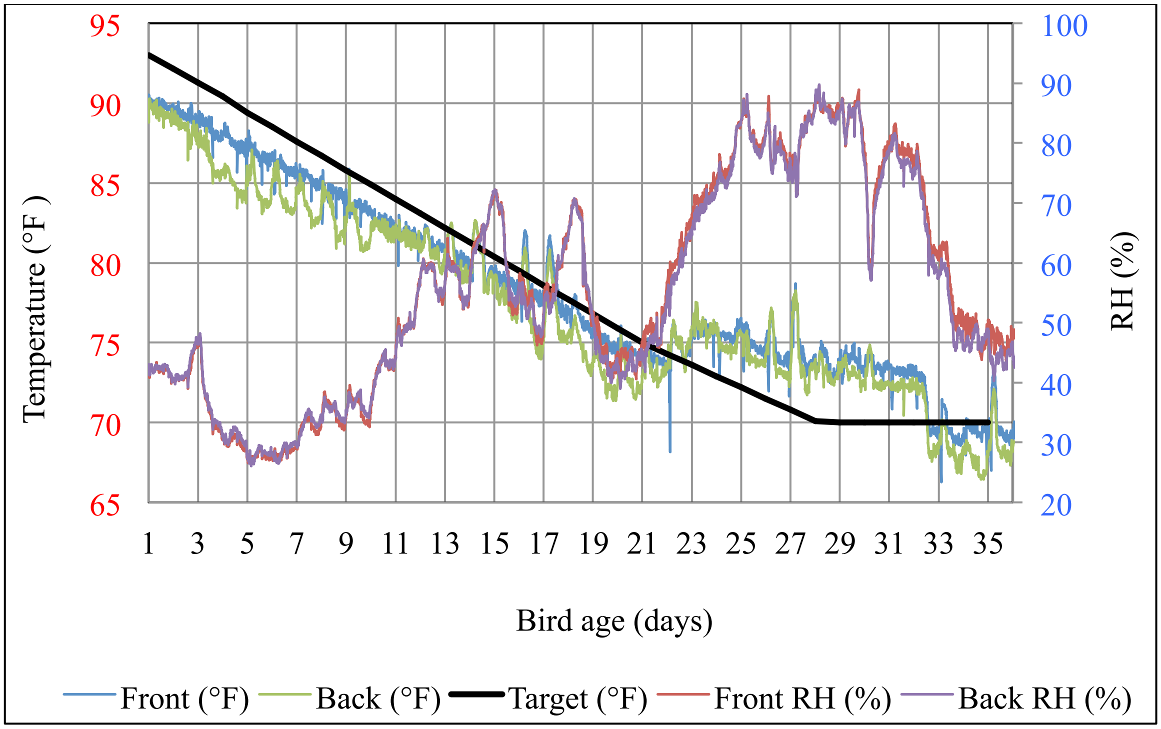


Figure 2. Trial 2 Temperature Front-Back (°F) and relative humidity (%) (15 min.)

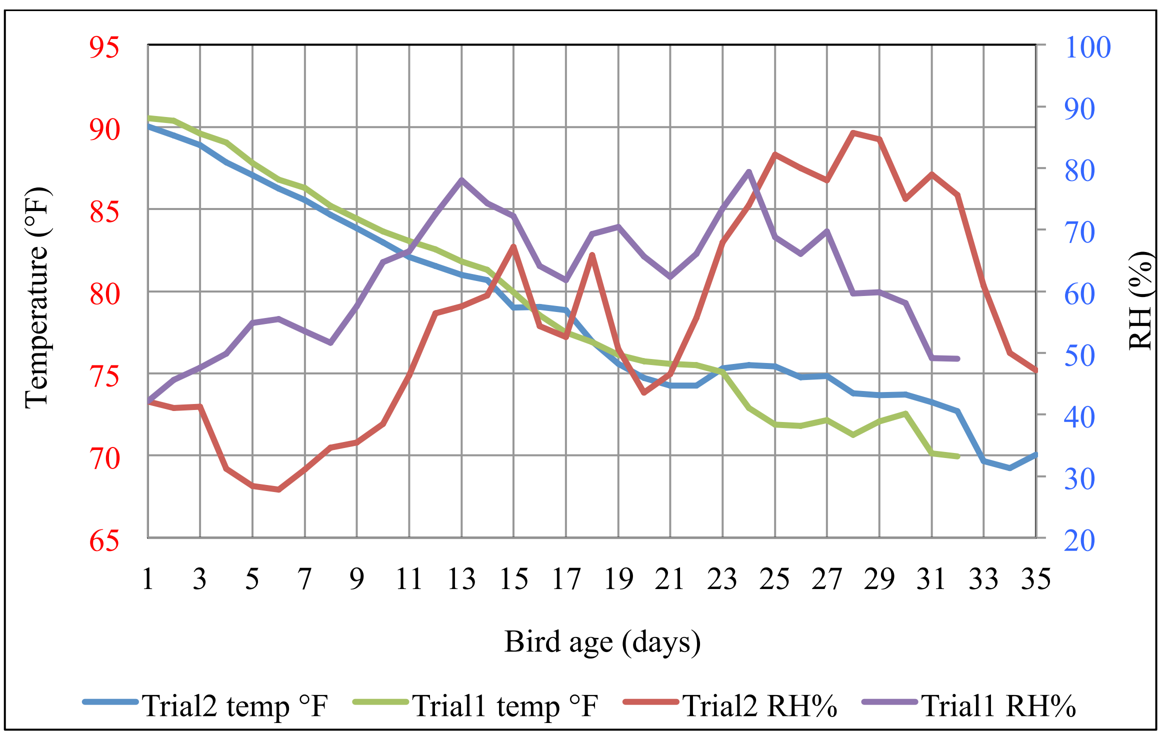


Figure 3. Trial 1, 2 Daily house temperature (°F) and relative humidity (%)

**Pen size and bird performance (Trial 1)**

There were no significant differences in BW among pen sizes at Day 7, 14, and 21 (Table 2). On Day 28, the birds raised in the 20 $ft^2$ pens showed the lowest BW (1,539 g) compared with the 30 $ft^2$ (1,615 g) and 40 $ft^2$ (1,605 g) pens ($p<0.05$). On Day 32, BW of the 20 $ft^2$ pens (1,879 g) were lower than the 30 (2,014 g) and 40 $ft^2$ (1,997 g) pens ($p<0.05$). There was no statistical difference between the 30 and 40 $ft^2$ pens in either the fourth and fifth week.

The significant difference in BW between the 20, 30, and 40 $ft^2$ pens was likely due to different stocking densities. High stocking densities have a negative effect on BW because FC and WU decreases due to the physical access to feed and water being impaired (Feddes et al. 2002; Nahashon et al., 2009; Shanawany 1988).

Table 2. Trial 1 average weekly body weight (BW) (g/bird) of birds raised in different pen sizes.

| | Pen size | Age (days) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 7 | 14 | 21 | 28 | 32 |
| | 20 $ft^2$ | 41 ± 0.3 | 179 ± 2 | 478 ± 6 | 971 ± 12 | 1,539 ± 13 $^{b}$ | 1,879 ± 16 $^{b}$ |
| | 30 $ft^2$ | 41 ± 0.6 | 180 ± 3 | 489 ± 7 | 981 ± 8 | 1,615 ± 11 $^{a}$ | 2,014 ± 17 $^{a}$ |
| | 40 $ft^2$ | 41 ± 0.4 | 183 ± 1 | 486 ± 3 | 987 ± 6 | 1,605 ± 21 $^{a}$ | 1,997 ± 32 $^{a}$ |
| BW | $\bar{X}$±SEM | 41 ± 0.2 | 181 ± 1 | 484 ± 3 | 979 ± 5 | 1,586 ± 12 | 1,963 ± 19 |
| | **Model1** | | | | | | |
| | TRT | NS | NS | NS | <0.05 | <0.05 | <0.05 |
| | **Model2** | | | | | | |
| | TRT | NS | NS | NS | NS | NS | NS |
| | NFR | NS | NS | NS | NS | NS | NS |

$^{a,b}$Means (± SEM) within a row with different superscripts significantly different ($p<0.05$) (n=6)

There were no significant differences in BWG, FC or FCR among pen sizes at Day 7, 14, and 21 (Table 2). On Day 32, the BWG was significant lower in the 20 $ft^2$ (345 g) pens than 30 $ft^2$ (405 g) pens and 40 $ft^2$ (392 g) pens. There was no significant difference between 30 $ft^2$ and 40 $ft^2$. On Days 28 and 32, the FC (g/day) was lower ($p<0.05$) in the 20 $ft^2$ pens than in the 30 and 40 $ft^2$ pens (Table 3). However, FC in the 30 $ft^2$ pen was not statistically different from the 40 $ft^2$ pen. FC decreased as stocking density increased likely due to the restricted access to water and feed (Shanawany 1988). On Day 32, FCR in the 30 $ft^2$ and the 40 $ft^2$ pens was 1.69 and 1.70, respectively, which was better ($p<0.05$) than birds raised in the 20 $ft^2$ pen 1.83 (Table 2). The FCR of birds in the 40 $ft^2$ pen did not differ statistically from those in the 20 or 30 $ft^2$ pens. The birds' FCR became more efficient as densities decreased, which agreed with Bilgili and Hess, 1995. Trial 1 mortality was 1% (20 $ft^2$), 3% (30 $ft^2$), and 1% (40 $ft^2$). There was no significant difference in mortality among pen sizes.

Table 3. Trial 1 average weekly body weight (BWG) (g/bird), feed consumption (FC) (g/bird), and feed conversion ratio (FCR) of birds raised in different pen sizes.

| | Pen sizes | Age (day) | | | | | Cumulative |
|---|---|---|---|---|---|---|---|
| | | 7 | 14 | 21 | 28 | 32 | |
| | $20ft^2$ | 138± 2 | 299± 5 | 494± 7 | 615± 51 | 345± 10 [b] | 1891± 44 |
| | $30ft^2$ | 139± 3 | 306± 3 | 497± 3 | 630± 9 | 405± 7 [a] | 1977± 18 |
| | $40ft^2$ | 141± 1 | 303± 2 | 502± 3 | 617± 19 | 392± 14 [a] | 1956± 31 |
| BWG | $\bar{X}$± SEM | 140± 1 | 303± 2 | 498± 3 | 621± 17 | 381± 9 | 1941± 20 |
| | **Model1** | | | | | | |
| | TRT | NS | NS | NS | NS | <0.05 | NS |
| | **Model2** | | | | | | |
| | TRT | NS | NS | NS | NS | NS | NS |
| | NFR | NS | NS | NS | NS | NS | NS |
| | $20ft^2$ | 149 ± 1 | 384 ± 5 | 727 ± 10 | 964 ± 9 [b] | 630 ± 4 [b] | 2,853 ± 23 [b] |
| | $30ft^2$ | 149 ± 2 | 394 ± 4 | 737 ± 8 | 1,014 ± 8 [a] | 684 ± 9 [a] | 2,978 ± 24 [a] |
| | $40ft^2$ | 151 ± 2 | 395 ± 4 | 743 ± 6 | 1,016 ± 14 [a] | 664 ± 18 [ab] | 2,969 ± 35 [a] |
| FC | $\bar{X}$± SEM | 150 ± 1 | 390 ± 3 | 735 ± 5 | 998 ± 8 | 658 ± 8 | 2,933 ± 21 |
| | **Model1** | | | | | | |
| | TRT | NS | NS | NS | <0.05 | <0.05 | <0.05 |
| | **Model2** | | | | | | |
| | TRT | NS | NS | NS | NS | NS | NS |
| | NFR | NS | NS | NS | NS | NS | NS |
| | $20ft^2$ | 1.08 ± 0.00 | 1.29 ± 0.01 | 1.47 ± 0.01 | 1.62 ± 0.11 | 1.83 ± 0.05 [a] | 1.51 ± 0.04 |
| | $30ft^2$ | 1.07 ± 0.01 | 1.29 ± 0.01 | 1.49 ± 0.01 | 1.62 ± 0.01 | 1.69 ± 0.01 [b] | 1.51 ± 0.01 |
| | $40ft^2$ | 1.07 ± 0.00 | 1.30 ± 0.01 | 1.48 ± 0.00 | 1.65 ± 0.03 | 1.70 ± 0.04 [ab] | 1.52 ± 0.01 |
| FCR | $\bar{X}$± SEM | 1.07 ± 0.00 | 1.29 ± 0.00 | 1.48 ± 0.00 | 1.63 ± 0.04 | 1.74 ± 0.02 | 1.51 ± 0.01 |
| | **Model1** | | | | | | |
| | TRT | NS | NS | NS | NS | <0.05 | NS |
| | **Model2** | | | | | | |
| | TRT | NS | NS | NS | NS | NS | NS |
| | NFR | NS | NS | NS | NS | NS | NS |

[a,b]Means (±SEM) within a row with different superscripts significantly different (p<0.05) (n= 6)

**Water usage and water to feed ratio (Trial 1)**

As shown in Table 4, there were no significant differences at Day 7, 14, 21, 28, and 32 in average water usage of the broiler chickens among pen sizes. Data showed that WFR at Day 7, 14, and 21 of age did not differ significantly between the pen sizes (Table 4). On Days 28 and 32, WFR increased significantly as pen size decreased ($P<0.05$). On Day 28, WFR of 20, 30, and 40 $ft^2$ pen sizes was 1.98, 1.91, and 1.88 respectively, while Day 32 was 1.91, 1.86, and 1.80 respectively. Birds in 20 $ft^2$ pens had a higher WFR than birds in 40 $ft^2$ pens in the fourth and fifth weeks. However, WFR of birds in 30 $ft^2$ did not differ statistically from those in 20 $ft^2$ or 40 $ft^2$ pens. The WFR was higher ($p<0.05$) in the 20 $ft^2$ pen size than in the 30 and 40 $ft^2$ pens, which may be due to the tendency of broilers to mimic behaviors (Webster and Hurnik, 1994). The smaller the pen, the closer the proximity of the birds to the drinker lines, and if one bird drinks, the other birds observe it and may be more likely to drink water out of mimicry rather than need. In larger pens, the birds are more spread out. Therefore, they may not be as likely to observe the other birds drinking activity and are thus less likely to mimic the behavior.

The WFR reported by Brake et al. (1992) was lower than the value noticed in the present study. This may be due to the genetic differences and management between broilers used in 1992 versus the modern broiler. The stocking densities may also have influenced WFR. Feddes et al. (2002) reported that WFR was higher in high stocking density conditions and increased independent of water usage.

Table 4. Trial 1 average weekly water usage (WU) (g/bird) and water to feed ratio (WFR) (gram of water/day: gram of feed/day) of birds raised in different pen sizes.

| | Pen sizes | Age (day) | | | | | Cumulative |
|---|---|---|---|---|---|---|---|
| | | 7 | 14 | 21 | 28 | 32 | |
| WU | $20ft^2$ | 360 ± 7 | 839 ± 19 | 1,443 ± 22 | 1,907 ± 13 | 1,205 ± 11 | 5,753 ± 40 |
| | $30ft^2$ | 365 ± 8 | 841 ± 11 | 1,443 ± 18 | 1,934 ± 28 | 1,269 ± 20 | 5,852 ± 65 |
| | $40ft^2$ | 368 ± 4 | 850 ± 12 | 1,447 ± 13 | 1,910 ± 42 | 1,197 ± 49 | 5,773 ± 98 |
| | $\bar{X}$± SEM | 364 ± 4 | 843 ± 8 | 1,444 ± 10 | 1,917 ± 17 | 1,224 ± 19 | 5,792 ± 40 |
| | **<u>Model1</u>** | | | | | | |
| | TRT | NS | NS | NS | NS | NS | NS |
| | **<u>Model2</u>** | | | | | | |
| | TRT | NS | NS | NS | NS | NS | NS |
| | NFR | NS | NS | NS | NS | NS | NS |
| WFR | $20ft^2$ | 2.42 ± 0.04 | 2.19 ± 0.02 | 1.99 ± 0.01 | 1.98 ± 0.02 $^{a}$ | 1.91 ± 0.02 $^{a}$ | 2.02 ± 0.01 $^{a}$ |
| | $30ft^2$ | 2.46 ± 0.02 | 2.14 ± 0.01 | 1.96 ± 0.01 | 1.91 ± 0.02 $^{ab}$ | 1.86 ± 0.01$^{ab}$ | 1.97 ± 0.01 $^{ab}$ |
| | $40ft^2$ | 2.44 ± 0.03 | 2.15 ± 0.03 | 1.95 ± 0.02 | 1.88 ± 0.03 $^{b}$ | 1.80 ± 0.03 $^{b}$ | 1.94 ± 0.02 $^{b}$ |
| | $\bar{X}$± SEM | 2.43 ± 0.02 | 2.16 ± 0.01 | 1.96 ± 0.01 | 1.92 ± 0.02 | 1.86 ± 0.02 | 1.98 ± 0.01 |
| | **<u>Model1</u>** | | | | | | |
| | TRT | NS | NS | NS | <0.05 | <0.05 | <0.05 |
| | **<u>Model2</u>** | | | | | | |
| | TRT | NS | NS | NS | NS | <0.05 | NS |
| | NFR | NS | NS | NS | NS | <0.05 | NS |

$^{a,b}$Means (± SEM) within a row with different superscripts significantly different ($p<0.05$) (n=6)

**Nipple flow rate**

On the daily water usage chart, high variation was observed between days 25 through 32 (Figure 4). In order to understand the high variations in WU among pens, the flow rate of each nipple (NFR) was measured. The variation in between NFR was between 14 mL/min and 41 mL/min and may have influenced the subsequent WFR due to water usage (Figure 5).

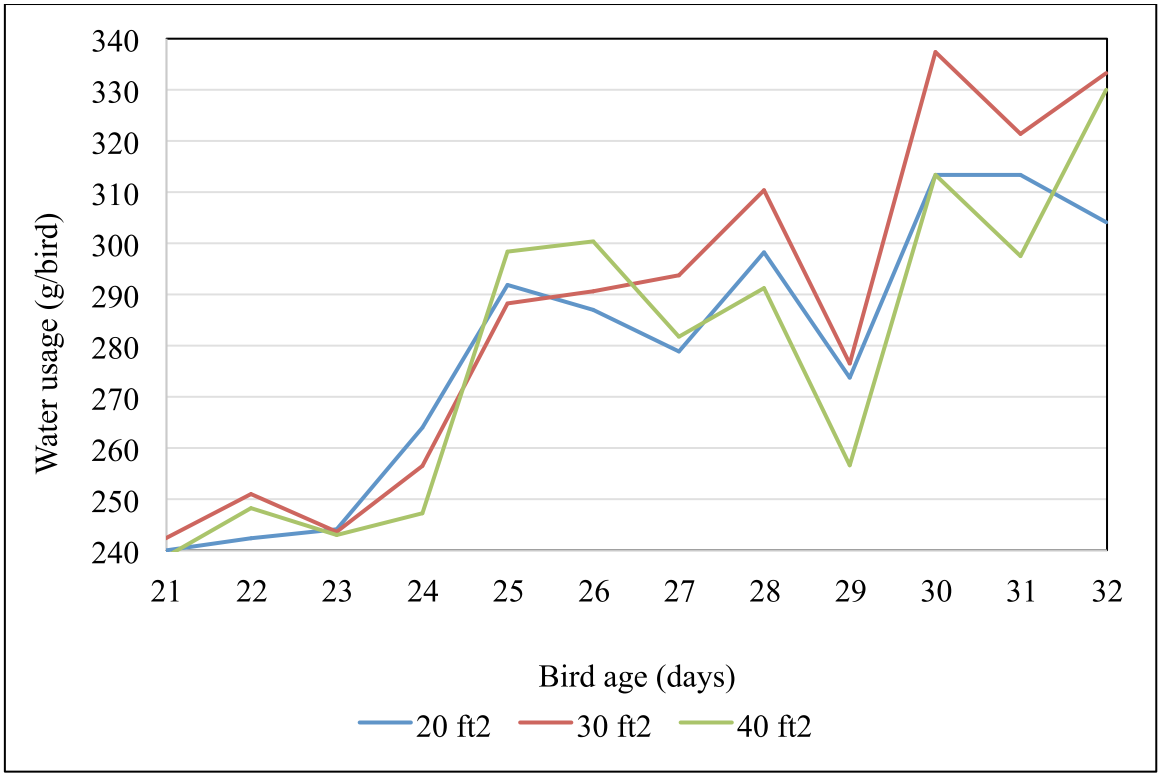


Figure 4. Trial 1 Broiler daily water usage 21-32 days

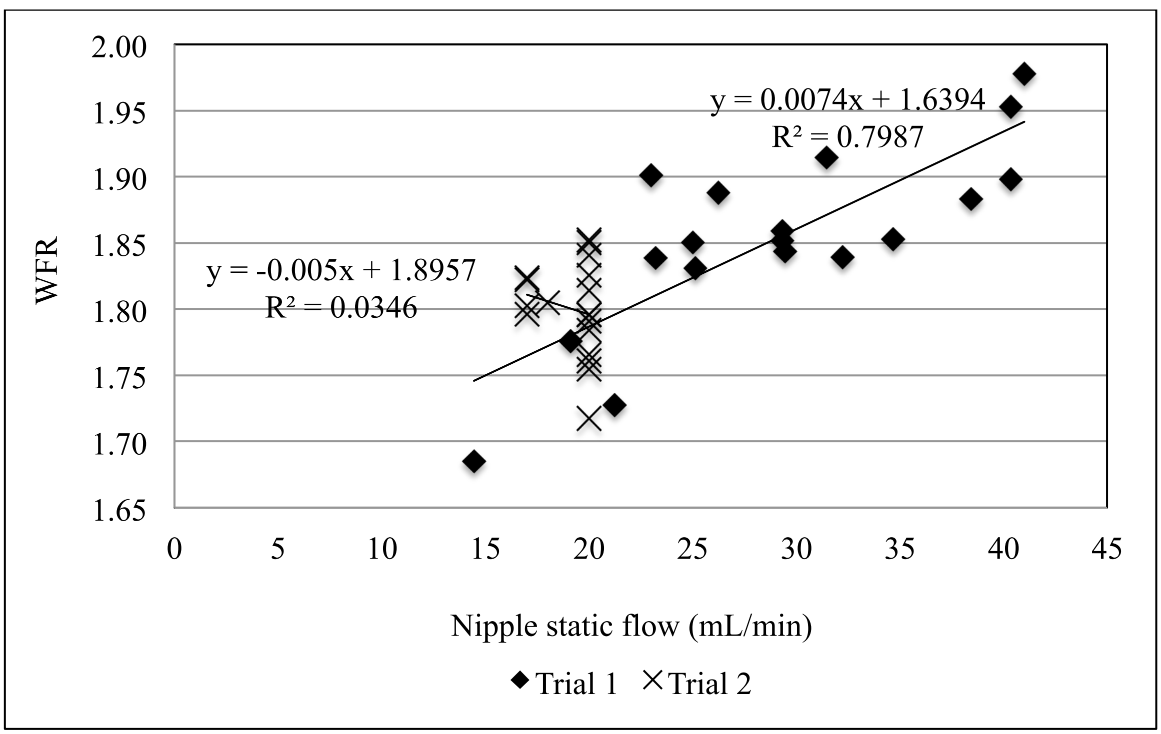


Figure 5. Trial 1, 2 Water to feed ratio vs. nipple static flow rate (week 5, 6' wc)

In Trial 1, a high correlation between WFR and NFR was observed (0.8). This may explain the effect of NFR on birds WFR. Only the fifth week WFR significantly differed by pen size and NFR ($p<0.05$); however, there was no interaction between pen size and NFR. The static flow rate of nipples was averaged and NFR in the 20, 30, and 40 $ft^2$ pens was 32, 29, and 26 mL/min, respectively (Figure 6). In Trial 2, nipples and regulators were changed and NFR was more uniform among the pens (Figure 6). In Trial 1 the NFR rate was highly variable, and these variations in nipple flow rate affected Trial 1 data. Therefore, to address this in Trial 2, the drinker line nipples and regulators were changed for each pen and a histogram shows how the NFR frequency compared in both trials (Figure 7). Trial 1 nipple flow rate varied between 3 and 44 ml/min between pens and even nipples within a pen (Figure 8). The new drinker line regulators and nipples in Trial 2 resulted in more uniform nipple flow rates (Figure 9).

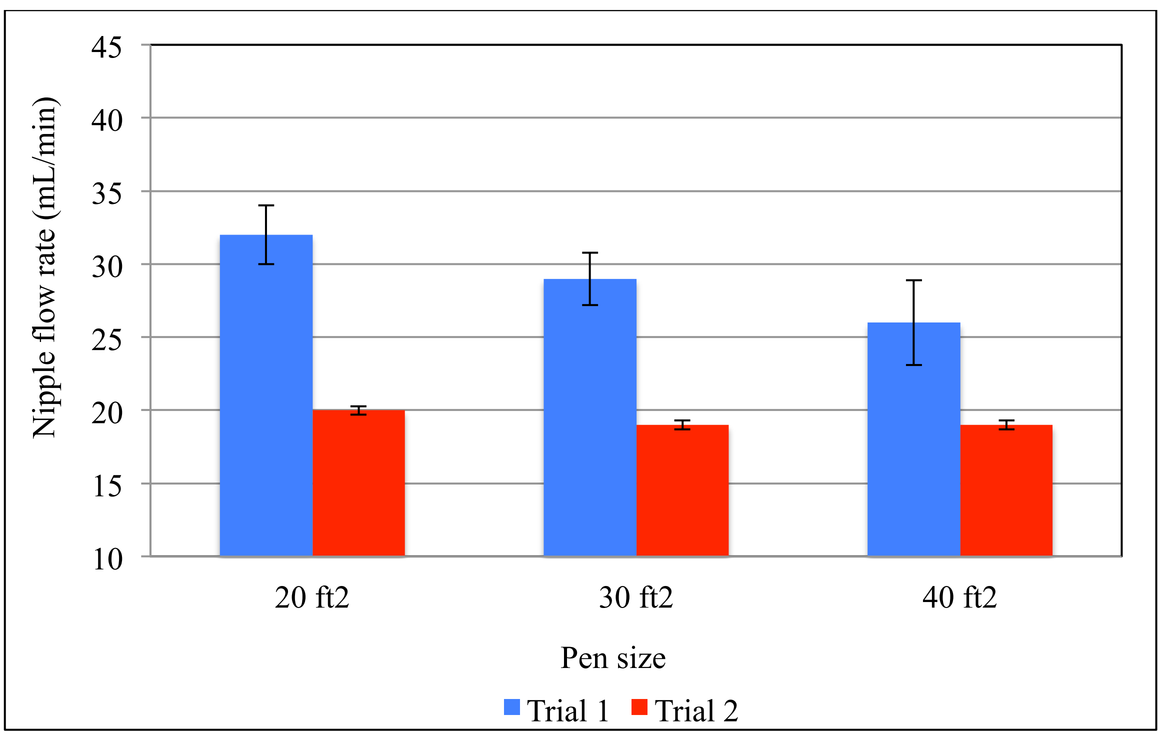


Figure 6. Trial 1, 2 Mean (±SEM) nipple flow rate (mL/min) for each pen size treatment (n=6)

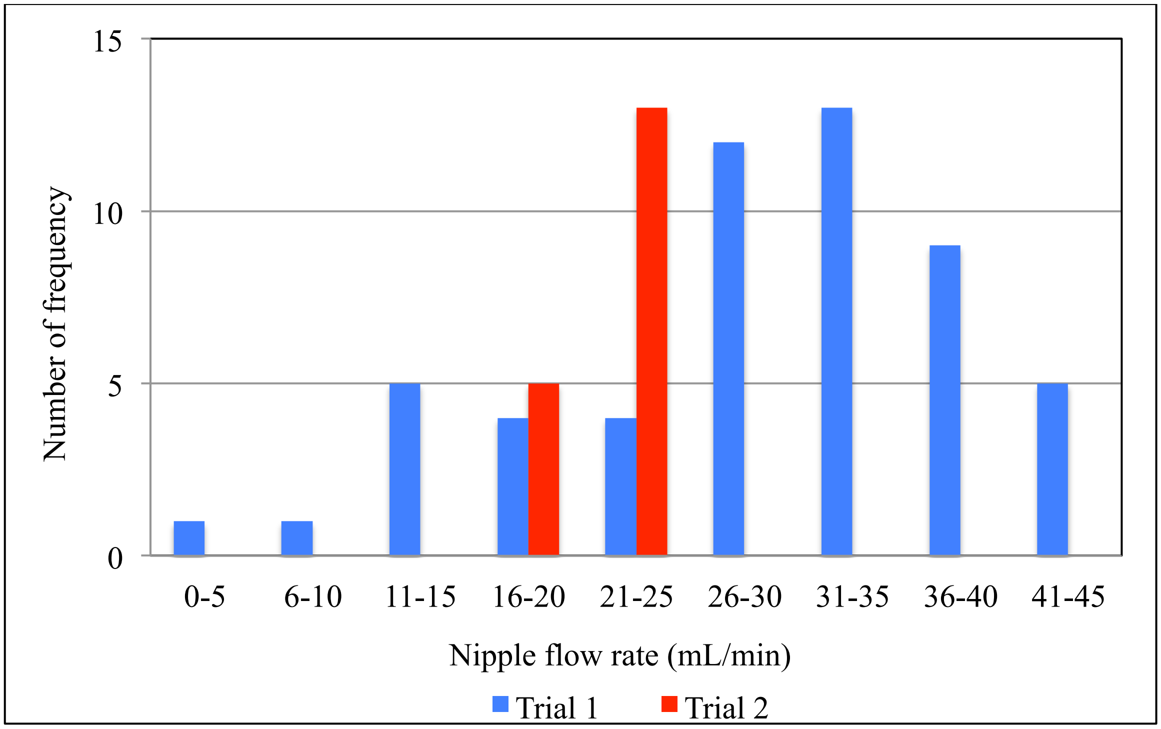


Figure 7. Trials 1, 2 Number of frequent nipple flow rate (mL/min) for each pen size treatment (n=6)

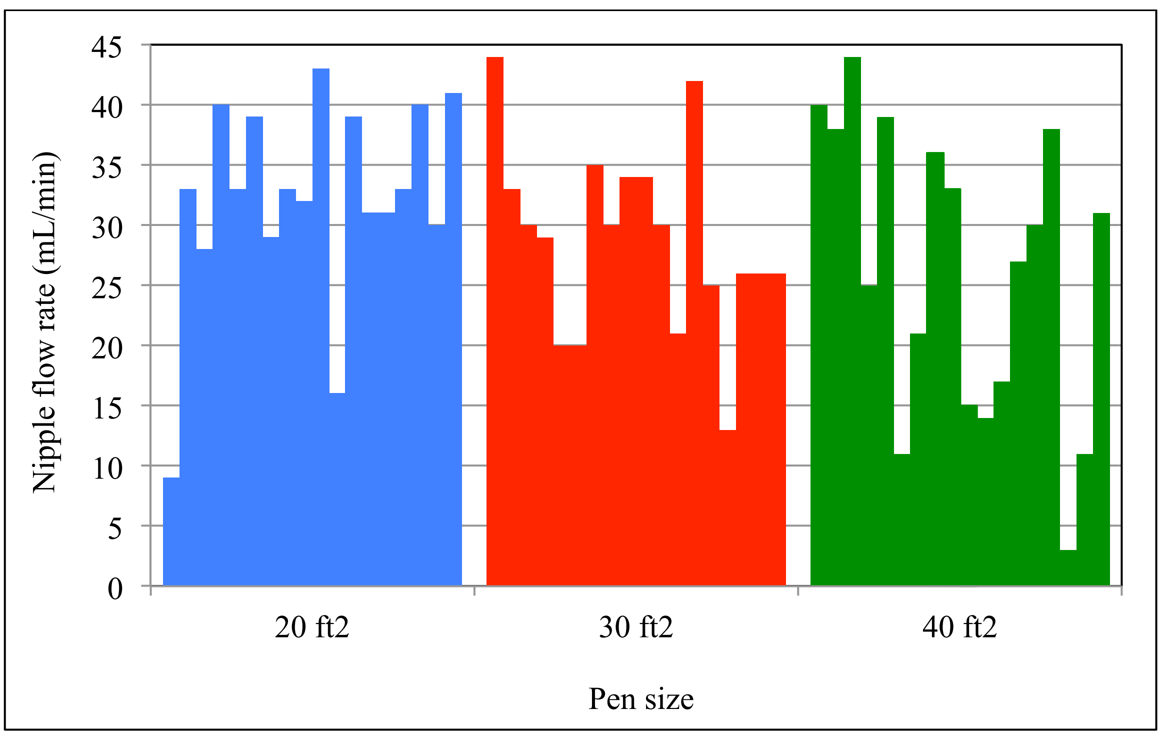


Figure 8. Trial 1 Water flow rate (mL/min) from all nipples for each pen size treatment (n=6)

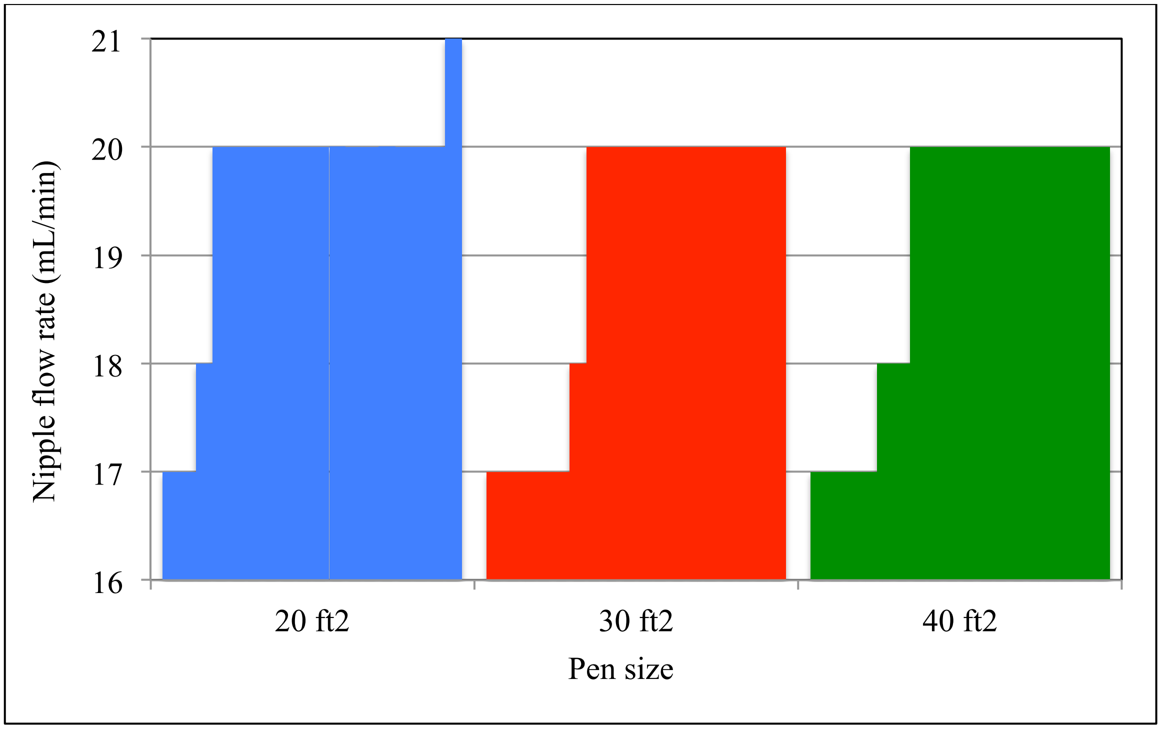

Figure 9. Trial 2 Nipple flow rate (mL/min) from all nipples for each pen size treatment (n=6)

In Trial 1, water pressure was adjusted to 2 inches on the first day and changed to 4 inches on day 14. It was changed in all pens on day 20 from 4 to 6 inches, thus water usage increased by 15% in all treatments. A day after, water usage decreased by 12% because water pressure was changed to 4 inches and kept until day 25. Water pressure was changed to 6 inches on day 25 and a 13% increase of water usage was observed, while only 7% was observed on the previous day. Water pressure was kept at 4 inches until day 25 and was changed to 6 inches until the end of the study. In Trial 2, water pressure was adjusted to 2, 4, 5, and 6 inches on days 1, 14, 21, and 28, respectively.

**Pen size and bird performance (Trial 2)**

No significant differences in average weekly bird BW at Day 7, 14, 21 were observed between pen sizes in Trial 2 (Table 5). These results agree with Trial 1. On Day 28, the birds raised in the 20 $ft^2$ pen size again showed the lowest BW (1577 g) compared with the 30 (1644 g) and 40 ft$^2$ (1657 g) pens ($p<0.05$). On Day 35, the birds in the 20 ft$^2$ pen again showed the lowest BW ($p<0.05$) compared with the 30 ft$^2$ and 40 ft$^2$ pens. The cumulative bird BW in the 20 ft$^2$ pens was significantly ($p<0.05$) lower than 30 and 40 ft$^2$ pens. However, as with Trial 1, no statistical difference was discovered between the birds in the 30 and 40 ft$^2$ pens.

Table 5. Trial 2 average weekly body weight (BW) (g/bird) of birds raised in different pen sizes.

| | Pen size | Age (day) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 7 | 14 | 21 | 28 | 35 |
| | 20 ft$^2$ | 42 ± 0.2 | 173 ± 2 | 501 ± 4 | 967 ± 11 | 1,577 ± 19 $^b$ | 2,208 ± 35 $^b$ |
| BW | 30 ft$^2$ | 42 ± 0.4 | 174 ± 2 | 498 ± 6 | 989 ± 9 | 1,644 ± 16 $^a$ | 2,366 ± 15 $^a$ |
| | 40 ft$^2$ | 41 ± 0.3 | 171 ± 3 | 488 ± 6 | 985 ± 12 | 1,657 ± 15 $^a$ | 2,409 ± 19 $^a$ |
| | $\bar{X}$±SEM | 41 ± 0.2 | 172 ± 1 | 495 ± 3 | 980 ± 6 | 1,626 ± 12 | 2,328 ± 25 |

$^{a,b}$Means (± SEM) within a row with different superscripts significantly different ($p<0.05$) (n=6)

There was no significant differences in average weekly bird BWG, FC, and FCR at Day 7, 14, 21 were observed between pen sizes in Trial 2 (Table 6). On Day 28, the BWG was significant lower in the 20 ft$^2$ (611 g) pens than 30 ft$^2$ (659 g) pens and 40 ft$^2$ (672 g) pens. On Day 35, the 20 ft$^2$ (623 g) pens was lower than 30 ft$^2$ (728 g) pens and 40 ft$^2$ (763 g) pens. There was no significant difference between 30 ft$^2$ and 40 ft$^2$ on Days 28 and 35. On Day 28 of Trial 2, FC (g/bird/day) was lower in the 20 ft$^2$ pen (978 g) than in the 30 (1015 g) and 40 ft$^2$ (1017 g) pens ($p<0.05$). Furthermore, FC on Day 35 was lower ($p<0.05$) in the 20 ft$^2$ pens (1161 g) than in the 30 (1285 g) and 40 ft$^2$ pens (1293 g).

On Day 28, FCR in the 30 (1.54) and 40 ft$^2$ pens (1.51) was lower than bird FCR raised in the 20 ft$^2$ (1.60) pens ($p<0.05$). On Day 35, FCR in the 30 (1.77) and 40 ft$^2$ pens (1.70) were better than birds raised in the 20 ft$^2$ (1.88) pens ($p<0.05$). The cumulative FCR of 20 ft$^2$ pens (1.56) was higher than 30 (1.53), and 40 ft$^2$ pens (1.50). However, the cumulative FCR of birds in the 30 $ft^2$ pens did not differ statistically from those in the 20 or 40 $ft^2$ pen sizes. It has been reported that FCR is not affected by stocking density (Cravener et al. 1992; Feddes et al. 2002; Puron et al. 1995). The high FCR of birds at small pens (higher density) could be related to low FC, which agrees with Dozier et al. (2006); Bilgili and Hess (1995); and Nahashon et al. (2009). However, the FCR among the pen sizes was similar to Trial 1 where it became more efficient as pen size increased (Table 4). That may be because birds had easier access to water and feed than they did in the small pens. Trial 2 mortality was 1% (20 $ft^2$), 3% (30 $ft^2$), and 4% (40 $ft^2$). There was no significant difference in mortality among pen sizes.

Table 6. Trial 2 average weekly body weight (BWG) (g/bird), feed consumption (FC) (g/bird), and feed conversion ratio (FCR) of birds raised in different pen sizes.

| | Pen sizes | Age (day) | | | | | Cumulative |
|---|---|---|---|---|---|---|---|
| | | 7 | 14 | 21 | 28 | 35 | |
| BWG | $20ft^2$ | 131± 2 | 326± 4 | 475± 9 | 611± 13 $^b$ | 623± 29 $^b$ | 2,166± 38 $^b$ |
| | $30ft^2$ | 132± 1 | 324± 5 | 484± 9 | 659± 10 $^a$ | 728± 3 $^a$ | 2,327± 16 $^a$ |
| | $40ft^2$ | 130± 3 | 317± 4 | 489± 8 | 672± 6 $^a$ | 763± 8 $^a$ | 2,370± 19 $^a$ |
| | $\bar{X}$± SEM | 131± 1 | 323± 3 | 483± 5 | 647± 8 | 705± 17 | 2,288± 26 |
| FC | $20ft^2$ | 142 ± 2 | 397 ± 4 | 700 ± 9 | 978 ± 16 $^b$ | 1,161 ± 24 $^a$ | 3,378 ± 43 $^b$ |
| | $30ft^2$ | 142 ± 2 | 397 ± 2 | 708 ± 3 | 1,015 ± 7 $^a$ | 1,285 ± 10 $^a$ | 3,547 ± 19 $^a$ |
| | $40ft^2$ | 141 ± 3 | 395 ± 6 | 705 ± 12 | 1,017 ± 8 $^a$ | 1,293 ± 15 $^a$ | 3,551 ± 40 $^a$ |
| | $\bar{X}$± SEM | 142 ±1 | 397 ± 2 | 704 ± 5 | 1,003 ± 8 | 1,246 ± 17 | 3,492 ± 28 |
| FCR | $20ft^2$ | 1.08 ± 0.01 | 1.22 ± 0.02 | 1.48 ± 0.01 | 1.60 ± 0.02 $^a$ | 1.88 ± 0.05 $^a$ | 1.56 ± 0.02 $^a$ |
| | $30ft^2$ | 1.08 ± 0.01 | 1.23 ± 0.02 | 1.47 ± 0.03 | 1.54 ± 0.01 $^b$ | 1.77 ± 0.01 $^{ab}$ | 1.53 ± 0.01 $^{ab}$ |
| | $40ft^2$ | 1.09 ± 0.01 | 1.25 ± 0.01 | 1.44 ± 0.02 | 1.51 ± 0.01 $^b$ | 1.70 ± 0.02 $^b$ | 1.50 ± 0.01 $^b$ |
| | $\bar{X}$± SEM | 1.08 ± 0.00 | 1.23 ± 0.01 | 1.46 ± 0.01 | 1.55 ± 0.01 | 1.78 ± 0.02 | 1.53 ± 0.01 |

$^{a,b}$Means (± SEM) within a row with different superscripts significantly different ($p<0.05$) (n=6)

Water usage and feed consumption were standardized by BW and there were no significant differences in WU and FC (Figure 10, 11). These results are more likely affected by stocking density than pen size. An analysis of variance for Trial 2 showed no differences in BW uniformity between the pen sizes.

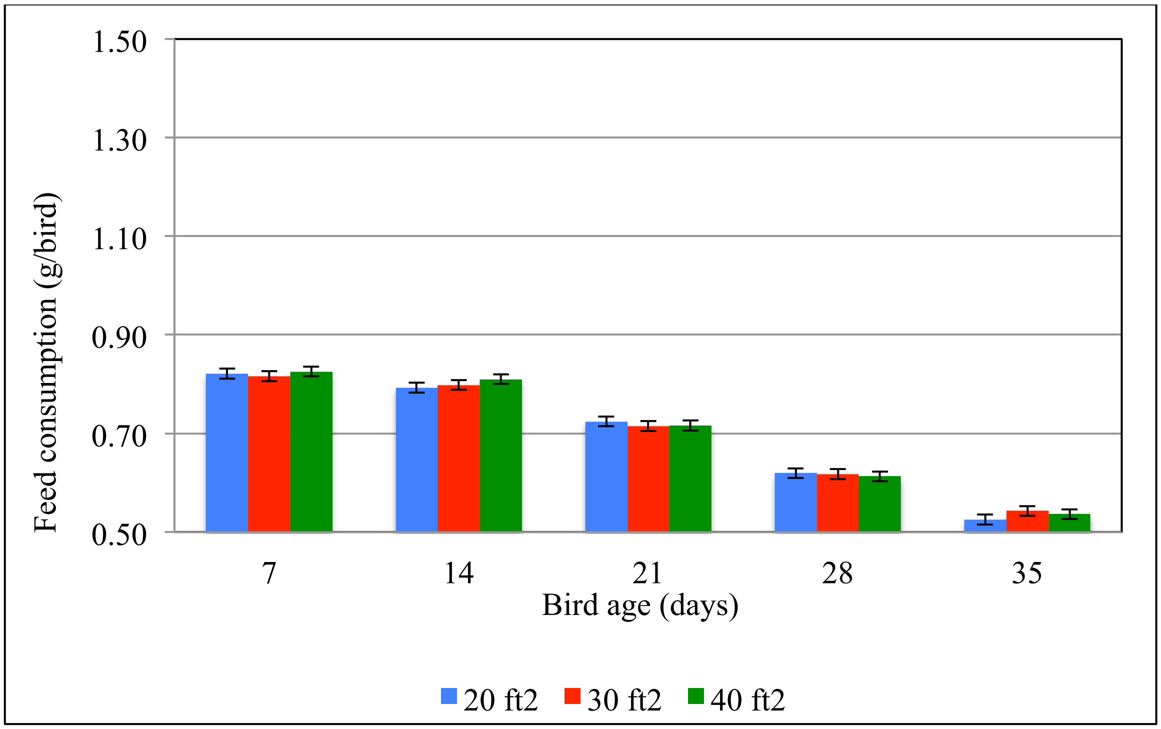


Figure 10. Trial 2 Mean (±SEM) feed consumption standardized by BW ($p<0.05$) ($n=6$)

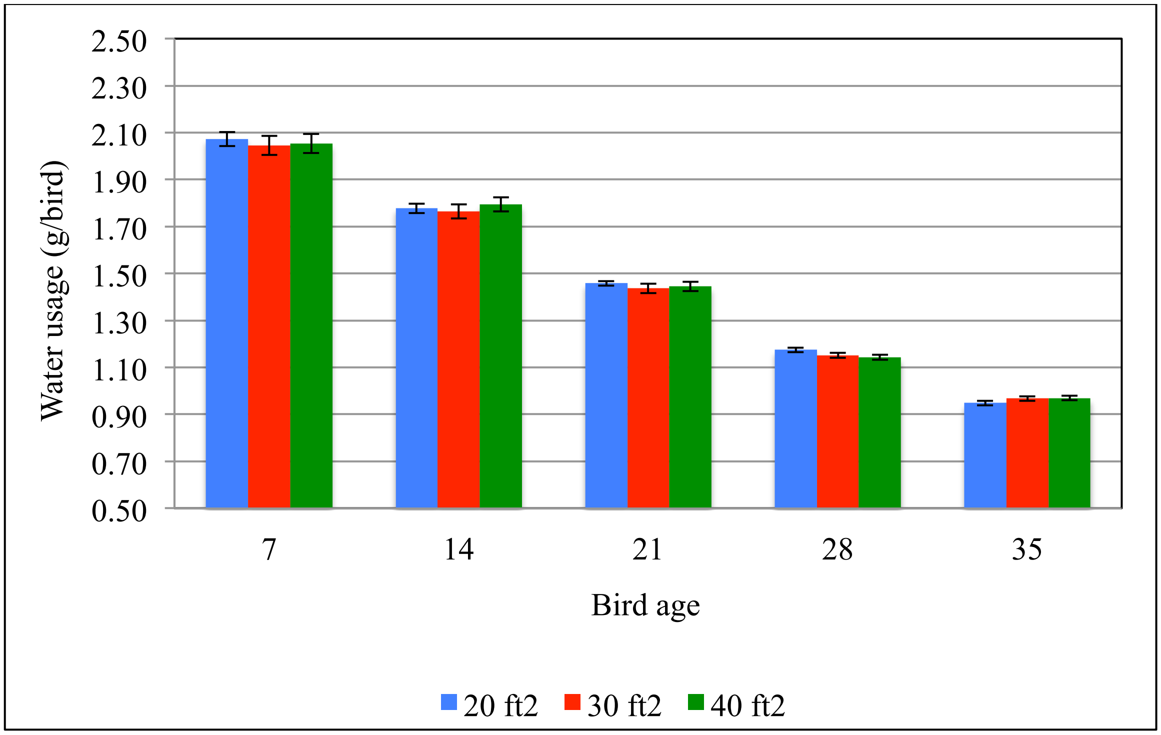

Figure 11. Trial 2 Mean (±SEM) water usage standardized by BW ($p<0.05$) ($n=6$)

**Water usage and water to feed ratio (Trial 2)**

As Table 7 reveals, no significant differences between pen sizes at Day 7, 14, 21, and 28 average broiler water usage were observed throughout the study, with the exception of Day 35 where the WU was significantly lower in the 20 $ft^2$ pens than in the 30 $ft^2$ and 40 $ft^2$ pens ($p<0.05$). The effect of higher stocking density on WU illustrates that smaller pens resulted in lower WU compared to birds in lower densities. This possible effect might be due to lower FC due to the physical access to feeder and drinker get harder in higher densities, which corresponds with the findings of Feddes et al. (2002).

Table 7. Trial 2 average weekly water usage (WU) (g/bird) and water to feed ratio (WFR) (gram of water/day: gram of feed/day) of birds raised in different pen sizes.

| | Pen sizes | Age (day) | | | | | Cumulative |
|---|---|---|---|---|---|---|---|
| | | 7 | 14 | 21 | 28 | 35 | |
| WU | $20ft^2$ | 358 ± 7 | 891 ± 8 | 1,410 ± 28 | 1,855 ± 38 | 2,096 ± 45 $^{b}$ | 6,609 ± 98 |
| | $30ft^2$ | 355 ± 5 | 878 ± 8 | 1,422 ± 15 | 1,893 ± 23 | 2,291 ± 23 $^{a}$ | 6,838 ± 57 |
| | $40ft^2$ | 351 ± 11 | 876 ± 24 | 1,424 ± 28 | 1,895 ± 28 | 2,337 ± 18 $^{a}$ | 6,883 ± 97 |
| | $\bar{X}$± SEM | 354 ± 5 | 881 ± 8 | 1,419 ± 13 | 1,881 ± 17 | 2,241 ± 30 | 6,777 ± 55 |
| WFR | $20ft^2$ | 2.52 ± 0.02 | 2.24 ± 0.01 | 2.01 ± 0.02 | 1.90 ± 0.01 | 1.81 ± 0.01 | 1.96 ± 0.01 |
| | $30ft^2$ | 2.51 ± 0.02 | 2.21 ± 0.01 | 2.01 ± 0.02 | 1.87 ± 0.01 | 1.78 ± 0.02 | 1.93 ± 0.01 |
| | $40ft^2$ | 2.48 ± 0.04 | 2.21 ± 0.04 | 2.02 ± 0.02 | 1.87 ± 0.02 | 1.81 ± 0.01 | 1.94 ± 0.01 |
| | $\bar{X}$± SEM | 2.50 ± 0.02 | 2.22 ± 0.02 | 2.01 ± 0.00 | 1.88 ± 0.01 | 1.80 ± 0.00 | 1.94 ± 0.01 |

[a,b]Means (± SEM) within a row with different superscripts significantly different ($p<0.05$) (n=6)

**Summary**

Water to feed ratio decreases, as birds get older (Figure 12). In both Trials WFR was higher in the first week, this is due to more WU than FC by the birds, which may be related to the metabolizing of the residual yolk sac. Chicks obtain nutrients from the yolk sac, so they do not eat as much feed (Bell, 2002). Therefore, residual yolk sac may explain the greater WFR in the first three days for both Trials. In the last two weeks, a variation in WFR was observed in both trials, this could be due to an adjustment in water pressure on Days 20, 21 and 25 (Figures 12, 13). In Trial 2, there was no significant difference in WFR between pens during the study. In order to separate the effect of stocking density from pen effect, water usage and feed consumption were standardized by BW. The WFR data were analyzed and there were no differences (Figure 14).

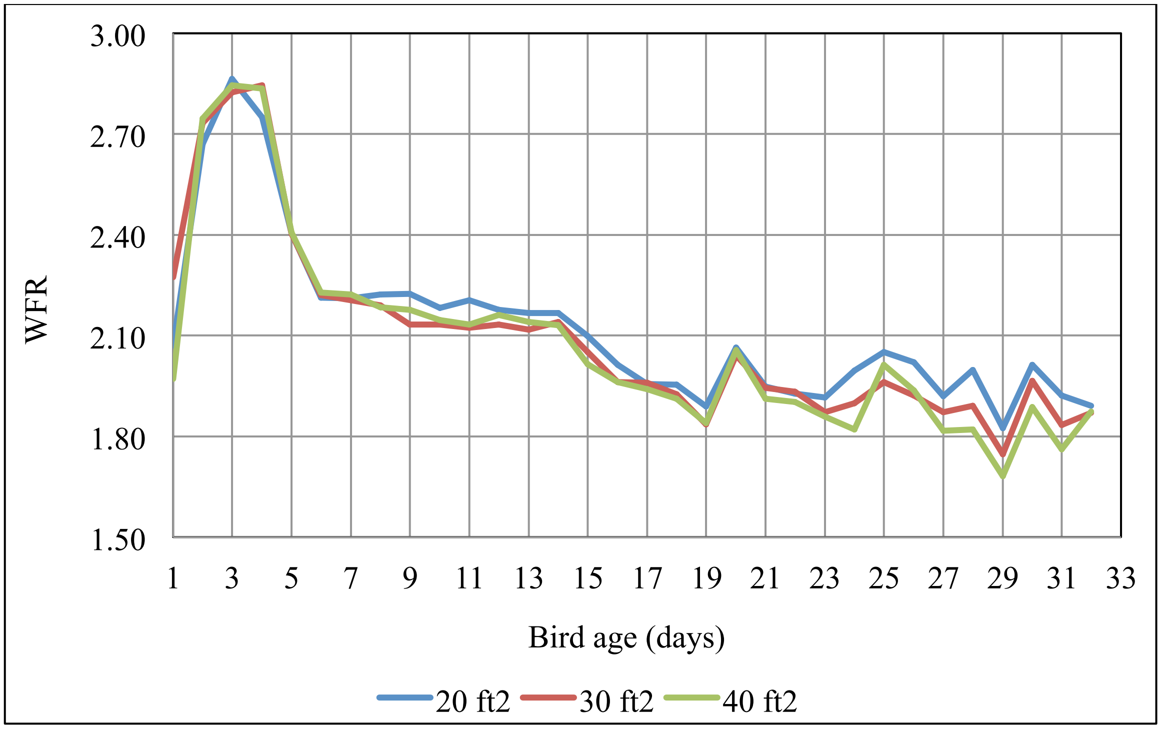

Figure 12. Trial 1 Daily water to feed ratio vs. bird age

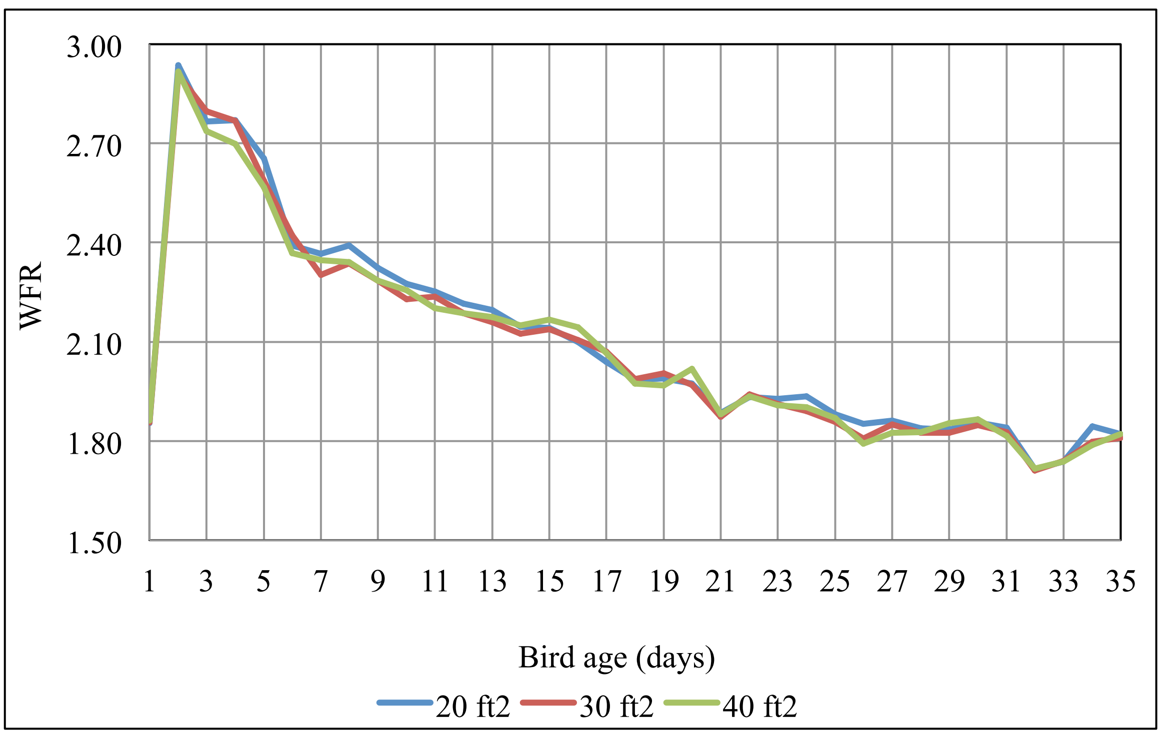

Figure 13. Trial 2 Daily water to feed ratio vs. bird age

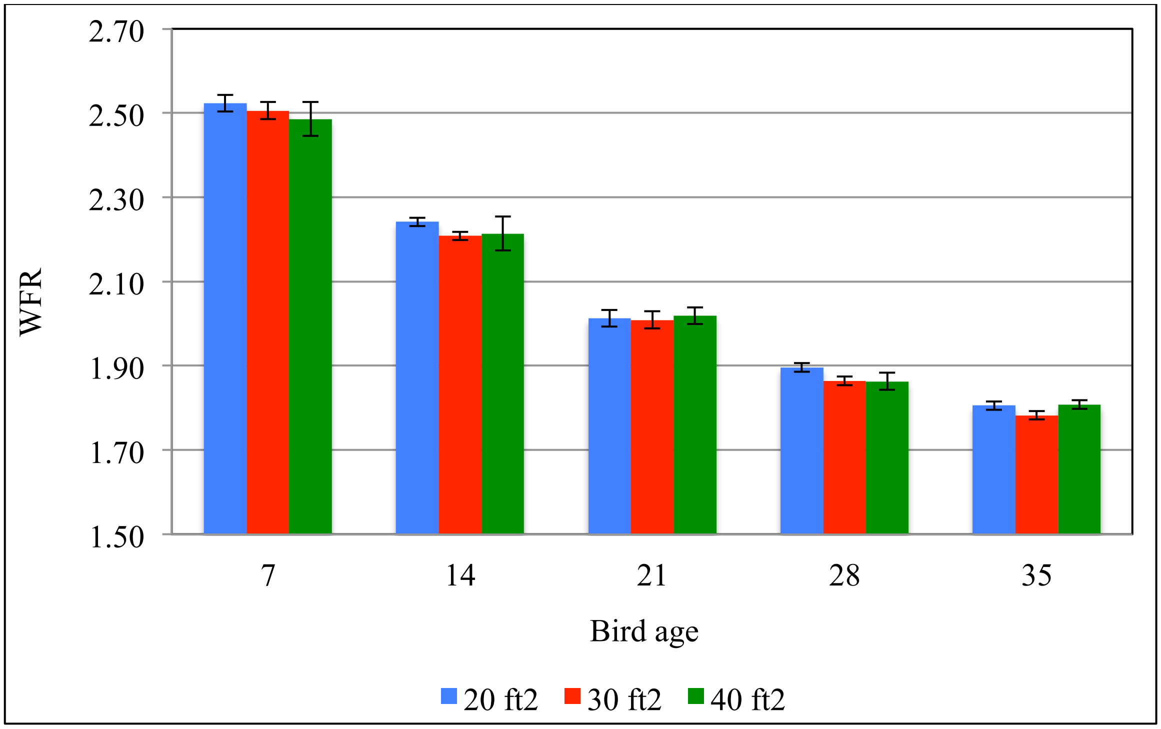


Figure 14. Trial 2 Mean (±SEM) water to feed ratio standardized by BW (n=6)

# CHAPTER 5

# CONCLUSION

Water to feed ratio in Trial 1 was influenced more by the differences in nipple flow rate within and between the pens rather than pen size. The data indicate that the smaller pens tend to have higher WFR. This higher WFR may be due to the broilers mimicking the behaviors of the other birds in the pen. As pen size had no effect on WFR, this study may suggest that different pen sizes are not an issue for consideration in broiler research. Additional research of pen size influence on WFR needs to be conducted in the future to separate the pen size effect from stocking density effect.

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