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Broiler performance and carcass characteristics at different stocking densities, ventilation rates, air speeds and levels of bird disturbance

by

Earlington Jerry Emmanuel ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

In

Animal Science

Department of Agricultural, Food and Nutritional Science

Edmonton, Alberta

Spring 2002

0-612-69703-7

University of Alberta

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Title of Thesis: Broiler performance and carcass characteristics at different stocking densities, ventilation rates, air speeds and levels of bird disturbance

Degree: Master of Science

Year this Degree Granted: 2002

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Oct. 31/01

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Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for the acceptance, a thesis entitled **Broiler performance and carcass characteristics at different stocking densities, ventilation rates, air speeds and levels of bird disturbance.** By Earlington Jerry Emmanuel in partial fulfillment of the requirements for the degree of Master of Science in Animal Science.

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Abstract

Broiler performance and carcass traits were observed under different stocking densities and drinker spacing. Stocking density treatments were 0.042, 0.055, 0.069 and 0.083m^2/bird and nipple drinker spacing was 5, 10 , 15, 20 birds/nipple. The stocking density of 0.042 m^2/bird had a lower liveweight(1898g), while the 0.069m^2/bird treatment had the highest liveweight(1985g). The broilers in the 0.083 m^2/bird treatment consumed the least amount of feed(2993g/bird) and birds in the 0.069m^2/bird treatment consumed the highest amount of feed(3183g/bird). Drinker spacing had no effect.

In the second experiment, broiler performance and carcass quality were measured under different ventilation rates, air speeds and levels of bird disturbance. The high and low ventilation rate treatments were 3.4 and 1.7L/s/bird, while the air speed treatments were 0.82m/s and 0.32m/s. A high air speed resulted in a significantly higher liveweight(1767g) than in the low air speed treatment (1737g). Water intake (6080ml/bird/cycle) increased with decreased ventilation rate.

ACKNOWLEDGEMENTS

We acknowledge the financial support of the Alberta Chicken Producers, Lilydale Cooperatives Ltd and Alberta Agriculture Research Institute. The care and management provided by the staff at the Poultry Research Center was invaluable to the study. The cooperation of the staff at Lilydale Cooperatives Ltd. in Edmonton was greatly appreciated. The plant operation was altered to accommodate the processing of the 32 individual groups for the two experiments.

I would like to thank my supervisor Dr. John Feddes for giving me the opportunity to complete my thesis studies under his guidance. I would also like to thank my co-supervisor Dr. Doug Korver for his support and encouragement towards a position within the poultry industry. I would like to thank Dr. Frank Robinson who introduced me to the fascinating world of poultry. I have definitely learned from the best!

I would like to thank my mother who has supported me since day one, as well as the rest of my family. Last but not least I would like to thank my wife Michele who has been by my side every step of the way, without you this wouldn't have happened.

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1. Introduction.

The goal of broiler producers is a profitable return on their product. One way that broiler producers can achieve a greater return is by increasing the stocking density within the barn. This allows the producer to grow more broilers per unit area, thus yielding a higher profit. Increasing the stocking density, however, may create a more stressful environment for the broiler. Such stress factors could include; heat stress, poor air quality, and more difficult access to feed and water. The overall effects of such stressors on the broiler may be reduced growth, poor feed efficiency and decreased livability. One way to overcome problems with high stocking densities, is to increase rates of ventilation and air circulation in the broiler's environment. With enough air circulating and room air exchange, broilers can grow more efficiently, since the excess heat is removed from their living space.

Another factor that can affect profitability is cellulitis, which is an infection of the skin caused by *Escherichia* coli that enters through skin lesions (Elfadil, 1996). According to Elfadil *et al* (1996) most of these lesions occur on the abdomen. There two types of cellulitis that can occur; Type 1 infects the navel of the chick at the hatchery and Type 2, which infects the body surface. The infected area may become bright to dull yellow or adopt a reddish brown color. In addition the skin becomes swollen at the site of inflammation (Elfadil *et al.*, 1996). This skin disease has had a major impact in the broiler industry. In 1997, Alberta producers had an average condemnation rate due to cellulitis of 0.5 % per flock, which was among the highest in Canada and reasons for the increase in the incidence of cellulitis may be attributed to an increase in stocking density. With this increase in stocking density there tends to be an increase in scratches on broilers. With an increase in scratches as well as an increase in environmental temperature, the bacteria can flourish and have a greater chance of infecting the exposed area, thus producing cellulitis.

Although cellulitis is becoming more of a problem in the broiler industry, maintaining the broiler environment to prevent this disease and making it optimal to rear birds in is an even larger challenge. While broiler barns today are well equipped with the technology to control barn temperature, with elevated outside temperatures, barn temperatures will increase. The real key is trying to keep the temperature ideal at bird level. By understanding what happens at the microclimate level in terms of heat stress, litter and microclimate temperature. Proper temperature and ventilation/air circulation adjustments can be made in providing a more suitable environment.

The objectives of this study were: a) to determine the stocking density and nipple drinker spacing to raise broilers at to obtain optimum weight and performance. b) to determine if different ventilation rates, air circulation rates and disturbance levels have an effect on the incidence of cellulitis and c) to determine the relationship between barn temperature and the microclimate temperature and how that affects broiler performance.

2. Broiler performance, liveweight variance, feed and water intake and carcass quality at different stocking densities

2.1 Introduction

Broilers must have adequate floor area so that feed and water is adequately supplied allowing them to express their genetic growth potential. High stocking densities can cause stress to broiler chickens as a result of a number of factors. One key factor can be high environmental temperature in the immediate vicinity of the bird resulting in their difficulty in dissipating the heat away from their bodies to the air space. Other factors that can cause stress to the birds include poor air quality due to in adequate air exchange, heated litter from an increase in ammonia and difficult access to feed and water.

The overall effect of reducing floor space on broiler chickens can be poorer growth rate, feed efficiency, liveability, and in some cases, carcass quality (Puron *et al.*, 1995). Also, decreased bird movement can result in skeletal deformities affecting the legs. According to Puron *et al.*, (1995), as stocking densities increased from 10 to 20 birds/m^2, male broilers had a linear reduction in liveweight and feed intake. However as stocking density increased, there was no difference found in feed conversion or mortality at 7 wk of age. Female broilers show a similar trend in response to increasing stocking densities; however, without a reduction in liveweight and feed consumption. Puron *et al.*, (1995) recommended a stocking density of 17 and 19 birds/m^2 for males and females, respectively for a maximum profit. An increase in stocking density would reduce the fixed costs of production and result in more mass of broiler chicken per unit area. Therefore, up to a critical point, profitability increases with increased stocking density. The effect of various stocking densities on carcass quality still needs to be determined. This study was undertaken to investigate the effects of stocking density and water nipple density on liveweight, feed/water consumption, and carcass quality.

2.2 Materials and Methods

A total of 6000 Ross x Ross female broiler chicks were used for each of the two trials in this study. The parents of these birds were 46 and 54 weeks for the birds in Trial 1 and 2, respectively. At one wk of age, the chicks were randomly placed into thirty-two pens (two sections with 16 pens each) (Figure 2-1). The stocking densities used in this study were 0.042 (0.45 ft^2/bird), 0.055 (0.56 ft^2/bird), 0.069 (0.75 ft^2/bird), and 0.083 m^2/bird (0.90 ft^2/bird) (Table 2-1) resulting in 260, 195,156, and 130 broilers per pen, respectively. The dimensions of the pens were 2.43 m x 5.79 m (8' x 19') or 14.06 m^2 of which 3.0 m^2 is considered non-utilizable space (feeder area and 15 cm along the walls). A 2-foot high brick wall was installed at the back of the pen when the stocking density changed by 0.05 m^2/bird due to mortality (Figure 2-1).

In the center of each pen a PVC nipple drinker system was installed (Figure 2-1). The nipple spacing varied from pen to pen to obtain a bird/nipple ratio of 5, 10, 15 and 20, for the corresponding densities (Table 2-1). Each nipple drinker was connected to a calibrated 200 L plastic barrel, which was filled about every 3 days. Each pen had one overhead fan that directed air to the center of the pen thus providing more air movement and additional cooling for the birds. Four pan feeders, each with a holding capacity of 10 kg were located in each pen with two in the back and two in the front on either side of the drinker system (Figure 2-1). For the stocking densities of 0.042 m^2/bird, two of the feeders had a capacity of 20 kg.

Each 16-pen room was ventilated by four 600 mm exhaust fans (capacity of 3000 L/s) and four 450 mm fans (capacity of 1200 L/s). To allow for sufficient amount of inlet air, four air inlets per room were available in the roof. At full capacity, the ventilation rate was estimated at 16,800 L/s (5.6 L/s per bird) at 30 Pa of negative pressure. The barn temperature required for the birds (determined by a standard temperature regime) was achieved as a result of the fan operation being controlled by room thermostats set at the desired temperature. Temperatures were maintained by a forced air heating system when ventilation was at the minimum adjustment.

Eight floor scales (Fancom, Panningen, Netherlands) were used to track the daily growth rate of the birds. Two floor scales per density treatment were used to record the live weight during the experiment. Also in Trial 2, four scales were connected to the front feeders in pens 35, 36, 41 and 42 (Table 2-1). These scales measured the weight of the feed that was consumed by the birds and was recorded by a computer every 15 min. These data were then used to observe feeding behavior over a 24h time period of broilers at the four different standard densities, but at the same bird to drinking nipple ratio.

Water and feed was provided ad libitum for each of the 32 pens for the entire 6 wk growth period with 23 hr light and 1 hr dark. For the first 3 wk the chicks were fed a standard starter diet (3200 kcal ME/kg, 22 % crude protein) that was medicated and from week 4 to week 6 the broilers were fed a medicated standard grower diet (3200 kcal

ME/kg, 20 % crude protein). At the end of each week, feed was weighed to determine weekly feed consumption. Daily water measurements were taken at 10:00 am for each pen and a total amount of water consumed was calculated for each wk and for the entire 6-wk period. Daily maximum and minimum temperatures for inside and outside the barn were recorded during both trials. Broiler mortality including culled broilers were tagged and weighed and were later examined by a veterinarian. The mortality was categorized (Appendix 1) as sudden death syndrome, ascites, valgus legs, septacemia, omphalitis, dehydration, and other causes of death.

On day 38 in Trial 1 and on day 39 in Trial 2, birds were individually weighed. In both trials, 224 broilers were selected (eight per pen) based on weight range (1800 g to 1899 g) and were processed to examine carcass quality The data recorded from these broilers included carcass weight, breast yield and area, measurements of the thighs, legs, and wings. On day 38 of Trial 1 and day 42 of Trial 2, the remaining broilers were shipped to Lilydale Co-operatives Ltd. processing plant in Calgary. At the plant, birds were unloaded as 32 separate lots and were identified by leaving approximately 40 empty shackles between groups during unloading. As the birds progressed along the processing line, the number of birds with severe (deep scratch), light (surface scratch), old (occurred before shipping) and new (occurred during shipping) were recorded for each lot. Condemned carcasses along with contaminated and bruised carcasses where trimming was needed were assessed and recorded for each pen group by the plant veterinarian. Once the carcasses were chilled, a machine counted the number of birds per group and recorded the eviscerated weights for each individual carcass (Appendix 1).

Trials 1 and 2 were identical, except for the environmental temperatures and the dates of the processing dates. By way of a two way analysis, data from Trial 1 and 2 were treated as separate blocks, which are presented separately in the tables, to demonstrate these block effects. The two trials were found to be identical and subsequently a four way analysis of variance was conducted. The GLM procedure of SAS® (SAS Institute, 1992) was used. Sources of variation were stocking density (df=3) and nipple density (df=3) and within each trial, the treatments were repeated two times. Differences among treatment and interaction means were separated by T-tests, using the PDIFF option of the LSMEANS statement of the GLM procedure of SAS® (SAS Institute, 1992). Correlation coefficients for water consumption, feed intake, live body weight (BW), eviscerated BW, mortality, and condemnations were computed using REG procedure of SAS® (SAS Institute, 1992). Differences were considered significant at $P < 0.05$.

2.3 Results and Discussion

2.3.1 Stocking density and live performance.

At 37 days of age in Trial 1 and 39 days of age in Trial 2, the production per unit floor area was almost identical (Table 2-2). The birds in Trial 2 appeared to have a reduced growth rate due to the relatively warmer temperatures (Appendix 3). The bird mass per unit area was 46.0, 34.6, 28.6 and 22.9 kg/m^2 for densities of 0.042, 0.055, 0.069 and 0.083 m^2/bird, respectively. The body weights obtained in both trials showed that the stocking density of 0.069 m^2/bird had the highest body weight (1995 g) that was significantly higher than that of the 0.042 m^2/bird stocking density treatment (1915g) (Table 2-2). The birds housed at 0.069 m^2/bird grew almost 100 grams more than these in the 0.042 m^2/bird treatment. However, for each square meter of floor space, bird mass increased by 17.4 kg in the 0.042 m^2/bird treatment. Although this density is not within the range of the optimum floor space determined by Ringer (1971), this would have a gross return of \$51/m^2 at 0.042 m^2/bird compared to \$38/m^2 at 0.069 m^2/bird (assumed price = \$1.12/kg). The body weight coefficient of variation (CV) is the standard deviation divided by the mean expressed as a percentage. The CV value is an indicator of the flock uniformity. The stocking density of 0.083 m^2/bird had a significantly higher CV value (15.3 %) among the four densities in the two trials indicating a lower flock uniformity, whereas the CV values for the other three density treatments were the same (CV value of 13.3%) (Table 2-2).

The mean body weight BW at 042 m^2/bird was not significantly different from 0.055 or 0.083 m^2/bird this density had numerically the lowest BW (1898 g) among the four treatments. This appears to have resulted from these birds being in such close proximity (less space) resulting in a slower growth rate as reported by Bolton *et al.*(1972). The higher variability in BW (CV) in the 0.083 m^2/bird treatment is a result of the generous floor space allowing the fast growing birds to grow to their potential. These birds tend to be more dominant over the slower growing birds at the feeder (Deaton *et al*, 1968). Low stocking densities allow for different growth rates within the flock and therefore lower flock uniformity. The average BW of the birds from Trial 2 were lower than the BW in Trial 1, even though birds in Trial 2 were 2 days older at time of individual weighing. Lower BW in Trial 2 might be attributed to higher environmental temperatures, which occurred during Trial 2 compared to Trial 1. Since this decrease applied to all four density treatments, the birds in the 0.042 m^2/bird treatment were not more heat stressed than those in the other treatments.

The discrepancy between the pen scale weights and the mean measured BW was 190 and 110g for Trial 1 and 2, respectively at the time the birds were individually weighed. The floor scale weights were lighter than the actual weights recorded, which suggests that the distribution of birds standing on the scales was skewed to the lighter birds. When projected to day 42, the mean weight of the 8 floor scales for each day suggests that the birds weighed the same (2.03 kg) at day 42. The slope of the gain during the last 10 days was estimated to be 62 g/day. The BW at the processing plant was 2.01 and 2.14 kg for the Trial 1 and 2, respectively, while the pen scales indicated 1.79 and 2.03 kg, respectively at this time.

2.3.2 Nipple Drinker Density

Nipple drinker density had no effect on broiler performance and carcass traits. It was speculated that as the bird/nipple density increased, water consumption (Table 2-4) would decreased (mL/bird) and the number of scratches would increase as a result of more competition for water. The fact that birds were a maximum of 1.3 m from any drinker may have negated the effect of nipple drinker spacing.

2.3.3 Feed and Water Consumption.

Shanwany (1988) indicated that as the stocking density increases, feed intake should decrease since an increase in density will deny the birds access to feed and water. Conversely, in this trial, high stocking densities did not decrease feed consumption.

Birds in the 0.069 m^2/bird treatment consumed significantly more feed (3183 g/bird) than birds in the other 3 treatments (Table 2-3). The overall effect of stocking density on feed conversion (Table 2-3) was not significant. The feed average conversion of the birds for all the treatments was 1.71. This agrees with Cravener et al. (1991), who reported that feed conversion was not affected by stocking density.

With respect to water consumption, the results in Table 2-3 showed that birds housed at 0.083 m^2/bird consumed significantly less water (5093 ml/bird) than those in the 0.042, 0.055 and 0.069 m^2/bird treatments. Water consumption ranged between 5093 to 5546 ml/bird. The effect of the nipple density treatment on water consumption was not significant (Table 2-4). An increase in the number birds per nipple drinker was assumed to decrease water consumption, however this did not occur. The reason may be that birds were a maximum of 1.3 m from a nipple drinker. Hence nipple density was not a factor ($P = 0.11$).

2.3.4 Diurnal Feed Consumption

The feeder space per bird was 1.93, 1.60, 1.28 and 0.886 cm for the 0.083, 0.069, 0.055 and 0.042 m^2/bird respectively. Figures 2-2 and 2-3 show feed consumption from day 23 to day 41 of the birds in Trial 2. Daily feed consumption was divided into four 6-h periods. Figure 2-2 shows that for the 0.083 m^2/bird treatment, the feed consumption during 6 am to noon and noon to 6 pm was higher than the other two time periods. However, in the 0.042 m^2/bird treatment, the feed consumption during each 6-h time period was more similar (Figure 2-3). In the 0.042 m^2/bird treatment, the birds consumed 40 to 56 g/bird in the 6 to noon period. In the 0.083 m^2/bird treatment, the birds consumed 56 to 64 g/bird in the 6 to noon period. Table 2-5 tabulates the percentage of feed consumed in each 6-h period in each treatment for the 11-day period. It is interesting to note that the 18-24 h period, 19-22 % of feed was consumed. In the 0-6 h period, the percentage increased from 20 to 25 % as the stocking density increased. There was an even further increase during the 6-12 h (28-32 %) period. In the 12-18 h period, the percentage decreased from 30 to 25% as the stocking density increased. As shown in Figure 2-3, the increase in stocking density results in a decrease in the diurnal variation in feed consumption. This decrease in variation should decrease the variation in BW. The reason is that when more birds eat at the same time, this will limit feed intake, which will prevent some birds from eating too much. With feed intake relatively the same, the flock should be more uniform.

2.3.5 Mortality.

The effect of stocking density on bird mortality was not significant and therefore had no effect. Mortality in Trials 1 and 2 was 2 and 4 %, respectively (Table 2-6). The higher mortality in Trial 2 may have been due to the higher ambient temperatures.

2.3.6 Breast yield.

There was no significant difference in breast yield and breast area among the four treatments (Table 2-7). The breast yield as a percentage of carcass weight was 24 % for each of the treatments. This agrees with Bilgili and Hess (1995) indicating that stocking density has no effect. Birds in the 0.069 m^2/bird treatment had the thickest breast muscle (27.7 mm) compared to the other three treatments. The implications of a thicker breast muscle means the producer will have a heavier bird to sell, and the processor will be able to sell more kilograms of breast meat. An increase in stocking density was expected to decrease breast thickness since the more crowded birds cannot grow to their full potential. The breast yield was greater in Trial 2 than that in Trial 1 since the birds were marketed four days later. The breast yield was approximately 19% of LW.

2.3.7 Carcass Quality

The average weight of the birds on the day of processing was 2.01 kg for Trial 1 and 2.14 kg for Trial 2. The distribution of eviscerated body weights and the coefficient of variation followed the same trend as the LW data. The 0.069 m^2/bird treatment for both Trials 1 and 2 had the highest eviscerated BW (1432 g), which was significantly different from the other treatment groups (Table 2-8). The eviscerated BW CV showed that the 0.083 m^2/bird had the highest percentage (14.6 %), while the CV values for the 0.042, 0.055 and 0.069 m^2/bird were the same at 13.1 %. These values were similar to the LW coefficient of variation values indicating that eviscerated CV can be used as an indicator of flock uniformity. Although the birds in the 0.069 m^2/bird treatment had the highest eviscerated weight (1432 g), eviscerated weights in all four treatments were 72 % of the LW (Table 2-8). The eviscerated weight of the birds in Trial 2 was higher than Trial 1 because the birds were shipped four days later. The analyses showed that stocking density had no effect on grade or removal of carcasses from the processing line due to contamination and condemnation (Table 2-9). Percent grade A carcasses in the two trials were 74.5, 73.4, 70.0 and 72.0 % for the stocking densities of 0.042, 0.055, 0.069 and 0.083 m^2/bird, respectively (Table 2-9). The results are not consistent with those of Proudfoot et al. (1979) who indicated that as stocking density increased, the percentage of grade A carcasses decreased. Density had a significant effect on the grade of the carcass along with the percentage of birds removed from the line. The percentage of condemned carcasses in the 0.069 m^2/bird treatment in Trial 2 was significantly lower (0.8 %) while the 0.042 m^2/bird treatment had the highest percentage (4.0 %).

2.3.8 Skin Scratches.

Elfadil et al. (1996) reported that scratches were directly associated with stocking density and as the density increases the incidence of severe scratches is likely to increase. The effect that stocking density had on light, severe and total scratches (Table 2-10), was not significant. It was hypothesized that the number of scratches would increase with stocking density. With the narrow pens, birds had to scramble over one another each time a worker entered the pen. The percentage of scratches was similar in each category in Trials 1 and 2, for both trials the total number of scratches was 30 % for all of the treatment groups. This level of scratching was assumed to increase the incidence of cellulitis, however, there were only 0.3 % (16 birds) and 0.8 % (46 birds) observed for Trial 1 and 2, respectively with no treatment effect.

2.4 Summary.

Nipple drinker density had no effect on broiler performance and carcass traits. In contrast, there was a significant effect of stocking density on broiler performance and carcass traits. The optimum performance of the bird occurred at 0.069 m^2/bird whereas the maximum mass of bird per m^2 occurred at 0.042 m^2/bird. This translates to a gross return of \$51/m^2 of floor area at 0.042 m^2/bird compared to \$38/m^2 at 0.069 m^2/bird at \$1.12/kg BW. The CV was the highest with the 0.083 m^2/bird treatment. This treatment had the highest value, probably due to social interaction in a larger space. Feed consumption decreased as bird density increased bird from 0.069 to 0.042 m^2/bird. However, feed conversion ratio was not significantly different.

Stocking density also affected the water to feed ratio in that the highest ratio of 1.85 occurred in the 0.042 m^2/bird treatment. These broilers consumed more water and ate less feed, which explains why they were lighter in weight. The effect of stocking density on carcass traits was negligible. Where the effects occurred was eviscerated BW as expected from the liveweight analysis. The breast yield and quality of the carcasses (grade A, condemnations, scratches) was not affected by stocking density, which disagrees with the results of Proudfoot et al. (1979).

The birds in the second trial were expected to gain less than those in the first trial because of the warmer weather during Trial 2. The birds in the 0.042 m^2/bird treatment were expected to perform poorly during this warm weather; however, their performance was similar to those in Trial one. The high ventilation rate of 5.6 L/s/bird and the air circulation fans were able to remove the heat from the bird microclimate to reduce heat stress.

From the data obtained in this experiment, the recommended stocking density for obtaining optimum body weight would be at 0.069 m^2/bird. If the goal of the producer is to produce more kilograms per unit space, the a density of 0.042 m^2/bird will work as long as there is enough air movement in providing enough fresh air and removing heat. A density lower than this is not recommended since it would most likely have negative effects on broiler performance. For nipple density, a density as low as 20 birds /nipple can be used but a density of 5 to 10 birds/nipple is more acceptable to allow each bird to consume water.

Table 2-1. Stocking density and nipple drinker density in each pen

Pen		Stocking density (m^2/bird)	Birds/pen	Nipple density (birds/nipple)
12^x	44	0.083	130	5
8	16^x	0.083	130	20
40^y	48	0.083	130	10
4	36^{yz}	0.083	130	15
5	43	0.069	156	5
7^x	15^x	0.069	156	10
3	35^{yz}	0.069	156	15
39^y	47	0.069	156	20
2	34^y	0.055	195	5
10^x	42^z	0.055	195	15
14^x	38^y	0.055	195	10
6	46	0.055	195	20
1	33^y	0.042	260	5
9	41^z	0.042	260	15
11^x	45	0.042	260	10
13^x	37^y	0.042	260	20

^{x}refers to pens with bird weigh scales in Trial 1
^{y}refers to pens with bird weigh scales in Trial 2
^{z}refers to pens with feeder scales in Trial 2

Table 2-2. The effects of stocking density on production per unit floor area (m^2/bird), bodyweight (BW), and coefficient of variation (CV) in body weight

Stocking density	Product per unit area (kg/m^2)			BW (g)			CV (%)		
m^2/bird	1[1]	2[2]	Average[3]	1[1]	2[2]	Average[3]	1[1]	2[2]	Average[3]
0.042	47.5^a	46.3^a	46.9^a	1911^b	1884	1898^b	12.3	13.7^b	13.0^b
0.055	34.9^b	34.4^b	34.6^b	1943^b	1917	1931^b	13.2	14.0^b	13.6^b
0.069	28.8^c	28.5^c	28.6^c	2004^a	1985	1995^a	13.3	13.5^b	13.4^b
0.083	22.9^d	22.9^d	22.9^d	1917^b	1912	1915^b	14.2	16.4^a	15.3^a
Mean	33.5	33.0	33.3	1944	1924	1934	13.3	14.4	13.8
P	0.0001	0.0001	0.0001	0.008	NS	0.0006	NS	0.0065	0.0023

[a,b,c,d]Means, within each trial with no common letter are significantly different ($P \leq 0.05$).
[1]Birds weighed at 37 days and shipped at 38 days of age in Trial 1.
[2]Birds weighed at 39 days and shipped at 42 days of age in Trial 2.
[3]Average of the two trials.

Table 2-3. Effects of stocking density on feed intake(g/bird), feed conversion ratio (FCR), water intake and the water to feed ratio (mL/g)

	Feed Consumption			Feed Conversion			Water Consumption			Water/Feed		
Stocking Density	(g/bird)			FCR			(mL/bird)			(mL/g)		
m²/bird	1[1]	2[2]	Average[3]	1[1]	2	Average[3]	1[1]	2[2]	Average[3]	1[1]	2[2]	Average[3]
0.042	3039^{b}	2967^{b}	3003^{b}	1.72	1.72	1.72	5505^{a}	5588^{a}	5546^{a}	1.81^{a}	1.88^{a}	1.85^{a}
0.055	3112^{ab}	3023^{b}	3068^{b}	1.73	1.72	1.72	5440^{a}	5399^{ab}	5390^{a}	1.75^{b}	1.76^{b}	1.75^{b}
0.069	3204^{a}	3162^{a}	3183^{a}	1.73	1.73	1.73	5483^{a}	5315^{ab}	5399^{a}	1.71^{bc}	1.68^{c}	1.70^{c}
0.083	3026^{b}	2961^{b}	2993^{b}	1.71	1.68	1.70	5040^{b}	5147^{b}	5093^{b}	1.66^{c}	1.74^{bc}	1.70^{c}
Mean	3095	3028	3061	1.72	1.71	1.71	5368	5362	5357	1.73	1.77	1.75
P	0.0081	0.0125	0.0001	NS	NS	0.092	0.0003	0.1105	0.0001	0.0014	0.0016	0.0001

^{a,b,c}Means, within each trial with no common letter are significantly different ($P \leq 0.05$).
[1]Birds weighed at 37 days and shipped at 38 days of age in Trial 1.
[2]Birds weighed at 39 days and shipped at 42 days of age in Trial 2.
[3]Average of the two trials.

Table 2-4. Effect of nipple density (birds/nipple drinker) on water consumption

	Water Consumption (ml/bird)		
	1[1]	2[2]	Average[3]
Nipple density			
5	5472	5422	5447
10	5394	5428	5411
15	5325	5330	5327
20	5277	5209	5243
Mean	5367	5347	5357
P	NS	NS	NS

[1]Water recorded for 37 days.
[2]Water recorded for 42 days.
[3]Average of the two trials.

Table 2-5. Percentage of feed consumed during each 6-h period for each stocking density (m^2/bird)

Stocking Density m^2/bird	0-6 h (%)	6-12 h (%)	12-18 h (%)	18-24 h (%)
0.083	20	32	30	18
0.069	22	28	29	21
0.055	22	28	28	22
0.042	25	28	25	22

Table 2-6. Effect of stocking density on mortality

Stocking Density	Mortality (%)		
m²/bird	1[1]	2[2]	Average[3]
0.042	2.0	5.3	4.4
0.055	1.8	4.6	3.6
0.069	2.2	3.1	3.3
0.083	1.7	4.3	3.7
mean	2.0	4.3	
P	NS	0.068	NS

[1]Birds weighed at 37 days and shipped at 38 days of age in Trial 1.
[2]Birds weighed at 39 days and shipped at 42 days of age in Trial 2.
[3]Average of the two trials.

Table 2-7. Effects of stocking density on breast yield, breast area and breast thickness

Stocking Density	Breast yield (g)			Breast area (cm²)			Breast thickness (mm)		
m²/bird	1[1]	2[2]	Average[3]	1[1]	2[2]	Average[3]	1[1]	2[2]	Average[3]
0.042	314	368	341	193	209	201	25.4[b]	28.4[a]	26.9[ab]
0.055	311	352	332	193	206	200	25.8[b]	27.9[ab]	26.8[ab]
0.069	319	357	338	195	209	203	27.0[a]	28.4[a]	27.7[a]
0.083	312	355	334	191	208	200	26.1[ab]	26.7[b]	26.4[b]
Mean	314	358	336	193	208	201	26.3	28.3	26.9
P	NS	NS	NS	NS	NS		0.026	0.035	0.027

[a,b]Means, within each trial with no common letter are significantly different ($P \leq 0.05$).
[1]Birds weighed at 37 days and shipped at 38 days of age in Trial 1.
[2]Birds weighed at 39 days and shipped at 42 days of age in Trial 2.
[3]Average of the two trials.

Table 2-8. The effects of stocking density on eviscerated body weight and eviscerated coefficient of variation (EVCV)

	Eviscerated Body Weight			EVCV		
Stocking Density	(g)			(%)		
m²/bird	1[1]	2[2]	Average[3]	1[1]	2[2]	Average[3]
0.042	1327[b]	1420[b]	1334[b]	11.5	14.1	12.9[b]
0.055	1332[b]	1448[ab]	1391[b]	12.0	14.5	13.4[b]
0.069	1377[a]	1485[a]	1432[a]	13.4	14.3	13.2[b]
0.083	1314[b]	1445[ab]	1380[b]	12.0	15.9	14.6[a]
Mean	1337	1450	1384	12.3	14.7	13.5
P	0.0062	0.046	0.0005	NS	NS	NS

[a,b]Means, within each trial with no common letter are significantly different ($P \leq 0.05$).
[1]Birds weighed at 37 days and shipped at 38 days of age in Trial 1.
[2]Birds weighed at 39 days and shipped at 42 days of age in Trial 2.
[3]Average of the two trials.

Table 2-9. Effects of stocking density on the percentage of grade A carcasses. Down graded carcasses and condemned carcasses

	Grade A Carcasses			Down Graded Carcasses			Condemned Carcasses		
Stocking Density	(%)			(%)			(%)		
m^2/bird	1[1]	2[2]	Average[3]	1[1]	2[2]	Average[3]	1[1]	2[2]	Average[3]
0.042	76.1	81.4	74.6	2.2	7.9	3.8	0.5	4.0^{a}	1.4
0.055	72.8	81.4	73.4	2.4	6.5	3.1	0.7	2.0^{b}	1.3
0.069	71.2	76.1	70.0	2.2	7.0	3.8	0.6	0.8^{c}	1.0
0.083	72.7	78.1	72.0	1.5	7.0	4.4	0.2	2.4^{ab}	1.9
Mean	73.2	79.3	72.5	2.1	7.1	3.8	0.5	2.4	1.4
P	NS	NS	NS	NS	NS	NS	NS	0.02	NS0

^{a,b,c}Means, within each trial with no common letter are significantly different ($P \leq 0.05$).
[1]Birds weighed at 37 days and shipped at 38 days of age in Trial 1.
[2]Birds weighed at 39 days and shipped at 42 days of age in Trial 2.
[3]Average of the two trials.

Table 2-10. Effects of stocking density on the percentage of light severe and total scratches found on the carcasses

	Light Scratches			Severe Scratches			Total scratches		
Stocking Density	(%)			(%)			(%)		
m^2/bird	1[1]	2[2]	Average[3]	1[1]	2[2]	Average[3]	1[1]	2[2]	Average[3]
0.042	29	9	19	2.6	22	12	32	31	31
0.055	29	11	20	2.7	21	11	31	32	31
0.069	27	9	18	2.8	13	8	30	22	26
0.083	24	11	18	3.7	20	12	28	31	30
Mean	27	10	19	3.0	19	11	30	29	29
P	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]Birds weighed at 37 days and shipped at 38 days of age in Trial 1.
[2]Birds weighed at 39 days and shipped at 42 days of age in Trial 2.
[3]Average of the two trials.

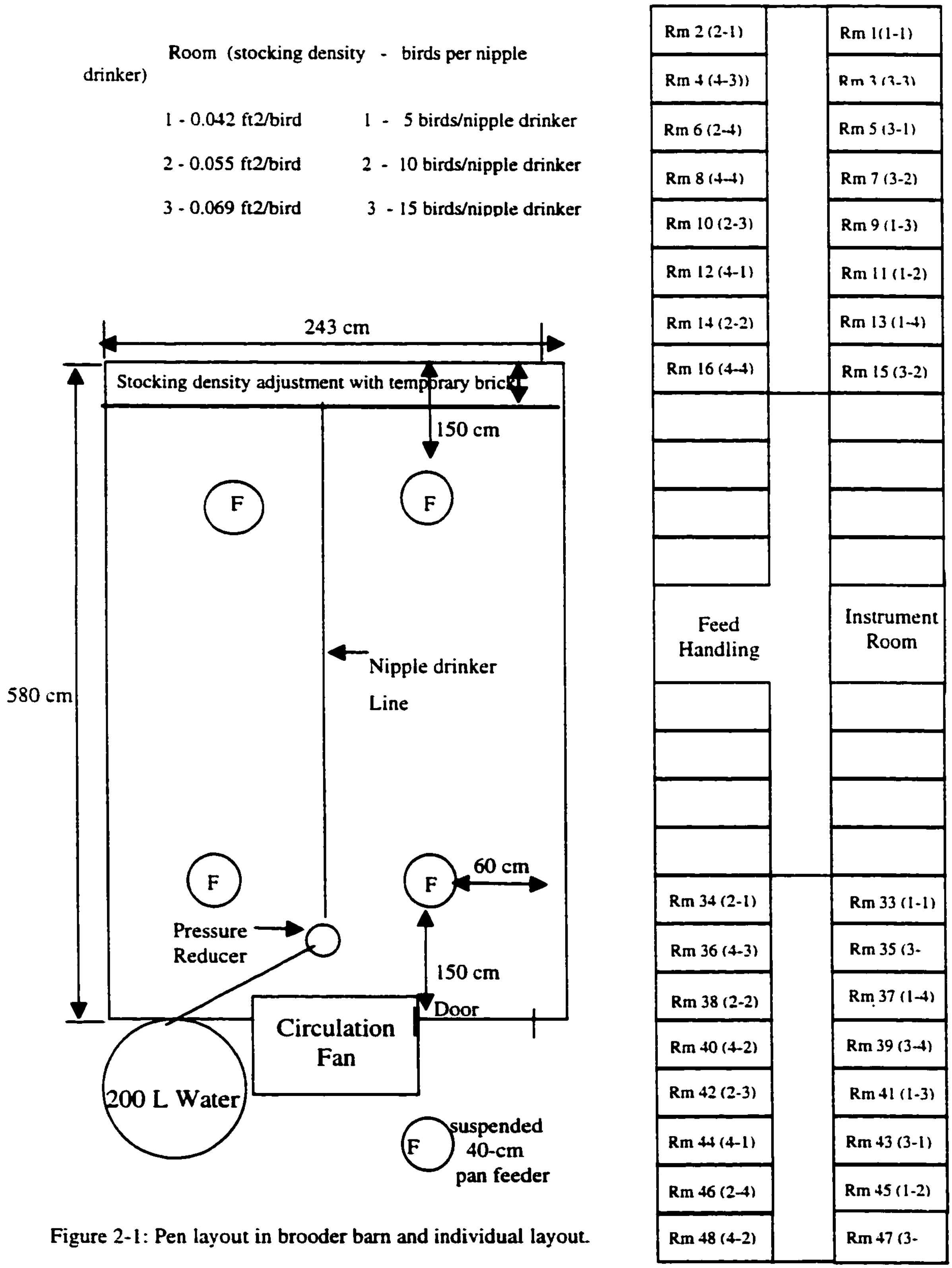

Figure 2-1: Pen layout in brooder barn and individual layout.

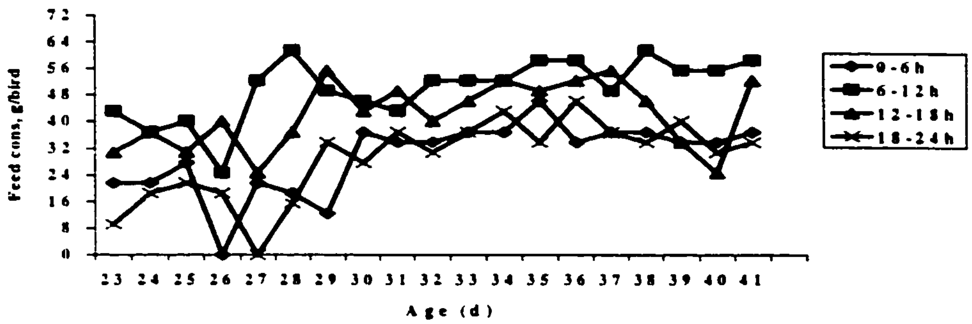

Figure 2-2. Feed consumption by the 0.083 ft^2/bird treatment during the four time periods (intakes based on data from one of the feeders).

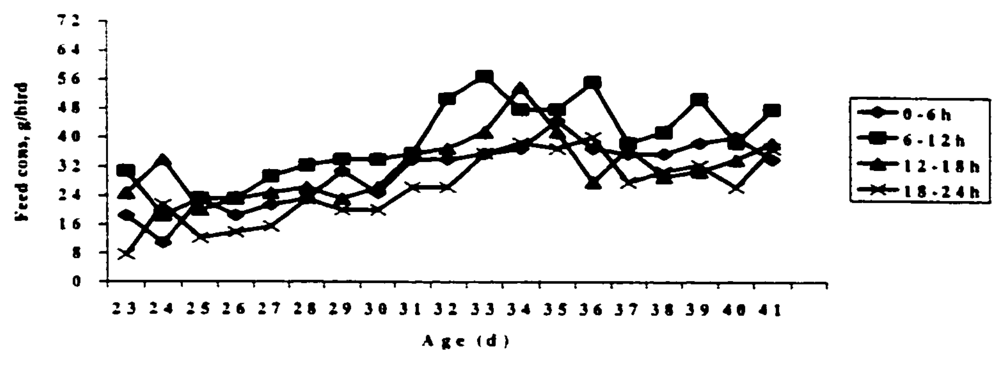

Figure 2-3 Feed consumption by the 0.042 ft^2/bird treatment during the four time periods (intakes based on data from one of the feeders).

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3. Effects of ventilation rate, air circulation and bird disturbance on the incidence of Cellulitis and broiler performance

3.1 Introduction

Cellulitis is an infection of the skin caused by *Escherichia coli* which enters through skin lesions (Elfadil, 1996). According to Elfadil *et al* (1996) most of these lesions occur on the abdomen. There two types of cellulitis that can occur; Type 1 which infects the navel of the chick at the hatchery and Type 2, which infects the body surface. The infected area may become bright to dull yellow or adopt a reddish brown color. In addition the skin becomes swollen at the site of inflammation (Elfadil *et al.*, 1996). Broilers with this infection are condemned resulting in a loss for both producers and meat packing plants.

Cellulitis is becoming a concern for producers and processing plant managers in Canada due to the progressive increase of incidence. From 1986 to 1996, the incidence of cellulites increased dramatically from 0.048 % to 0.568 %, respectively of all condemnations. The increase to 0.568 % represented 30.1 % of all condemnations making it the largest category (Kumor *et al.*, 1998). Where Alberta has one of the highest incidence of this disease in Canada, at 0.5% (Onderka *et al.*, 1997). A possible cause for the increase in cellulitis cases is increased stocking densities, as high as 0.5 m^2/bird. The result of this is increased crowding in the floor area, which can lead to higher incidences of scratches (skin lesions). Broilers generally grow in accordance with their environment. If the environment is ideal the birds will grow to their potential while if the environment is poor the birds will fail to thrive. Two factors that contribute to the broiler's environment include stocking density and temperature. Increased stocking density can create more stress for the bird, especially heat stress, as broilers have difficulty alleviating the excess heat as a result of a closer proximity to one another. The end result is an elevated temperature in the barn, which leads to less activity in the birds (i.e., less feed intake) (Cooper *et al.*, 1998). With adequate ventilation and sufficient air circulation, the excess heat that is produced by the broilers can be removed effectively and at the same time maintain a minimum of 3°C difference between outside and inside the barn during the summer months

Although a lower temperature is ideal, understanding how the barn temperature affects the microclimate temperature, is of great importance. By understanding this relationship, proper ventilation adjustments can be made to provide a more ideal environment for the broilers. Previous research studies, conducted on the effects of various ventilation rates, have indicated that different ventilation rates do not affect body weight (BW) (Weaver *et al.*, 1990). Studies have also indicated that there is no effect on feed intake and mortality (Weaver *et al.*, 1990). In the Southern United States, where tunnel ventilation is used, broilers have gained more weight in comparison to those housed under cross ventilation (Lott *et al.*, 1998). The greater weight gain is said to be attributed to the higher air velocity; which increases sensible heat loss and reduces latent heat loss (Timmons *et al.*, 1993). In Canada, most of the barns have cross ventilation, which tends to have a lower air velocity than a tunnel ventilated system. The use of this type of ventilation, may give reason to why cellulitis is on the rise in Canada. By providing broilers with a higher ventilation rate, the growth of feathers should occur quicker, as a result of a cooler environment. With quicker feather growth, the number of scratches, and incidence of cellulitis, should be minimized. In addition, with the increased ventilation rate, there will be less particulate matter in the air (Zuidhof *et al.*, 1992). Therefore the increased air speed will help remove *E. coli* away from the bird zone (Davies *et al.*, 1994). The study was undertaken to determine if a higher ventilation rate causes a decrease in cellulitis, compared to a lower rate. Also to see if a higher disturbance level increases the incidence of cellulitis compared to a lower level of disturbance.

3.2 Materials and Methods

A total of 7000 female Hubbard x Hubbard broiler chicks were used for each of the two trials in this study. At 1 week (wk) of age, the chicks were randomly placed into thirty-two pens (four individual rooms with eight pens) (Figure 3-1) after being counted and group weighed. Each pen contained 226 birds stocked at a density of 0.5 m^2/bird for the 6-wk period. The dimensions of the pens were 2.43 m x 5.79 m (8' x 19') or 14.06 m^2 of which 3.0 m^2 was considered non-utilizable space (feeder area and 15 cm along the walls). To maintain a constant stocking density, a 7.5' x 3' adjustable partition at the rear of the pen was moved inward as the stocking density changed due to mortality (Figure 3-1).

In the center of each pen was a PVC nipple drinker system, which was directly connected to a calibrated 200-L water barrel (Figure 3-1). Each pen had one overhead circulation fan to recirculate the air the cool air in each pen, in addition to providing additional air movement in the vicinity of the birds in Trial 1 (Figure 3-2). The even numbered pens had a higher mean pen air speed (0.82 m/s) while the odd numbered pens had a lower air speed (0.32 m/s). Four pan feeders with a holding capacity of 10 kg were located in each pen with two in the back and two in the front on either side of the drinker system (Figure 3-1). In addition 16 of these pens had an automatic feed system by using an auger system. This was one of the treatment effects tested to see if automatic feeding (minimal disturbance) compared to pail feeding (regular disturbance) affected the incidence of cellulitis.

Each individual room (eight pens/room) was ventilated by two 24" fans and two 18" fans. This air is simply brought into the barn through inlets to allow for air exchange The high ventilation treatment, used were (2x the recommended summer rates) 3.4 L/s/bird (full capacity of the 4 fans), while the low ventilation treatment was 1.7 L/s/bird. To adjust the ventilation rate, a carbon dioxide (CO_2) tracer technique was used where an initial reading of CO_2 was measured (background) in the room (Table 3-1). This was done using a CO_2 monitor that was placed in front of each 24" fan, which were operating at the time, and another in the center of the room. Readings were taken every 5 min until all three monitors stabilized. When this occurred an average of the three was calculated. CO_2 was then released at a rate of 0.24 L/s in the middle of the room between the two fans. Readings were recorded every 5 minutes until the monitors stabilized. An average was then again calculated which represented the concentration of the $C0_2$ added to the room (Table 3-1). Using this method this method, it was determined that a 21" orifice was required was required in the plywood to cover the 24" fans in order to obtain a ventilation a rate of 1.7 L/s/bird. This air flow rate was also checked by using the standard protocol fan performance test (Fan Engineering, 1983). This involved a discharge duct downstream from each fan. The duct had air straighteners (tubes) to provide a more laminar flow of air in the duct. Near the end of the duct, six ports were drilled into the duct (Figure 3-3) for air flow measurements. The air flow meter (TSI Inc., St. Paul, Minnesota) was used to obtain measurements in each opening at different traverse locations (heights) of; 2, 4, 6, 8, 10 and 304 mm from the edge of the duct. The mean values for each port were calculated (Table 3-2) and by using these mean values in the calculation the flow rate of 1.7 L/s/bird was determined. The ventilation rates determined by the CO_2 method and the duct method were in agreement.

The barn temperature required for the birds (determined from a broiler housing manual) was maintained in the high ventilation treatments by controlling fan operation from room thermostats. The temperatures were maintained by a forced air heating system when ventilation was at the minimum adjustment. Barn rooms, outside maximum, outside minimum and actual temperatures were recorded daily in mid afternoon. Within the center of each pen a black bottle (absorbed radiant heat) filled with water (approximately the same heat capacity as a chicken) was measured daily at the same time. This was done by measuring the surface temperature using a non-contact infrared thermometer (Oakton Distributors, Chippewa Falls, Wisconsin), which operated best within 1200 mm of the bottle.

Water and feed were provided ad libitum for each of the 32 pens for the entire 6 wk growth cycle with 23 hour (hr) light and 1 hr dark per day. For the first 3 wk, the chicks in Trial 1 were fed a standard starter diet (3000 kcal ME/kg, 21.4 % crude protein) and from 4 to 6 wk the broilers were fed a standard grower diet (3000 kcal ME/kg, 18.8 % crude protein). Due to poor body weight (BW) performance of the birds in Trial one, the birds in Trial two were given a different feed which had 3100 kcal ME/kg and 19.4 %

crude protein for the starter. The grower contained 3050 kcal ME/kg and 18.8 % crude protein. At the end of each wk, feed was weighed back to determine weekly feed consumption on a per bird basis for each pen. Daily water measurements were obtained at 10:00 am for each pen from the graduated 200 L barrels therefore the total amount of water consumed was calculated for each wk for the entire 6 wk period. Broiler mortality was recorded including culls, and these birds were weighed and tagged and kept on file to estimate the amount of feed consumed.

Trials 1 and 2 were identical, except for the environmental temperatures and the dates of the processing. By way of a two way analysis, data from Trial 1 and 2 were treated as separate blocks, which are presented separately in the tables, to demonstrate these block effects. The two trials were found to identical and subsequently a four way analysis of variance was conducted. The GLM procedure of SAS® (SAS Institute, 1992) was used. Sources of variation were ventilation rate (df=1), air speed (df=1) and disturbance level (df=1), where within each trial, the treatments were repeated two times. Differences among treatment and interaction means were separated by T-tests, using the PDIFF option of the LSMEANS statement of the GLM procedure of SAS® (SAS Institute, 1992). Correlation coefficients for water consumption, feed intake, live body weight (BW), eviscerated BW, mortality, and condemnations were computed using REG procedure of SAS® (SAS Institute, 1992). Differences were considered significant at $P < 0.05$.

3.3 Results and Discussion

3.3.1 Live weight performance

In this experiment, the broilers grown in Trial 2 performed better in terms of BW in comparison to those grown in Trial 1. In both trials, the effects of ventilation rate and disturbance on production per unit floor area, were not significant (Table 3-4). The effect of a higher air speed resulted in a significantly higher production per unit floor area (38.0 kg/m^2), in comparison to the minimal air speed (37.4 kg/m^2) (Table 3-4). The birds grown at a mean air speed of 0.82 m/s gained more kilograms per m^2. In terms of financial return, this would equal \$41/m^2 and \$42/m^2 (price of \$1.12/kg) for low and high air speeds, respectively. The BW data obtained showed that ventilation and disturbance had no significant effect (Table 3-4), while air speed did have a significant effect. The higher air speed treatment (1767 g) was 30 grams heavier than the minimal air speed treatment (1737 g). This is consistent with Lott *et al.*, (1998) in that an increase in air speed results in better BW gain. The body weight coefficient of variation (CV) is the standard deviation divided by the mean expressed as a percentage. The CV value is an indicator of the flock uniformity. The different disturbance levels among the birds had a significant effect on the BW CV. There was more uniformity in weights of birds that were minimally disturbed, in comparison to the regularly disturbed birds (Table 3-4). The lower uniformity may suggest that some of those birds didn't adapt as quickly compared to others. Therefore these birds took more time to recover and stayed of feed longer in trying to recover while the others went back and ate more. The effect of ventilation rate and air speed was not significant. These results do not support Rosario's research (1999), which indicated that poor ventilation might result in an early exposure to ammonia which would in turn damage the broiler's respiratory system. The non significant effect of ventilation rate on flock uniformity in this trial may be a result of the minimum ventilation providing adequate fresh air for the broilers, thus preventing high levels of ammonia exposure. Another interesting finding was an interaction between disturbance and ventilation rates and its positive affect on the broilers. The lower disturbance and low ventilation rates, resulted in a more uniform flock. Those birds that were disturbed less, but given higher ventilation rates were less uniform. The more uniform broilers were theoretically exposed to higher temperatures, which results in less activity and less feeding, to keep their body temperature from increasing (Cheng *et al.*, 1997). The end result of this lower level of activity, is that feed may have been consumed primarily at night, as the barn temperature decreased. With most of the feed being consumed at night, this meant that more of the birds ate at night which then lead to more uniform feed intake and more uniform body weight.

3.3.2 Feed and Water Consumption

Given a high stocking density, feed consumption is generally suppressed with the addition of high environmental temperature. The end result of these factors can be poorer growth rate and feed conversion, which becomes more pronounced as the birds become older (May *et al.*, 1998). The results in Table 3-5 show that ventilation, air speed, and disturbance did not significantly affect feed intake. The effect of ventilation rate does not support the research of Howlider and Rose (1989), who determined from simple observations, indicated that at a higher barn temperature in the low ventilation rooms, the broilers were less active and therefore consumed less feed. Though one major difference between these two experiments is that they had two set temperatures of 21 and 31°C for the entire trial, while this experiment didn't. From observations made during this experiment, at those temperatures broilers will consume less feed.

The effects of ventilation rate on water consumption were significant showing that birds exposed to low ventilation (higher environmental temperatures) consumed more water (6080 ml/bird), compared to birds in the high ventilation environment (5895 ml/bird). The results are consistent with Lott (1990), who found that broilers subjected to more heat stress consumed more water in trying to reduce their body temperature. The interaction between ventilation rate and air speed (Table 3-6) showed that broilers in the high ventilation/low air speed treatment consumed the least amount of water. For the high ventilation/high air speed treatment, the ideal environment allowed the broilers to consume more feed, which coincided with the increased water consumption. Broilers subjected to low ventilation/low and high air speed treatment were more heat stressed and simply drank more to keep cool. The effects of ventilation rate air speed and disturbance on feed conversion and water to feed ratio were non-significant. The non-significant effect of ventilation on feed conversion was not consistent with Lott *et al.*, (1998) who indicated that increased air velocity results in a more efficient feed utilization. This finding, however, supports the research of Weaver *et al.*, (1990) who found no significant effect of ventilation on feed conversion. Looking at the water to feed ratio (which was approaching significance) we see that the birds in the lower ventilation treatments, did have a higher ratio. This indicated that these birds were trying to keep cool by drinking more water. Still, the water to feed ratios were similar which might indicate that the heat stressed birds did not increase their water consumption. Instead they simply consumed less feed.

3.3.3 Mortality

The effect of ventilation and air speed and disturbance on broiler mortality was not significant. Mortality was 5.0 % on average for each treatment (Table 3-7). Although the trials were not compared statistically, Trial 1 did have a higher greater percentage (5.8 %) compared to Trial 2 (4.0 %). The non-significant effect of ventilation rate on mortality is consistent with the findings of Weaver *et al.*, (1990).

3.3.4 Carcass Characteristics

3.3.4.1 Breast Yield

There was no significant difference in breast yield (pectoralis major and minor) among the different treatments (Table 3-8). On average the total breast yield (sum of major and minor) was 296 grams, which made up approximately 24 % of the BW. The results do not agree with those Howlider *et al* (1989). They found that increased temperatures, above 21°C, would result in a decrease in breast yield along with an increase in dark meat development (for males).

3.3.4.2 Carcass Quality

The eviscerated body weight did not follow the same trends as the live BW. Instead of having heavier BW at high air speed, there were no significant differences within each treatment (Table 3-9). The effects of ventilation rate are consistent with Prince *et al.* (1961), who stated that carcass quality is not affected by ventilation. More recent research suggests that ventilation does in fact have an effect on carcass quality (May *et al.*, 1998; Cooper and Washburn, 1998). What is interesting from the results in Table 3-9, is that the low ventilation rate; minimal air speed and regular disturbance treatments resulted in higher BW (1215 g on average).

From the analyses, the data show that neither ventilation rate , air speed nor disturbance had a significant effect on the percentage of grade A carcasses (Table 3-10). Compared to other studies, it was hypothesized that lower ventilation rates would decrease the amount of grade A carcasses (Weaver and Meijerhof, 1990), but that was not the case. The percentage of removed carcass (RC), from the processing line, was not significantly affected by the treatments (Table 3-10) also.

Ventilation rate or air speed (Table 3-11) did not significantly affect the percentage of condemned carcasses, but the effect of disturbance was approaching significance ($P = 0.06$). These birds that were regularly disturbed were presumably stressed, and inflicted more damage on one another, as they tried to avoid the farm staff during feeding. The interaction between ventilation rate and air speed was significant ($P = 0.0027$), where low ventilation and minimum air speed resulted in the highest percentage of condemned carcasses (1.19 %). The higher rate of condemnations, could be due to the poor air quality (causing ascites) or the increase in temperature (resulting in poorer litter conditions) (William and Meijerhof, 1991). Of additional interest is the interaction of high ventilation and maximum air speed, which resulted in second highest condemnation rate (1.12 %). This increased rate of condemnation, could be a result of the birds being more active in a suggested optimal environment, as well as the fact that these birds grew at a faster rate (leading to more skeletal problems such as vargus legs).

3.3.5 Skin Scratches and Cellulitis

Elfadil *et al.*, (1996) indicated that cellulitis infections occur through skin lesions or simple scratches. Carcasses that have scratches on them are down graded from an A to B in Canada, and have less saleable meat since the scratches are trimmed off. Scratches can also lead to skin tearing by processing machinery, thus down grading the carcass (Schleifer, 1988). The data of most interest were the severe, light and the total number of scratches. The hypothesis was that the more scratches that occurred, the higher the incidence of celluitis. The increase in the number of scratches should also correlate with an increase in disturbances. The results indicate that there were no significant differences among the three treatments (ventilation rate, air speed, disturbance) tested (Table 3-12). The insignificant effect of various ventilation rates, supports the findings of Christensen et al. (1993), who found that temperature had no effect on skin strength (tearing).

The effects of ventilation rate, air speed and disturbance on cellulitis were also non-significant (Table 3-13). There were only a total of 78 incidences of celluiltis out of the 14,000 in the two trials. The hypothesis was that at a lower ventilation rate, lower air speed, and increased disturbances, the incidence of cellulitis would be higher. The trials were conducted during the summer months of June, July and August, when cellulitis is more prevalent (Schleifer, 1988). It is speculated that the environment provided at the research facility was not conducive for *E.coli* to flourish. One possible reasons for such a low incidence of cellulitis, may be due to the fact that the barns were washed and disinfected thoroughly between flocks. According to Joseph *et al.*, (2000), adequate ventilation and low levels of humidity can reduce *E.coli* and *Salmonella*.

3.4 Summary

The ventilation rate, air speed and disturbance level had no significant effect on the incidence of cellulitis in broiler chickens. It was hypothesized that at a higher ventilation rate, the incidence of cellulitis would decrease, as a larger volume of air would remove the *E. coli* from the broiler environment. The incidence of cellulitis was found to be very low (78 incidences out of 14,000 birds), even though the trials were conducted during the summer months when cellulitis is more prevalent.

The effects of the three treatments on broiler performance, however, were significant in some aspects. A higher BW was achieved with a higher circulation air speed (1767 g), compared to a lower air speed (1737 g). In addition, more kilograms of broilers were produced per floor area with a higher air speed (38.0 kg/m^2), compared to a low air speed (37.4 kg/m^2). This translates to $1.00 more return/m^2, when a higher air speed is provided to the broilers.

Ventilation rate and air speed had no significant effects on flock uniformity, while regular disturbance did have a significant effect. The data show that broilers that were less disturbed (automatic feeding) were more uniform (CV = 13.7 %), compared to those that were hand fed (CV = 14.0 %). Ventilation rate, air speed and disturbance did not have an affect on feed consumption, but it did affect water consumption. A lower ventilation rate increased the consumption rate of water (6080 mL/bird), compared to a higher ventilation rate (5895 mL/bird). This occurred due to the higher temperature, which caused the broilers to drink more in order to keep cool (Lott, 1990). The ratio of water to feed was not significantly affected by the three treatments tested. The average ratio was 1.76, which is in the range that producers try to obtain.

The effects of ventilation rate, air speed and disturbance on carcass traits and scratching was not significant. Breast yield, which was of most interest, was on average 24 % of the BW for each of the treatments. Carcass quality and the number of condemned carcasses was not significantly affected by ventilation rate and air speed.

From these results, the overall productiveness of the broiler chickens was higher with a higher air speed, than those exposed to a lower air speed. If the microclimatic temperature is closely monitored, the data should further explain that these conditions were more favorable.

TABLE 3-1. Example of CO_2 measurement to determine room ventilation rate

Background CO_2 (ppm)			CO_2 added to the room (ppm)		
Fan 1	Fan 2	Average	Fan 1	Fan 2	Average
559	624	592	845	790	818

Using these values in the formula:

$$L/s\ air = \frac{L/s\ CO_2 \times 10^6}{ppm\ (CO_2\ added)\ -\ ppm\ (CO_2\ background)}$$

$L/s\ CO_2$ = measured by a flow meter and adjusted for density

TABLE 3-2. Sample Air flow measurements (m/s) for fan testing at 6 hole locations with a 21" orifice

	Hole					
Height (mm)	**1**	**2**	**3**	**4**	**5**	**6**
		Air flow (m/s)				
50	2.10	2.04	2.27	2.18	2.32	2.32
100	2.54	2.10	2.62	2.32	2.26	2.73
150	2.93	2.38	2.94	2.66	2.81	3.34
200	3.20	2.83	3.38	2.93	3.50	3.73
250	3.68	3.01	3.70	3.12	3.68	4.21
300	3.66	2.96	3.46	2.75	3.43	3.81
Mean	3.02	2.55	3.06	2.66	3.00	3.36
Total mean	2.94 m/s					
Duct area (m^2)	0.46					
Flow rate (L/s)	(1352 x 2)/1600 birds		= 1.7 L/s/bird			

TABLE 3-4. The effects of ventilation, air speed and disturbance on production per unit area, bodyweight (BW) and bodyweight coefficient of variation (BWCV)

	Live Product per unit area	BW	BWCV
	kg/m^2	(g)	%
Ventilation			
High[1]	37.8	1746	14.3
Low[2]	37.5	1759	13.8
Mean	37.7	1753	14.1
P	NS	NS	NS
Air Circulation			
HA[3]	38.0^a	1767^a	14.1
LA[4]	37.4^b	1737^b	14.1
Mean	37.7	1752	14.1
P	0.02	0.01	NS
Disturbance level			
Regular[5]	37.7	1753	14.4^a
Minimal[6]	37.7	1752	13.7^b
Mean	37.7	1753	14.1
P	NS	NS	0.05

[a,b]Means, within each column, with no common letter are significantly different ($P \leq 0.05$).
[1]High Ventilation rate of 3.4 L/s/bird.
[2]Low Ventilation rate of 1.7 L/s/bird.
[3]High Air speed of 0.82 m/s.
[4]Low air speed of 0.32 m/s.
[5]Regular disturbed birds that were hand fed.
[6]Minimal disturbed birds that were auger fed.

TABLE 3-5. Ventilation, air speed and disturbance effects on feed consumption, water consumption, feed conversion and water to feed ratio

	Feed Consumption (g/bird)	Feed Conversion FCR	Water Consumption (mL/bird)	Water/Feed (mL/g)
Ventilation				
High	3404	2.07	5895[a]	1.74
Low	3424	2.10	6080[b]	1.77
Mean	3414	2.09	5988	1.76
P	0.0553	NS	0.0034	NS
Air speed				
HA	3437	2.09	6031	1.76
LA	3391	2.08	5943	1.76
Mean	3414	2.09	5987	1.76
P	NS	NS	NS	NS
Disturbance level				
Regular	3413	2.09	5942	1.75
Minimal	3414	2.09	6031	1.77
Mean	3414	2.09	5987	1.76
P	NS	NS	NS	NS

[a,b]Means, within each column, with no common letter are significantly different ($P \leq 0.05$).
[1]High Ventilation rate of 3.4 L/s/bird.
[2]Low Ventilation rate of 1.7 L/s/bird.
[3]High Air speed of 0.82 m/s.
[4]Low air speed of 0.32 m/s.
[5]Regular disturbed birds that were hand fed.
[6]Minimal disturbed birds that were auger fed.

TABLE 3-6. The interaction effect of ventilation and air speed on water consumption

Ventilation	Air Speed	Water Consumption
L/s	m/s	mL/bird
High[1]	LA[4]	5784[b]
High[1]	HA[3]	6004[a]
Low[2]	LA[4]	6100[a]
Low[2]	HA[3]	6058[a]
Mean		5986.5
P		0.034

[a,b]Means, within each column, with no common letter are significantly different ($P \leq 0.05$).
[1]High Ventilation rate of 3.4 L/s/bird.
[2]Low Ventilation rate of 1.7 L/s/bird.
[3]High Air speed of 0.82 m/s.
[4]Low air speed of 0.32 m/s.

TABLE 3-7. Effect of ventilation, air speed and disturbance on mortality

Mortality (%)					
Ventilation		Air Speed		Disturbance level	
High[1]	4.79	HA[3]	4.96	Regular[5]	4.74
Low[2]	5.03	LA[4]	4.87	Minimal[6]	5.08
Mean	4.9	Mean	4.92	Mean	4.91
P	NS	P	NS	P	NS

[1]High Ventilation rate of 3.4 L/s/bird.
[2]Low Ventilation rate of 1.7 L/s/bird.
[3]High Air speed of 0.82 m/s.
[4]Low air speed of 0.32 m/s.
[5]Regular disturbed birds that were hand fed.
[6]Minimal disturbed birds that were auger fed.

TABLE 3-8. The effects of ventilation, air speed and disturbance on breast yield

	Pectoralis major	Pectoralis minor
	g	g
Ventilation		
High[1]	231	64.5
Low[2]	232	63.6
Mean	232	64.1
P	NS	NS
Air Speed		
HA[3]	232	63.4
LA[4]	232	64.7
Mean	232	64.1
P	NS	NS
Disturbance level		
Regular[5]	232	65.6
Minimal[6]	231	62.5
Mean	232	64.1
P	NS	NS

[1]High Ventilation rate of 3.4 L/s/bird.
[2]Low Ventilation rate of 1.7 L/s/bird.
[3]High Air speed of 0.82 m/s.
[4] Low air speed of 0.32 m/s.
[5]Regular disturbed birds that were hand fed.
[6]Minimal disturbed birds that were auger fed.

TABLE 3-9. Effects of ventilation, air speed and disturbance on eviscerated bodyweight

Eviscerated body weight					
g					
Ventilation		**Air Speed**		**Disturbance level**	
High[1]	1208.7	HA[3]	1208.9	Regular[5]	1214.6[a]
Low[2]	1216.1	LA[4]	1215.9	Minimal[6]	1210.1[b]
Mean	1212.4	**Mean**	1212.4	**Mean**	1212.3
P	NS	**P**	NS	**P**	0.042

[a,b]Means, within each column, with no common letter are significantly different ($P \leq 0.05$).
[1]High Ventilation rate of 3.4 L/s/bird.
[2]Low Ventilation rate of 1.7 L/s/bird.
[3]High Air speed of 0.82 m/s.
[4] Low air speed of 0.32 m/s.
[5]Regular disturbed birds that were hand fed.
[6]Minimal disturbed birds that were auger fed.

TABLE 3-10. Effects of ventilation, air speed and disturbance on the percentage of grade A carcasses, and removed carcasses (RC) from the processing line , for trimming, condemnation and contamination

	Grade A carcasses	RC
	%	%
Ventilation		
High[1]	89.1	10.0
Low[2]	89.6	9.1
Mean	89.4	9.59
P	NS	0.0552
Air Speed		
HA[3]	89.4	9.53
LA[4]	89.3	9.64
Mean	89.4	9.59
P	NS	NS
Disturbance		
Regular[5]	89.1	9.36
Minimal[6]	89.6	9.81
Mean	89.4	9.59
P	NS	0.0554

[1]High Ventilation rate of 3.4 L/s/bird.
[2]Low Ventilation rate of 1.7 L/s/bird.
[3]High Air speed of 0.82 m/s.
[4]Low air speed of 0.32 m/s.
[5]Regular disturbed birds that were hand fed.
[6]Minimal disturbed birds that were auger fed.

TABLE 3-11. Effects of ventilation, air speed, disturbance on condemned carcasses and the interaction of air speed and ventilation rate

Condemned Carcasses %							
Ventilation		**Air Speed**		**Disturbance level**		**Air Speed*Ventilation**	
High[1]	0.82	HA[3]	0.83	Regular[5]	1.05	High*LA	0.52[a]
Low[2]	0.84	LA[4]	0.85	Minimal[6]	0.72	High*HA	1.12[b]
						Low*LA	1.19[b]
Mean	0.89	**Mean**	0.88	**Mean**	0.89	Low*HA	0.71[a]
P	0.46	**P**	NS	**P**	0.06		
						Mean	0.89
						P	0.0027

[a,b]Means, within each column, with no common letter are significantly different ($P \leq 0.05$).
[1]High Ventilation rate of 3.4 L/s/bird.
[2]Low Ventilation rate of 1.7 L/s/bird.
[3]High Air speed of 0.82 m/s.
[4]Low air speed of 0.32 m/s.
[5]Regular disturbed birds that were hand fed.
[6]Minimal disturbed birds that were auger fed.

TABLE 3-12. Effects of ventilation, air speed and disturbance on the percentage of scratches

	Light scratches	Severe scratches	Total scratches
	%	%	%
Ventilation			
High[1]	10.7	11.8	21.4
Low[2]	11.9	12.7	23.9
Mean	11.3	12.3	22.7
P	NS	NS	NS
Air Speed			
HA[3]	10.8	12.6	22.4
LA[4]	11.8	12.0	22.9
Mean	11.3	12.3	22.7
P	NS	NS	NS
Disturbance			
Regular[5]	11.5	11.3	21.8
Minimal[6]	11.1	13.2	23.5
Mean	11.3	12.3	22.7
P	NS	NS	NS

[1]**High Ventilation rate of 3.4 L/s/bird.**
[2]**Low Ventilation rate of 1.7 L/s/bird.**
[3]**High Air speed of 0.82 m/s.**
[4]**Low air speed of 0.32 m/s.**
[5]**Regular disturbed birds that were hand fed.**
[6]**Minimal disturbed birds that were auger fed.**

TABLE 3-13. The effects of ventilation rate, air speed and disturbance on the percentage of cellulitis

Cellulitis %					
Ventilation		**Air speed**		**Disturbance level**	
High[1]	0.055	HA[3]	0.76	Regular[5]	0.73
Low[2]	0.86	LA4	0.70	Minimal[6]	0.73
Mean	0.73	**Mean**	0.73	**Mean**	0.73
P	NS	**P**	NS	**P**	NS

[1]**High Ventilation rate of 3.4 L/s/bird.**
[2]**Low Ventilation rate of 1.7 L/s/bird.**
[3]**High Air speed of 0.82 m/s.**
[4]**Low air speed of 0.32 m/s.**
[5]**Regular disturbed birds that were hand fed.**
[6]**Minimal disturbed birds that were auger fed.**

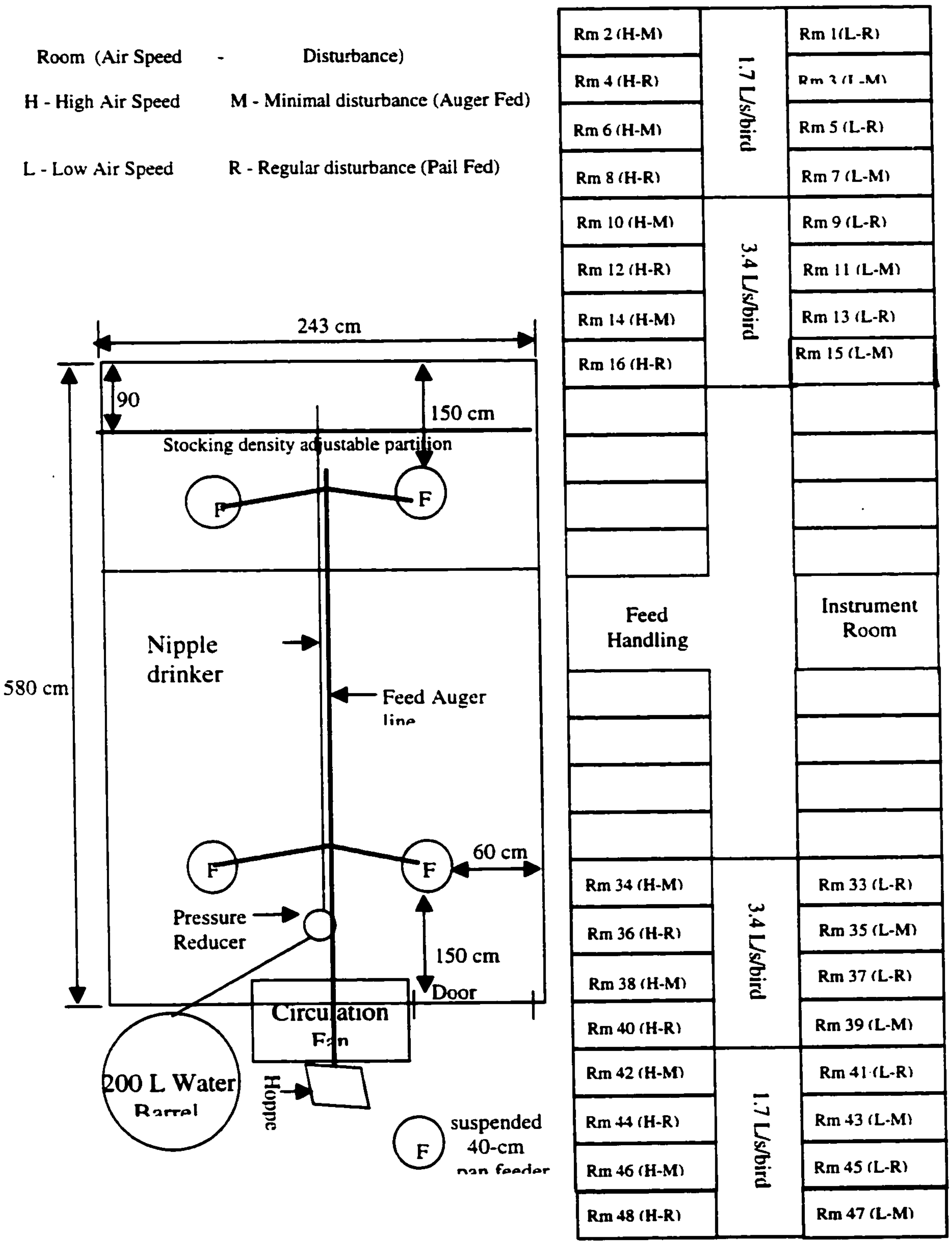

Figure 3-1: Pen layout in brooder barn and individual pen

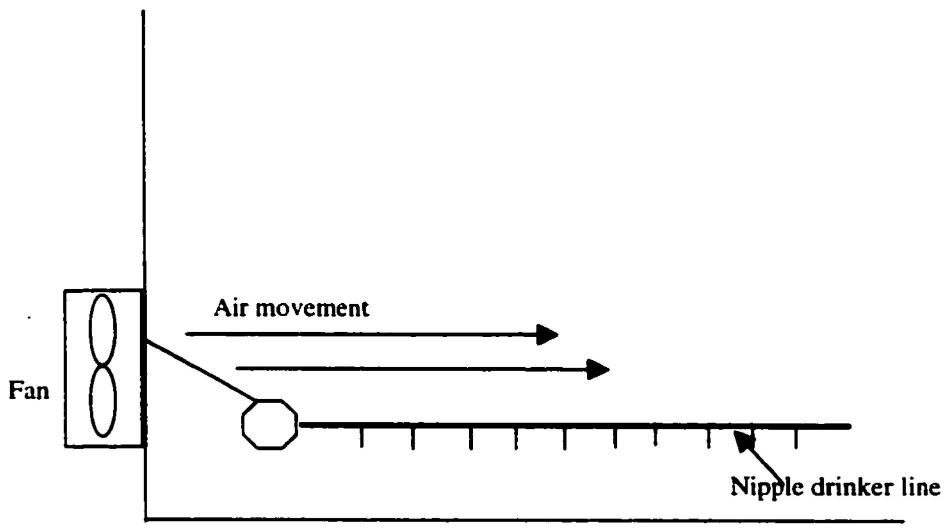

Figure 3-2. Positioning of air speed fans in trials 1 and 2.

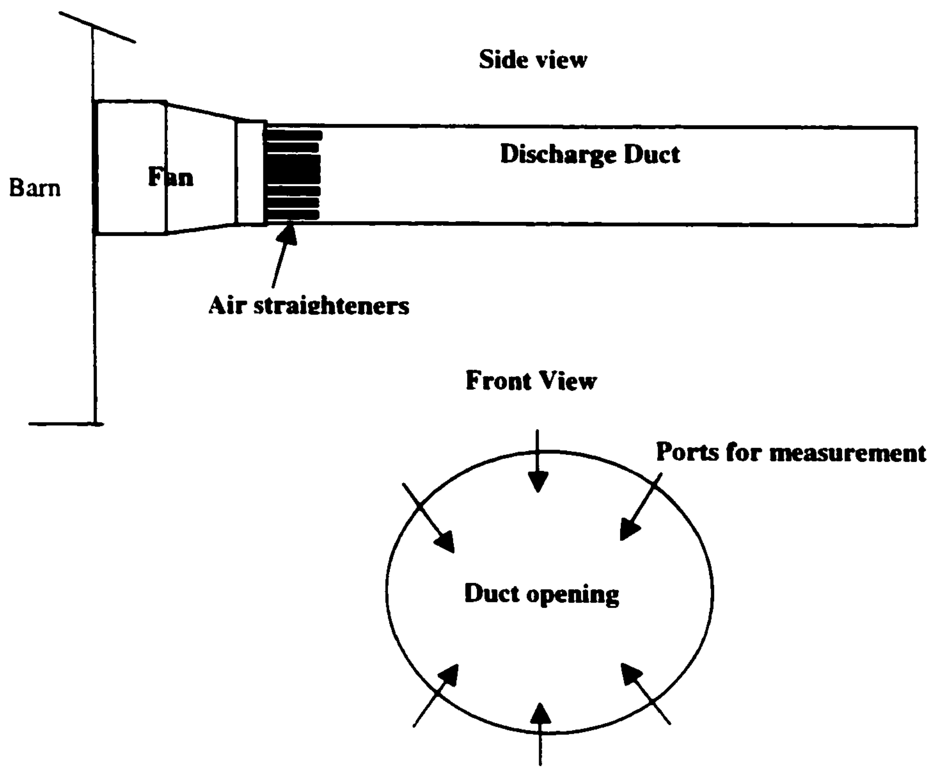

Figure 3-3. Discharge duct for fan

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4. Microclimate Environment

4.1 Introduction.

The microclimate temperature that the broiler actually perceives in its environment, is one of the determining factors for broiler performance (Boshouwer *et al.*, 1996). The optimal temperature for rearing broilers in the last 2 weeks before marketing is 21°C (Deaton *et al.*, 1978). If the temperature is too high the birds have difficulty in dissipating their heat, therefore consume less feed as indicated by Deaton (1968). One major factor that can increase the microclimate temperature, is the broiler's heat production. The total heat output of a broiler is estimated to be about 17 W, (Feddes *et al.*, 1984), calculated by measuring the energy intake of the bird, efficiency of feed utilization and from the metabolizable energy in the feed. Other factors that can directly affect the broiler's microclimate is the heat produced by the litter, the heating system, the set point temperature, and relative humidity. One means of controlling such factors is by providing adequate ventilation rate, to remove the bird heat from the building air space. With enough air circulating in the microclimate, excess heat is effectively removed from the broiler's space.

The effect of ventilation rate and air circulation rate on pen temperature and broiler performance was of interest in this study. The main objective was to further understand how pen temperature and microclimate temperature are correlated at different ventilation rates and air speeds. The relationship between heat stress index and pen temperature, and the relationship between the ventilation rates and the litter was also studied, and how the change in litter temperature affects the microclimate of the broiler chicken was also of interest.

4.2 Materials and Methods

A total of 7000 female Hubbard x Hubbard broiler chicks were used for each of the two trials in this study. At 1 week (wk) of age, the chicks were randomly placed into thirty-two pens (four individual rooms with eight pens) (Figure 3-1) after being counted and group weighed. Each pen contained 226 birds stocked at a density of 0.5 m^2/bird for the 6-wk period. The dimensions of the pens were 2.43 m x 5.79 m (8' x 19') or 14.06 m^2 of which 3.0 m^2 was considered non-utilizable space (feeder area and 15 cm along the walls). To maintain a constant stocking density, a 7.5' x 3' adjustable partition at the rear of the pen was moved inward as the stocking density changed due to mortality (Figure 3-1).

In the center of each pen was a PVC nipple drinker system, which was directly connected to a calibrated 200-L water barrel (Figure 3-1). Each pen had one overhead circulation fan to recirculate the air the cool air in each pen, in addition to providing additional air movement in the vicinity of the birds in Trial 1 (Figure 3-2). Each individual room (eight pens/room) was ventilated by two 24" fans and two 18" fans. This air is simply brought into the barn through inlets to allow for air exchange The high ventilation treatment, used were (2x the recommended summer rates) 3.4 L/s/bird (full capacity of the 4 fans), while the low ventilation treatment was 1.7 L/s/bird. To adjust the ventilation rate, a carbon dioxide (CO_2) tracer technique was used where an initial reading of CO_2 was measured (background) in the room (Table 3-1). This was done using a CO_2 monitor that was placed in front of each 24" fan, which were operating at the time, and another in the center of the room. Readings were taken every 5 min until all three monitors stabilized. When this occurred an average of the three was calculated.

CO_2 was then released at a rate of 0.24 L/s in the middle of the room between the two fans. Readings were recorded every 5 minutes until the monitors stabilized. An average was then again calculated which represented the concentration of the CO_2 added to the room (Table 3-1). Using this method this method, it was determined that a 21" orifice was required was required in the plywood to cover the 24" fans in order to obtain a ventilation a rate of 1.7 L/s/bird. This air flow rate was also checked by using the standard protocol fan performance test (Fan Engineering, 1983). This involved a discharge duct downstream from each fan. The duct had air straighteners (tubes) to provide a more laminar flow of air in the duct. Near the end of the duct, six ports were drilled into the duct (Figure 3-3) for air flow measurements. The air flow meter (TSI Inc., St. Paul, Minnesota) was used to obtain measurements in each opening at different traverse locations (heights) of; 2, 4, 6, 8, 10 and 304 mm from the edge of the duct. The mean values for each port were calculated (Table 3-2) and by using these mean values in the calculation the flow rate of 1.7 L/s/bird was determined. The ventilation rates determined by the CO_2 method and the duct method were in agreement.

The barn temperature required for the birds (determined from a broiler housing manual) was maintained in the high ventilation treatments by controlling fan operation from room thermostats. The temperatures were maintained by a forced air heating system when ventilation was at the minimum adjustment. Barn rooms, outside maximum, outside minimum and actual temperatures were recorded daily in mid afternoon.

Water and feed were provided ad libitum for each of the 32 pens for the entire 6 wk growth cycle with 23 hour (hr) light and 1 hr dark per day. For the first 3 wk, the chicks in Trial 1 were fed a standard starter diet (3000 kcal ME/kg, 21.4 % crude protein) and from 4 to 6 wk the broilers were fed a standard grower diet (3000 kcal ME/kg, 18.8 % crude protein). Due to poor body weight (BW) performance of the birds in Trial one, the birds in Trial two were given a different feed which had 3100 kcal ME/kg and 19.4 % crude protein for the starter. The grower contained 3050 kcal ME/kg and 18.8 % crude protein. At the end of each wk, feed was weighed back to determine weekly feed consumption on a per bird basis for each pen. Daily water measurements were obtained at 10:00 am for each pen from the graduated 200 L barrels therefore the total amount of water consumed was calculated for each wk for the entire 6 wk period. Broiler mortality was recorded including culls, and these birds were weighed and tagged and kept on file to estimate the amount of feed consumed.

To observe the microclimate temperature, pen temperatures were recorded. This was achieved by suspending a black bottle in the center of the 32 pens and using a non-contact infrared thermometer (Oakton Distributors, Chippewa Falls, WI) to measure the surface temperature of a bottle. The bottle was black, as this color absorbs radiant heat, and therefore would be absorbing the radiant heat that was in the microclimate. The temperature of the bottle, which represented pen temperature, was measured daily at the same time (2:00 pm). Data were collected for the last 20 days for both Trials 1 and 2 Experiment 2 (Chapter 3) (Appendix 3) and these data were then used in calculating the pen temperatures in Experiment 1(Chapter 2).

The relationship between bird performance and pen temperature was of interest. In order to estimate the effect of temperature on broiler performance, an arbitrary heat stress index (Appendix 3) was assumed ($\Sigma(\Delta T * \text{day})$). This index assumes that the difference in temperature (ΔT) between pen (ambient) and recommended temperature becomes more critical as the birds become older (day). The mathematical expression of $\Sigma(\Delta T * day)$ captures this concept.

To determine the litter temperature and how it affects on the microclimate, the litter temperatures were recorded in two pens per room from 3 to 5 weeks using the non contact infrared thermometer (Oakton Distributors, Chippewa Falls, WI). A 225 cm^2 piece of Styrofoam was used to represent a broiler, as they have a comparable thermal resistance. The Styrofoam was suspended above the broilers, initially, for 5 min to determine the pen temperature. The Styrofoam was then placed on the litter for another 5 min, and the surface temperature (litter temperature) of the Styrofoam was recorded (Figure 4-1).

The difference in surface temperature was determined and the average for each treatment (ventilation rate, air circulation) was calculated (Appendix 4).
Bird microclimate temperatures were analyzed daily using Pen(Ventilation Rate*Air Circulation*Run) as the error term. Means were separated by the least significant difference test using the pdiff option of the LSMEANS statement of the GLM procedure of SAS with significance being assessed at $P \leq 0.05$.

4.3 Results and Discussion

4.3.1 Pen Temperature.

In Experiment 1 (Stocking Density Trial), it was assumed that the barn hallway temperature was representative of the pen temperatures (floor level) and thus was not measured. In Experiment 2 (Cellulitis Trial), temperatures were measured in the different sections of the barn hallway. These temperatures were found to be different from the pen temperatures. To test the hypothesis of a correlation between hallway and pen temperature, the actual pen temperatures were measured and then correlated with the barn hallway temperature. By realizing that differences in temperature exist between the two zones, proper adjustments could be made to the temperature data in Experiment 1. The results show that ventilation rate had a significant effect on pen temperature (Table 4-1). The low ventilation rate resulted in a significantly higher temperature (28.6°C) than the high ventilation rate (27.7°C). For the air circulation fans, there was no significant effect on pen temperature. The relationship between the pen and barn hallway temperature was determined using the y-intercept. It was determined that the pen temperature was 4°C and 2°C higher than the barn hallway temperature, for the high and low ventilation rates respectively (Table 4-1). The reason for the higher temperature difference is that the air entering the barn at 3.4 L/s/bird (high ventilation rate) is traveling at a relatively high speed into the barn hallway, resulting in the hallway temperature being similar to the outside temperature. With the lower ventilation rate (1.7 L/s), the air is moving slower and therefore has less effect on the barn hallway temperature. The result is an increase in barn hallway temperature, suggesting the reason for the difference between barn and pen temperature of only 2°C.

The effects of the air circulation fan (Table 4-1), showed neither a high or low air speed had a significant effect on pen temperature. Figures 4-1 and 4-2 show a comparison between the outside temperature, the barn hallway, and pen temperatures at the different ventilation rate and air speeds.

Using the pen intercept of 4°C, which was determined from Experiment 2, pen temperature was estimated for Experiment 1 (Chapter 2), where a high ventilation rate was used throughout the experiment. The pen temperatures for the last 21 days in Experiment 1 are shown in Figures 4-3 and 4-4. In Experiment 1, Trial 2, the difference between pen and barn hallway temperature was greater than the temperature difference in Trial 1. The resulting higher difference produced a lower body weight gain during Trial 2 (Experiment 1). A 3°C difference between the inside and the outside temperature is considered the minimum difference in designing for maximum ventilation. If this temperature is not achieved, excess heat may adversely affect the broilers growth. To maintain this difference, at least 4.0 L/s of building air must be exchanged within the barn. In both experiments, the maximum ventilation rate in the barn was estimated to be 3.4 L/s per bird. This means that the minimum difference between the outside and the inside temperature would have been higher than 3°C. As shown in Figures 4-3 and 4-4, the pen temperature exceeded the outside temperature by more than 6°C from days 21 to 41. Other recommended ventilation rates for broilers is 2.4 L/s (Agriculture Canada, 1988), which suggests that the difference between the outside and the inside should be about 5°C. This temperature difference may result in less feed consumption and ultimately lower weight gain.

For the cellulitis trials (Experiment 2), the pen temperatures were also compared to the outside, barn hallway, and recommended temperatures (Figure 4-5 & 4-6). These pen temperatures were also more than 6°C higher than the recommended temperature, as noted in the last 20 days.

The resulting high temperatures identified in both Experiments 1 and 2, demonstrate the importance of proper air mixing in the broiler's microclimate. Sufficient air exchange is also of importance, to remove the heat produced and maintain an acceptable ambient temperature. This can reduce the amount of heat stress affecting the birds and maintain a high level of overall performance.

The metabolizable energy retained by each bird (mean BW 2.14 kg) was estimated to be 19.8 MJ (Charles, 1993). Each bird consumed 3.095 kg or 41.4 MJ over a 42 day period. Therefore, the heat production of each bird was estimated to be 21.6 MJ (41.4 – 19.8 MJ) over 42 days (43 kJ/hr-12W). The heat production of the bird was assumed to increase linearly from 0 to 43 kJ/hr at day 42 (mean 21.5 kJ/hr). At a stocking density of 0.042 m^2/bird, this translates to 1030 kJ/h/m^2 or 285 W/m^2 of the floor area at day 42.

4.3.2 Heat Stress Index

From the results of this study, the heat index value was much higher in Trial 2; Experiment 1 (5625°C·day) (Appendix 3). This was the highest index between the two experiments. The effects of such a high heat index in Trial 2 would make it more difficult for the broilers to dissipate heat away from their bodies, causing a decrease in their growth rate due to less feed consumption. This high index did negatively affect the broiler's performance compared to Trial 1. However, the difference between the liveweight of the birds in Trials 1 and 2 (Experiment 1), was only 106 g at day 38. The high ventilation rate and air circulation rate (Experiment 1) appears to have been effective in removing excess heat from the broiler space. By removing this excess heat,

heat stress had a minimal effect on the broiler's liveweight performance. In Experiment 2, the heat index values of the pen temperature were also based on the last 20 days for Trials 1 and 2, (Table 4-3). The effects of a low ventilation rate on pen temperature heat indexes (rooms 1 and 4), resulted in a higher average heat index (1703°C·days). The high pen temperatures did not negate their performance and this may be due to the air circulation. The affects of the air circulation fan rate in Experiment 2 are shown in Table 4-4. These values were calculated based on the average pen temperature within each treatment. The low air speed treatment had an average heat index of 1905 °C·days, which was almost 800 units higher than the high air speed heat index (1109 °C·days). With a lower heat index it can be assumed that it would have a positive effect on the broilers, which it did. The broilers with a higher air speed treatment had significantly higher body weight than the low air speed treatment

4.3.3 Litter Temperature.

The results in Table 4-5 show the effects of ventilation rate on litter temperature, which was not significant ($P = 0.51$). With a higher ventilation rate, however, the litter was warmer since it was dryer (25.3°C), compared to a lower ventilation rate where the litter was moist. There was more moisture being transferred between the air and litter at the higher air circulation rate (Van Beek *et al.*, 1995). Also with a higher air speed, there is a more effective transfer of sensible heat from the broiler's microclimate to the air. Therefore the broilers should have perceived their microclimate as being cooler, as the excess heat is being removed from their living space. With the lower ventilation rate treatment, the litter temperature was lower (24.4°C) since it contained more moisture and encouraged more microbial activity and The effect of air speed on litter temperature (Table 4-5) was non-significant ($P = 0.0832$). There is a noticeable trend that occurred with both treatments. During week 3 the litter temperature was cooler than the barn (23°C). By week 4 it was almost the same temperature as the barn (26.5°C). By the end of the trial (week 5), the litter was warmer (24.9°C) than the barn (Figure 4-2) by more than 3.0°C. These same results occurred with Van Beek *et al.*, (1995) and with Boshouwers *et al.*, (1996), where they mentioned that the litter for the first week could be as low as 2.5 to 4°C lower than the barn temperature. When the broilers reach 5 wk of age the litter is 0.7 to 2.2°C higher than the barn temperature. The reason why the litter is cooler during the first 3 wk could be due to the cool concrete floor that the litter was placed on. In addition, the amount of feed eaten daily by broilers compared to 4 and 5 weeks of age is less and there is not as much fermentation occuring. This translates to less heat being transferred by the broilers to warm the litter as they sit on it. According to Van Beek *et al.*, 1995, the high litter temperature during the last week is a result of the broilers own heat production. Their body heat (12 W) can heat up the litter by 1.5°C because of their larger size and by microbial activity in the litter which leads to fermentation, which will increase the temperature. In addition, the amount that the litter is heated up by the birds can be directly related to the air circulation. Mitchell (1985) stated that with an increase in air velocity there would be more sensible heat loss from the broiler. The data in Table 4-6 indicate that, the litter is cooler at the higher air speed than the lower air speed.

In order for broilers to grow efficiently, the environment should impose as little stress on the birds as possible. Two such factors that have a major effect in the environment are temperature of the bird's microclimate, and heat production by the birds and their litter. Accumulated heat within the environment will have detrimental effects in terms of performance and growth rate. According to Deaton *et al.*, (1978) during the last two weeks before marketing, the optimum barn temperature is 21°C. It is difficult to maintain this since the birds alone can produce up to 17 W/broiler. With a high stocking density, this will easily increase the temperature within the barn if ventilation rate is inadequate. Therefore, producers strive to maintain a minimum difference of 3°C between outside and inside the barn during the warm summer months. This can be achieved by exchanging about 4.0 L/s of air per bird during warm weather conditions. To further understand the importance of heat stress affecting broiler performance, a heat index [$\Sigma(\Delta T * day)$] was developed during the last 20 days of the growth cycle. Experiment 1, Trial 1 had a lower heat index (1490 units) compared to Trial 2 (3813 units). This high index had a negative affect on the birds due their lower body weight. In Experiment 2 (Cellulitis), the high ventilation rate and high air circulation rate had a lower heat index compared to the low ventilation rate air circulation rate, and the lower heat index, these birds did perform better

The microclimate temperature was significantly affected by ventilation rate. The low ventilation rate had a significantly higher pen temperature (28.6°C) than the high ventilation rate (27.7°C). Other factors such as the litter temperature were examined, to determine its affect on the broiler's microclimate. A regression analysis was applied to the data, and it demonstrated that a high ventilation rate had a y intercept of 4°C and that the low rate had a y intercept of 2°C. This suggests that if the barn hallway temperature is 0°C, then the pen temperature would be 4°C and 2°C for the high and low ventilation rate, respectively. The air circulation data showed the y intercept for the lower air speed at 3.6°C, compared to 2.4°C with a higher air speed. This indicates that faster moving air at bird level provided a more favorable condition for the broilers to live in. A slower air speed showed to have a negative effect on broiler performance, particularly in body weight. The effects of litter on the broiler's microclimate was not evident until week 5 of the cycle. The temperature of the litter is initially cooler than the pen temperature at 3 weeks, and therefore does not create more heat stress for the broilers. In week 5 though, the litter is almost 4.0°C higher than the pen temperature, which was also noted by Van Beek *et al.* (1995) and Boshouwers *et al.*, (1996). The effect of the ventilation rate and air circulation fan rate was not significant, but it clearly showed that the litter with a lower air speed was cooler because of its higher moisture content. The increase in litter temperature can be attributed to the broilers heat production. Their body heat alone can heat the litter as much as 1.5°C during the last week of the production cycle (Van Beek *et al.*, 1995). This heat is transferred to the litter, and along with the microbial fermentation in the litter (Boshouwers *et al.*, 1996), this excess heat needs to be removed to reduce heat stress on the birds.

The data obtained may be a useful tool in helping producers estimate the actual temperature at bird level. By knowing the pen microclimate temperature, proper adjustments can be made in order to provide an ideal environment for the broilers. With proper ventilation rate broilers will grow to their potential. Also of importance, it is necessary to provide adequate air circulation systems. With enough air speed, a more direct effect on pen temperature will be achieved.

TABLE 4-1. Effects of ventilation and air speed on pen temperature and pen intercept in experiment 2

	Ventilation				Air Speed		
	Pen °C	Hallway °C	Pen Intercept °C		Pen °C	Hallway °C	Pen Intercept °C
High[1]	27.7^{a}	23.9	4.1	HA[3]	28.2	23.9	2.4
Low[2]	28.6^{b}	25.1	1.9	LA[4]	28.1	25.1	3.6
P	0.0021			P	NS		

[a,b]Means, within each column, with no common letter are significantly different ($P \leq 0.05$).
[1]High Ventilation rate of 3.4 L/s/bird.
[2]Low Ventilation rate of 1.7 L/s/bird.
[3]High air speed of 0.82 m/s.
[4] Low air speed of 0.32 m/s.

Table 4-2. The effect of ventilation rate (L/s) on pen heat stress index in experiment 2

	Pen Heat Stress Index		
	Trial 1	Trial 2	
Room 1[1]	1707	1543	Average[3] 1 & 4
Room 4[1]	1690	1873	1703
Room 2[2]	1386	1206	Average[3] 2 & 3
Room 3[2]	1263	1653	1352

[1]Low Ventilation rate of 1.7 L/s/bird.
[2]High Ventilation rate of 3.4 L/s/bird.
[3]Average for both trials for the last 20days

TABLE 4-3. The effects of air speed on heat stress index.

	Pen Heat Index		
	Trial 1	Trial 2	Average[3]
LA[1]	2609	1202	1905
HA[2]	906	1311	1109

[1]Low air speed of 0.32 m/s.
[2]High Air speed of 0.82 m/s.
[3]Average for both trials for the last 20day

TABLE 4-4. The effects of ventilation rate on litter temperature from 3 to 5 weeks

Ventilation Rate	Week	Ambient[3]	Insulated litter[4]	Difference[5]
		°C	°C	°C
High[1]	3	25.6	24.0	-1.6
Low[2]	3	23.4	22.1	-1.3
High[1]	4	26.7	26.9	0.2
Low[2]	4	26.9	26.1	-0.8
High[1]	5	21.3	24.9	3.6
Low[2]	5	21.8	25.0	3.2
		Mean - High	**25.3**	**-0.57**
		Mean - Low	**24.4**	**-0.19**
		P	**0.51**	**0.28**

[1]High Ventilation rate of 3.4 L/s/bird.
[2]Low Ventilation rate of 1.7 L/s/bird.
[3]Ambient - Styrofoam surface temperature before contact with litter.
[4]Final - Styrofoam surface after contact with litter.
[5]Difference - Final subtracted from ambient.

TABLE 4-5. Effect of air speed on litter temperature from 3 to 5 weeks

Air Speed	Week	Ambient[3]	Insulated litter[4]	Difference[5]
		°C	°C	°C
HA[1]	3	24.5	23.0	-1.5
LA[2]	3	25.0	23.1	-1.9
HA[1]	4	27.0	26.4	-0.055
LA[2]	4	26.9	26.6	-0.3
HA[1]	5	21.8	24.9	3.1
LA[2]	5	21.4	24.9	3.5
		Mean - HA	**24.8**	**-0.33**
		Mean - LA	**24.9**	**-0.42**
		P	**0.0832**	**0.78**

[1]High Air speed of 0.82 m/s.
[2]Low air speed of 0.32 m/s.
[3]Ambient - Styrofoam surface temperature before contact with litter.
[4]Final - Styrofoam surface amer contact with litter.
[5]Difference - Final subtracted from ambient.

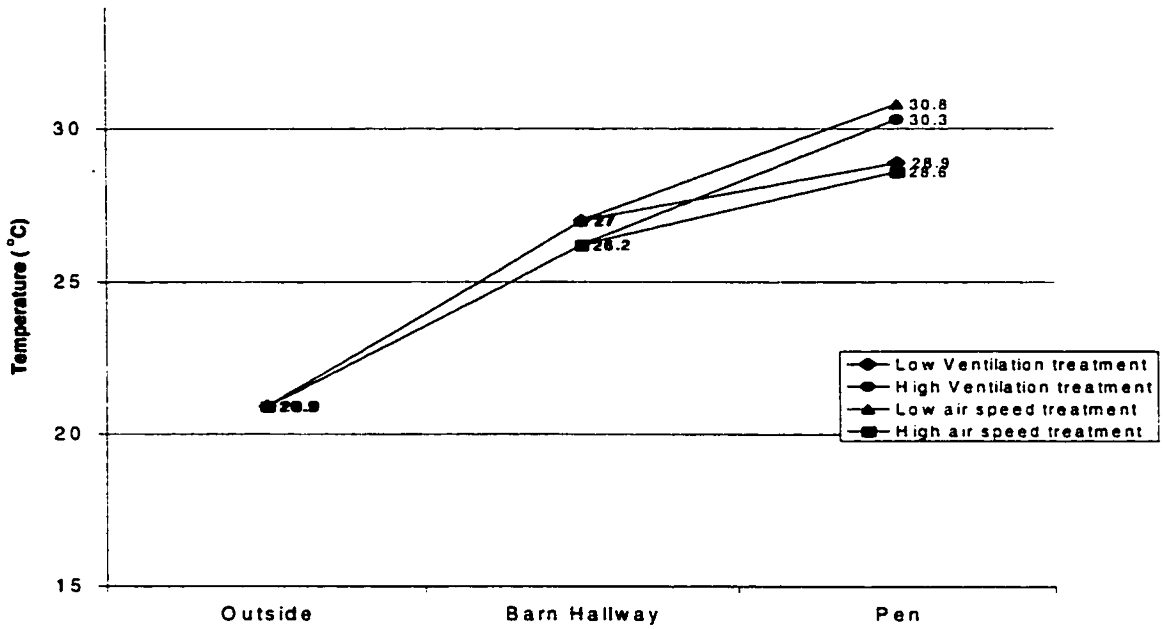

Figure 4-1. A comparison of outside, barn hallway and pen temperatures due to ventilation and air circulation effects in Trial 1.

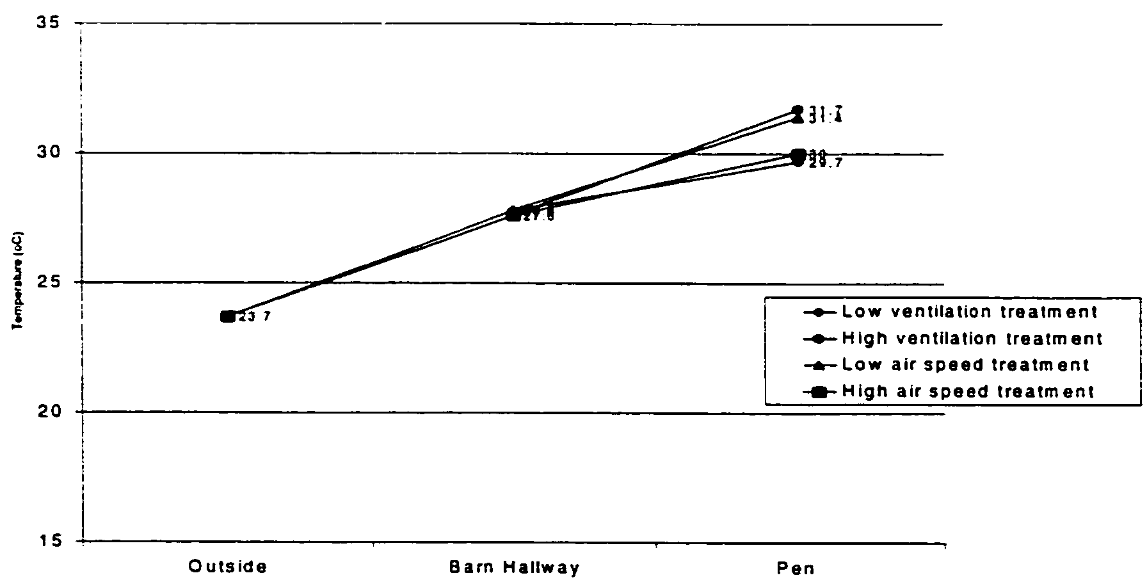

Figure 4-2. A comparison of outside, barn hallway and pen temperatures due to ventilation and air circulation effects in Trial 2.

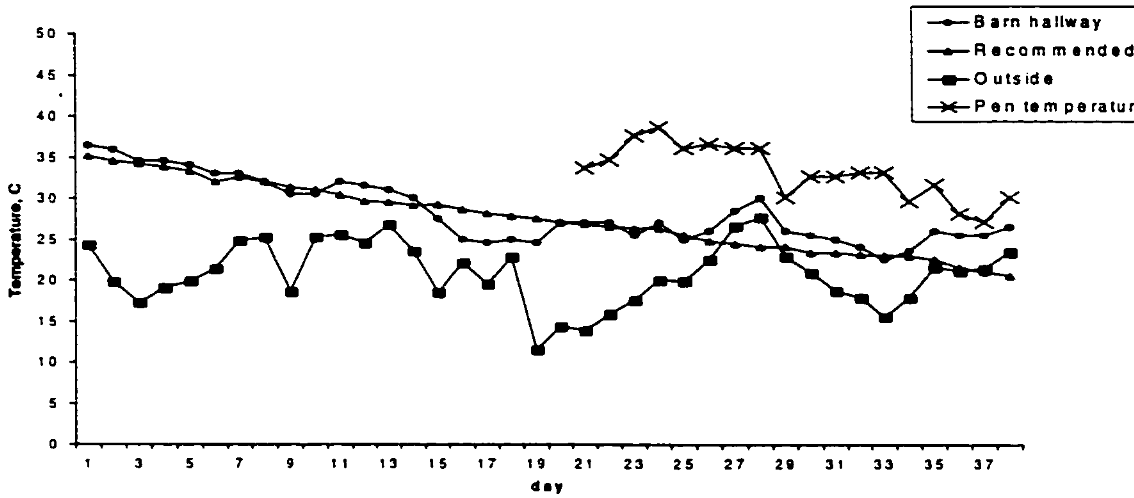

Figure 4-3. Experiment 1, Trial 1 - Maximum predicted pen temperature compared to barn hallway, recommended and outside temperature.

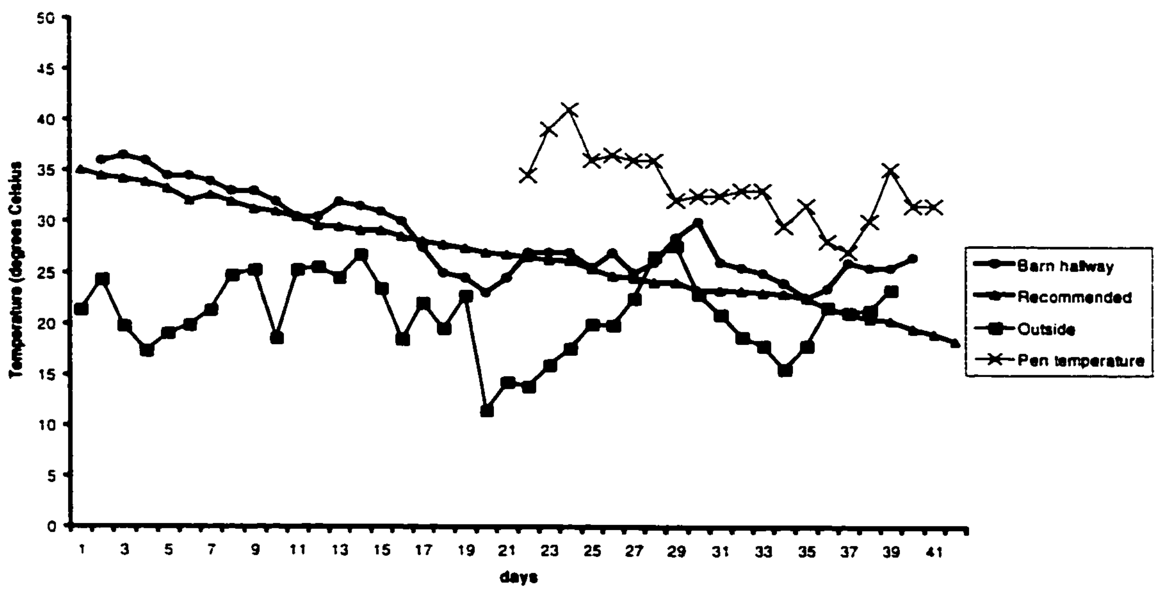

Figure 4-4. Experiment 1, Trial 2 - Maximum predicted pen temperature compared to barn hallway, recommended and outside

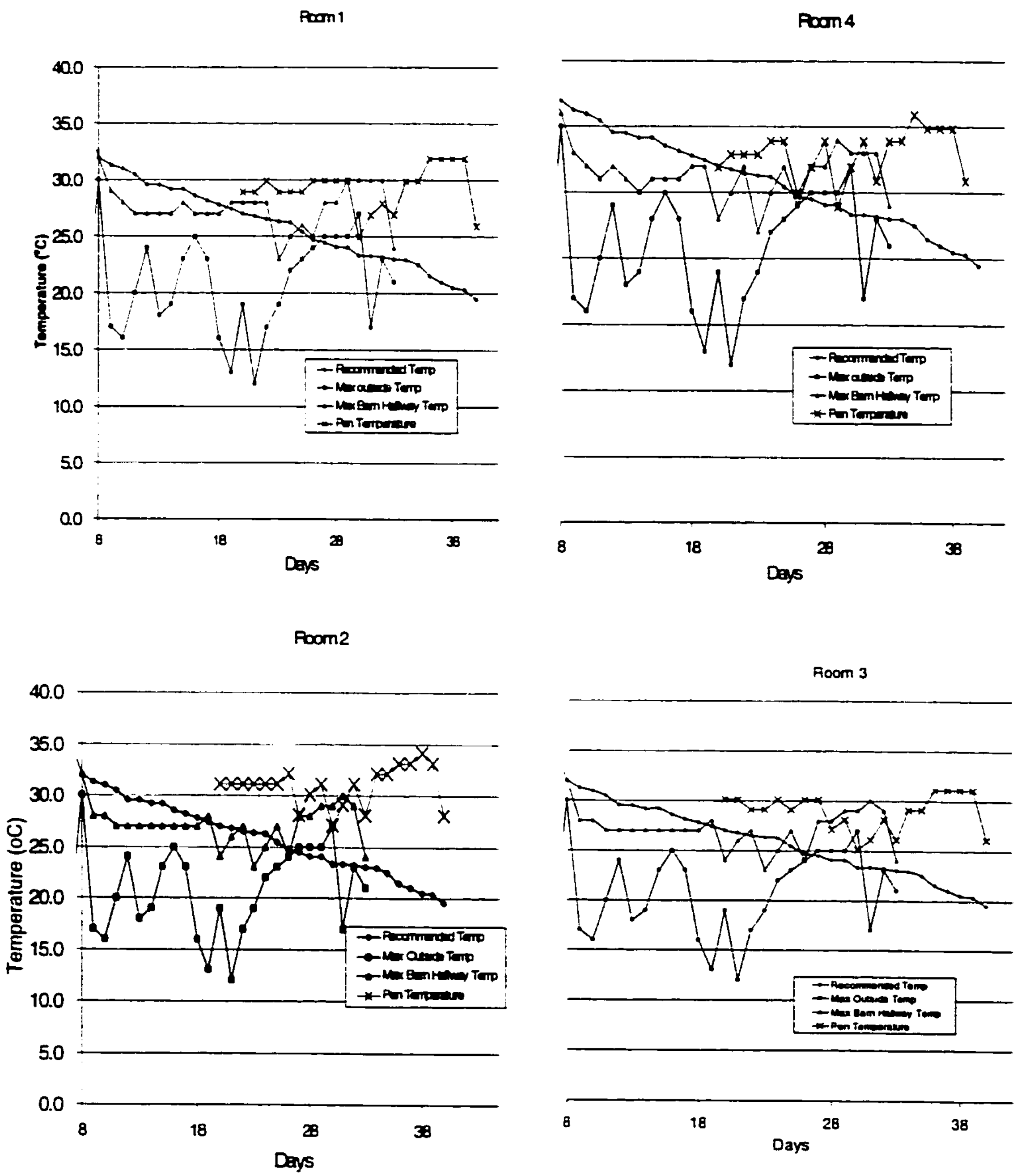

Figure 4-5. Experiment 2 - Trial 1, A comparison of pen temperature to barn hallway, recommended and outside temperature.

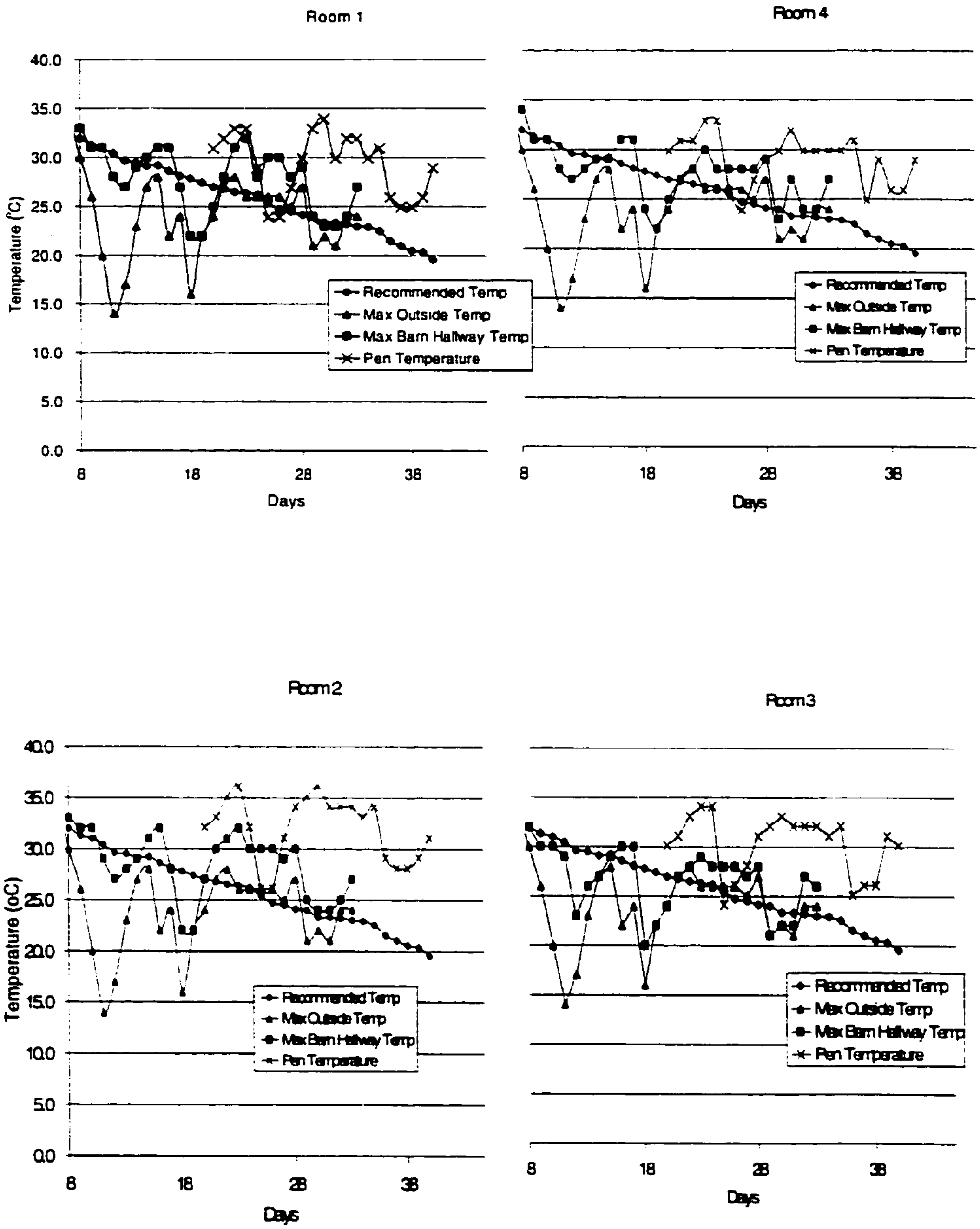

Figure 4-6. Experiment 2 - Trial 2, A comparison of pen temperature to barn hallway, recommended and outside

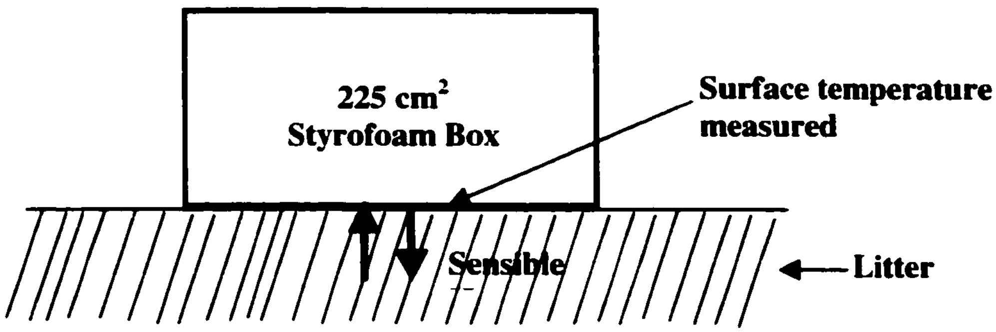

Figure 4-7. Changes in Styrofoam temperature due to litter

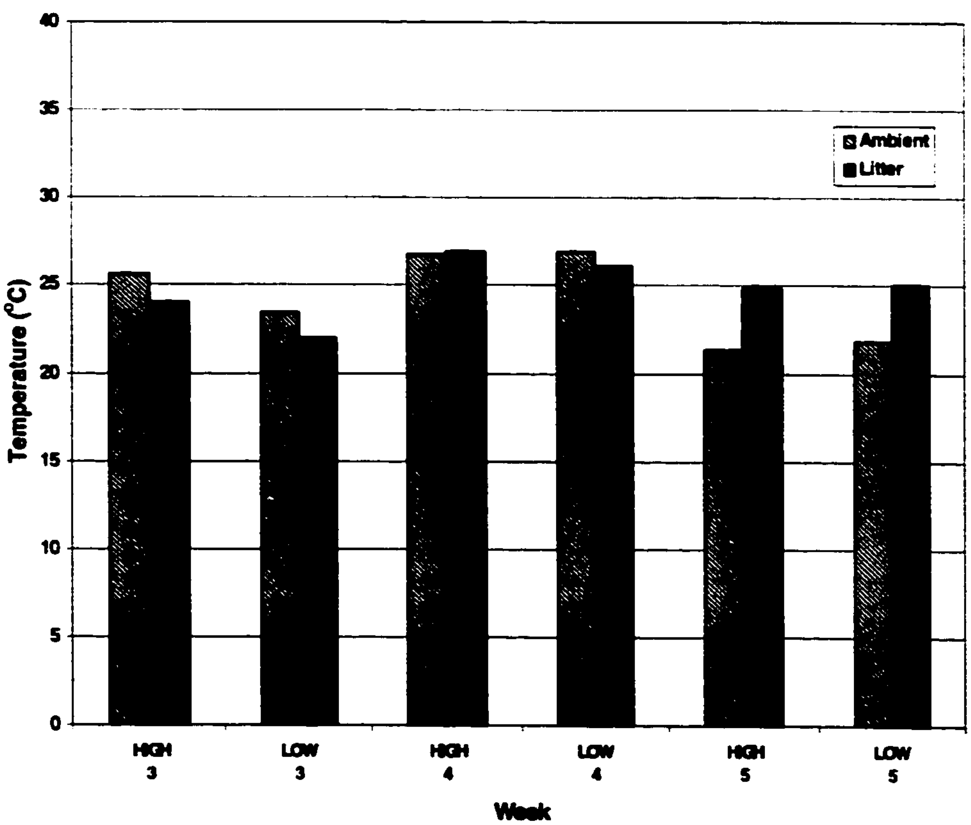

Figure 4-8. Change in litter temperature from 3 to 5 wk.

4.4 References

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5. Final Discussion

In Experiment 1, four nipple drinker densities (5,10, 15, 20 birds/nipple) and four stocking densities (0.042, 0.055, 0.069, 0.083 m^2/bird) were tested. The objective was to determine which nipple drinker and stocking density treatments resulted in greater performance by the broilers. The key for performance is providing sufficient floor area so that feed and water is adequately accessed, allowing broilers to express their genetic potential. High stocking densities can cause stress to broiler chickens as a result of a number of factors. One key factor can be high environmental temperature in the immediate vicinity of the bird, resulting in their difficulty in dissipating the heat away from their bodies to the air space. Once broilers are heat stressed they lower their feed intake resulting in decreased liveweight.

The effect of nipple drinker density on broiler performance was not significant. The reason for the non significance, was that water supplied through the nipple line is more accessible than the bell drinker. There is a short distance for the broilers to walk to the water and thus, less competition for water occurs.

The effects of stocking densities tested in this experiment, did have significant effects in some key aspects of performance for broilers. In terms of broiler production (kg/m^2), the optimum density occurred at a density of 0.042 m^2/bird, which produced 46 kg/m^2. This equates to \$51/m^2 compared to \$25/m^2 when placed at a density of 0.083 m^2/bird. At a \$1.12/kg, these findings represent a greater profit for the producer, when more birds are placed per unit area. For body weight gains, the optimum stocking density was at 0.069 m^2/bird, where these birds had a bodyweight of 1995g. This was almost 100g heavier than the 0.042 m^2/bird treatment, which equates to a better return per kilogram of broiler sold.

Stocking density did have an effect on feed consumption, where the highest consumption occurred at a stocking density of 0.069 m^2/bird. This resulted in a heavier body weight as mentioned earlier. Flock uniformity was significantly affected at a stocking density of 0.083 m^2/bird, which was the least uniform of the four treatments. Water consumption was not significantly different with any of the four treatments, but the water to feed ratio was significantly different. The ratio that is sought after in the industry is about 1.70 ml/g. The 0.042 m^2/bird treatment had the highest ratio of 1.85 ml/g. This high ratio indicated that these broilers consumed more water relative to feed, at the highest stocking density. The result was a decreased body weight.

The results of this experiment, leave broiler producers with an option on how much space to provide for their flocks. If the main goal is obtain a high body weight, then the stocking density of 0.069 m^2/bird is preferred. In contrast, if the goal is to produce the maximum kilogram of broiler per unit area, then a higher density up to 0.042 m^2/bird will achieve that goal. It is important to recognize that enough feeder space is available, as well as an adequate supply of feed and water lines, must be provided to be able to grow a large number of birds in the facility.

The second experiment focused on ventilation rate (1.7 L/s/bird compared to 3.4 L/s/bird), air speed (0.32 m/s compared to 0.82 m/s) and bird disturbance level (regular compared to minimal), and its affect on broiler performance, the incidence of cellulitis and the broilers' microclimate. Maintaining an optimum environment for the broilers to grow is difficult, especially at higher stocking densities. The fifth week is one of the more crucial weeks of the growth cycle. The reason being that the birds are generating more heat in a closer proximity to one another. This makes it more difficult for the birds to dissipate the heat away from their body. In addition, by growing birds in a reduced floor area, the incidence of cellulitis tends to increase due to less free movement between the birds.

From the study, the incidence of cellulitis was non-significant (only 0.4% of 14,000 birds processed). The percentage of cellulitis was too low for statistical analysis. The low incidence may be attributed to proper clean out and disinfecting of the barn between cycles, and lower humidity levels within the barn. Also it the low incidence may be due to the use of only females instead of males since females feather quicker than males.

The effect of ventilation rate, air speed and disturbance on broiler performance was significant. The higher air speed (0.82 m/s) at bird level produced a heavier bird and more kilograms per m^2, as the excess heat was removed away from the birds, which allowed for increased activity. Birds at a lower ventilation rate (1.7 L/s/bird) drank more water since they were in a relatively warmer environment. Broilers that were disturbed more, were significantly less uniform and had a higher percentage of condemnations, since they were more scratched. Scratching, carcass quality and other characteristics were not affected by ventilation rate and air speed.

In the broiler's microclimate, the temperature was determined to be 4°C higher than that of the barn hallway, at a high ventilation rate (3.4 L/s/bird). What contributes to this higher temperature, is the heat production of the birds, and the heat produced from the litter itself. From the research conducted in this experiment, the higher air speed did lower the pen temperature and kept the litter dryer. While the lower air speed, however, had a higher pen temperature, and coolert litter. Thus, this represents an ideal environment for bacterial growth.

Without proper air movement, heat stress can occur. This leads to less growth and even death, in serious circumstances. The heat stress index that was developed, did show that birds did not grow as well with a high heat stress index, compared to a low heat stress index. This shows the necessity of proper air mixing, to remove excess heat from the broiler space and minimize heat stress. Once this is achieved, the birds have a better chance of expressing their true growth potential. This ultimately leads to improved performance and profitability for the producer.

Appendix 1

Broiler Performance Summary Trials 1 & 2 Data Experiment 1

STDEN – Stocking Density

MJZProc – Selected birds for Martin Zuidhof's trial

Bw37c - Body weight corrected at 37 days of age

Penwt7 – Pen weight at day 7

BW7 – Body weight at day 7

PenWt37 – Pen weight at day 7

PenWt40 – Pen weight at day 40

EvisBW39 – Eviscerated body weight at day 39

EvisBW42 – Eviscerated bodyweight at day 42

Red – Condemned carcasses

White – Trimmed carcasses

Blue – Internal contamination

Mortality report – Percentages based on the number of dead birds

Summary Trial 1

Pen	STDEN	NIPP	Placed	kg/m^2	Culls	Males	MJZProc	Deads	Birds weighed day 37	Count day 37	ShipLily day 39	Estmated Count	Count Lilydale
1	0.45	5	270	44.5	0	3	7	13	241	257	247	238	234
2	0.60	5	200	35.0	0	5	7	4	191	196	184	173	178
3	0.75	15	163	28.4	3	2	7	4	154	159	147	142	140
4	0.90	15	137	22.3	0	3	7	5	134	132	122	121	123
5	0.75	5	158	28.9	1	1	6	2	156	156	148	146	144
6	0.60	20	199	34.3	3	2	6	3	195	196	185	176	175
7	0.75	10	161	28.3	2	0	8	4	159	157	147	143	149
8	0.90	20	135	21.5	1	1	8	3	132	132	122	122	127
9	0.45	15	267	47.1	2	2	8	6	260	261	249	246	146
10	0.60	15	204	34.9	2	1	8	7	199	197	186	185	284
11	0.45	10	266	47.3	0	1	6	5	252	261	254	251	239
12	0.90	5	135	22.7	4	2	6	3	132	132	120	120	121
13	0.45	20	267	45.8	2	5	7	5	265	262	248	245	253
14	0.60	10	199	34.0	4	2	7	3	194	196	183	182	181
15	0.75	10	159	29.6	0	2	7	2	163	157	148	148	153
16	0.90	20	133	23.1	3	1	7	1	134	132	121	118	116
33	0.45	5	264	46.5	1	7	7	6	252	258	243	239	241
34	0.60	5	197	35.1	0	2	7	3	197	194	185	184	169
35	0.75	15	159	28.9	2	2	7	6	159	153	142	141	143
36	0.90	15	132	22.7	0	1	7	1	130	131	123	122	118
37	0.45	20	264	44.2	0	2	6	2	266	262	254	246	232
38	0.60	10	198	35.1	1	2	6	1	196	197	188	187	187
39	0.75	20	160	28.2	1	1	8	5	155	155	145	143	142
40	0.90	10	132	23.6	1	0	8	2	127	130	121	118	106
41	0.45	15	266	45.7	12	3	8	6	266	260	237	233	235
42	0.60	15	198	35.2	4	4	8	5	196	193	177	172	174
43	0.75	5	160	28.7	3	1	6	3	159	157	147	144	149
44	0.90	5	133	24.1	1	2	6	2	133	131	122	120	122
45	0.45	10	268	44.7	8	1	7	6	265	262	246	237	243
46	0.60	20	200	35.4	0	1	7	3	199	197	189	182	185
47	0.75	20	158	29.1	7	3	7	2	158	156	139	131	134
48	0.90	10	132	23.5	4	2	7	1	136	131	118	114	119
Total/Average			6074	33.1	72	67	224	124	5955	5950	5587	5469	5462

Pen	STDEN	NIPP	Penwt7	BW7	PenWt37	PenWt37c	BW37c	CV	EvisBW39	EvCV	Gain	Gainc
	.		kg	g/bird	kg		g/bird	%	g/bird			
1	0.45	5	38.5	142.6	448.3	478.1	1860	10.7	1398	10.6	409.8	439.6
2	0.60	5	30.2	151.0	372.3	382.0	1949	10.7	1318	11.6	342.1	351.8
3	0.75	15	23	141.1	304.6	314.5	1978	13.4	1401	12.5	281.6	291.5
4	0.90	15	17.7	129.2	249.5	245.8	1862	15.1	1280	15.0	231.8	228.1
5	0.75	5	22.7	143.7	314.4	314.4	2015	13.7	1384	12.8	291.7	291.7
6	0.60	20	28	140.7	373	374.9	1913	14.0	1310	12.7	345	346.9
7	0.75	10	22.2	137.9	313.5	309.6	1972	13.7	1353	13.3	291.3	287.4
8	0.90	20	17.9	132.6	237.3	237.3	1798	16.1	1258	15.3	219.4	219.4
9	0.45	15	37.5	140.4	512	514.0	1969	12.4	1347	.	474.5	476.5
10	0.60	15	28.4	139.2	387.5	383.6	1947	12.2	1333	.	359.1	355.2
11	0.45	10	37.4	140.6	497.8	515.6	1975	11.5	1347	11.0	460.4	478.2
12	0.90	5	20.3	150.4	250	250.0	1894	15.4	1312	15.2	229.7	229.7
13	0.45	20	39.8	149.1	507.1	501.4	1914	14.7	1304	12.7	467.3	461.6
14	0.60	10	28.6	143.7	367.2	371.0	1893	15.1	1312	13.7	338.6	342.4
15	0.75	10	24.3	152.8	336.6	324.2	2065	10.6	1416	10.3	312.3	299.9
16	0.90	20	19.6	147.4	258.4	254.5	1928	12.1	1315	10.9	238.8	234.9
33	0.45	5	37.5	142.0	490.2	501.9	1945	10.4	1337	10.4	452.7	464.4
34	0.60	5	28.7	145.7	385.4	379.5	1956	14.5	1352	12.3	356.7	350.8
35	0.75	15	23.4	147.2	320.2	308.1	2014	12.5	1374	10.8	296.8	284.7
36	0.90	15	19.4	147.0	247	248.9	1900	13.9	1311	13.2	227.6	229.5
37	0.45	20	38.3	145.1	491.2	483.8	1847	11.0	1290	11.9	452.9	445.5
38	0.60	10	29.3	148.0	384	386.0	1959	13.8	1342	12.1	354.7	356.7
39	0.75	20	22.8	142.5	305	305.0	1968	14.2	1338	13.7	282.2	282.2
40	0.90	10	19.5	147.7	250.9	256.8	1976	29.8	1305	12.6	231.4	237.3
41	0.45	15	36.9	138.7	508.1	496.6	1910	14.3	1311	11.5	471.2	459.7
42	0.60	15	27.1	136.9	384.4	378.5	1961	13.3	1344	11.1	357.3	351.4
43	0.75	5	23.2	145.0	317.9	313.9	1999	13.4	1366	10.5	294.7	290.7
44	0.90	5	18.7	140.6	268.5	264.5	2019	11.5	1382	10.5	249.8	245.8
45	0.45	10	35.9	134.0	495.1	489.5	1868	13.7	1288	12.2	459.2	453.6
46	0.60	20	28.3	141.5	392.7	388.8	1973	12.1	1352	11.8	364.4	360.5
47	0.75	20	24.1	152.5	320.1	316.0	2026	14.7	1390	12.3	296	291.9
48	0.90	10	18.9	143.2	267.4	257.6	1966	16.5	1356	14.3	248.5	238.7
Total/Average			27.1	143.1	361.2	360.8	1944	13.8	1338.3	11.5	334.0	333.7

Pen	STDEN	NIPP	pen feed	dead feed	Feed/bd	PenWater (L)	ml/bird	water/feed	FCR
			kg	kg	g/bird				
1	0.45	5	769.7	16.93	2994.8	1568	6101	2.04	**1.75**
2	0.60	5	617.3	4.40	3149.5	1080	5510	1.75	**1.75**
3	0.75	15	485.9	13.35	3055.7	851	5352	1.75	**1.67**
4	0.90	15	393.1	4.22	2977.8	638	4833	1.62	**1.72**
5	0.75	5	503.6	4.08	3228.3	852	5462	1.69	**1.73**
6	0.60	20	596.7	9.04	3044.2	1025	5230	1.72	**1.72**
7	0.75	10	495.8	4.04	3157.7	843	5369	1.70	**1.73**
8	0.90	20	386.4	5.29	2927.3	629	4765	1.63	**1.76**
9	0.45	15	802.8	10.25	3075.7	1445	5536	1.80	**1.68**
10	0.60	15	603.2	17.51	3061.9	1061	5386	1.76	**1.70**
11	0.45	10	807.8	6.63	3094.9	1404	5379	1.74	**1.69**
12	0.90	5	390.9	15.17	2961.6	677	5129	1.73	**1.70**
13	0.45	20	792.4	7.61	3024.4	1420	5420	1.79	**1.72**
14	0.60	10	594.2	12.17	3031.8	1071	5464	1.80	**1.74**
15	0.75	10	530.0	2.25	3376.1	901	5739	1.70	**1.77**
16	0.90	20	403.0	6.66	3053.3	673	5098	1.67	**1.72**
33	0.45	5	820.3	7.75	3179.3	1458	5651	1.78	**1.77**
34	0.60	5	624.3	6.40	3218.0	1034	5330	1.66	**1.78**
35	0.75	15	489.0	17.01	3196.0	863	5641	1.76	**1.72**
36	0.90	15	380.3	0.91	2903.0	626	4779	1.65	**1.66**
37	0.45	20	804.5	1.98	3070.7	1419	5416	1.76	**1.81**
38	0.60	10	622.0	1.29	3157.4	1060	5381	1.70	**1.74**
39	0.75	20	491.8	5.60	3172.9	804	5187	1.63	**1.74**
40	0.90	10	372.3	4.18	2864.0	653	5023	1.75	**1.57**
41	0.45	15	769.3	30.54	2958.7	1389	5342	1.81	**1.67**
42	0.60	15	590.4	26.36	3059.3	1106	5731	1.87	**1.68**
43	0.75	5	498.3	9.18	3174.0	864	5503	1.73	**1.71**
44	0.90	5	420.8	1.96	3212.5	703	5366	1.67	**1.71**
45	0.45	10	767.6	19.71	2929.7	1433	5469	1.87	**1.69**
46	0.60	20	624.7	1.82	3171.0	1082	5492	1.73	**1.73**
47	0.75	20	510.1	18.55	3269.6	876	5615	1.72	**1.75**
48	0.90	10	413.7	11.37	3158.2	698	5328	1.69	**1.73**
Total/Average			574.1	9.5	3090.9	1006.4	5375.9	1.7	1.72

					Scratches			
Pen	STDEN	NIPP	light	light	Severe	Severe	Total	Total
				%		%		%
1	0.45	5	70	29.9	0	0.0	70.0	29.9
2	0.60	5	73	41.0	0	0.0	73.0	41.0
3	0.75	15	44	31.4	2	1.4	46.0	32.9
4	0.90	15	43	35.0	1	0.8	44.0	35.8
5	0.75	5	37	25.7	3	2.1	40.0	27.8
6	0.60	20	49	28.0	4	2.3	53.0	30.3
7	0.75	10	50	33.6	1	0.7	51.0	34.2
8	0.90	20	35	27.6	4	3.1	39.0	30.7
9	0.45	15	65	44.5	3	2.1	68.0	46.6
10	0.60	15	69	24.3	5	1.8	74.0	26.1
11	0.45	10	74	31.0	5	2.1	79.0	33.1
12	0.90	5	35	28.9	1	0.8	36.0	29.8
13	0.45	20	78	30.8	11	4.3	89.0	35.2
14	0.60	10	51	28.2	6	3.3	57.0	31.5
15	0.75	10	47	30.7	5	3.3	52.0	34.0
16	0.90	20	33	28.4	9	7.8	42.0	36.2
33	0.45	5	89	36.9	3	1.2	92.0	38.2
34	0.60	5	50	29.6	4	2.4	54.0	32.0
35	0.75	15	40	28.0	8	5.6	48.0	33.6
36	0.90	15	26	22.0	5	4.2	31.0	26.3
37	0.45	20	71	30.6	16	6.9	87.0	37.5
38	0.60	10	36	19.3	7	3.7	43.0	23.0
39	0.75	20	29	20.4	2	1.4	31.0	21.8
40	0.90	10	25	23.6	9	8.5	34.0	32.1
41	0.45	15	61	26.0	7	3.0	68.0	28.9
42	0.60	15	48	27.6	7	4.0	55.0	31.6
43	0.75	5	40	26.8	5	3.4	45.0	30.2
44	0.90	5	15	12.3	6	4.9	21.0	17.2
45	0.45	10	66	27.2	6	2.5	72.0	29.6
46	0.60	20	48	25.9	7	3.8	55.0	29.7
47	0.75	20	27	20.1	6	4.5	33.0	24.6
48	0.90	10	25	21.0	1	0.8	26.0	21.8
Total/Average			1549	28.0	159	3.0		31.0

			Remove from processing line			Remove from processing line			
Pen	STDEN	NIPP	Red	White	Blue	Red White Blue Removed	Red White Blue %	Overall Gr A	% Gr A
1	0.45	5	3	5	1	9	3.8	88	91
2	0.60	5	6	4	1	11	6.2	67	70.8
3	0.75	15	3	2	0	5	3.6	63	65.7
4	0.90	15	0	0	1	1	0.8	79	79.7
5	0.75	5	1	1	0	2	1.4	79	79.7
6	0.60	20	2	3	4	9	5.1	70	73.7
7	0.75	10	0	3	1	4	2.7	68	69.8
8	0.90	20	0	0	0	0	0.0	84	84.3
9	0.45	15	1	2	0	3	2.1	79	80.8
10	0.60	15	0	1	0	1	0.4	79	79.6
11	0.45	10	1	2	0	3	1.3	77	77.8
12	0.90	5	0	0	0	0	0.0	74	74.4
13	0.45	20	1	2	0	3	1.2	70	70.8
14	0.60	10	1	0	1	1	0.6	69	70.2
15	0.75	10	0	0	0	0	0.0	69	69.3
16	0.90	20	0	3	0	3	2.6	66	68.1
33	0.45	5	1	2	1	4	1.7	68	68.9
34	0.60	5	1	1	0	1	0.6	71	72.2
35	0.75	15	1	0	0	1	0.7	70	70.6
36	0.90	15	0	1	0	1	0.8	67	67.8
37	0.45	20	1	3	4	8	3.4	73	75.4
38	0.60	10	0	0	1	1	0.5	72	72.2
39	0.75	20	1	1	0	2	1.4	71	71.8
40	0.90	10	0	3	0	3	2.8	62	64.2
41	0.45	15	1	3	0	4	1.7	70	71.5
42	0.60	15	1	3	1	5	2.9	67	69
43	0.75	5	0	1	2	3	2.0	69	70.5
44	0.90	5	0	1	1	2	1.6	69	70.5
45	0.45	10	2	4	3	9	3.7	70	72.8
46	0.60	20	2	4	1	7	3.8	72	74.6
47	0.75	20	1	6	2	8	6.0	68	72.4
48	0.90	10	2	2	0	4	3.4	70	72.3
Total/Average			33	63	25	118	2.1	72	73.2

					Condemnations								
Pen	STDEN	NIPP	DOA	Ascites	Ascites %	Bruising	Bruising %	cellulitis	cellulitis %	contamination	contamination %	Cyanosis	Cyanosis %
1	0.45	5	0	0	0.0	0	0.0	2	0.9	1	0.4	0	0.0
2	0.60	5	0	1	0.6	0	0.0	4	2.2	0	0.0	0	0.0
3	0.75	15	0	1	0.7	0	0.0	2	1.4	0	0.0	0	0.0
4	0.90	15	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
5	0.75	5	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
6	0.60	20	0	1	0.6	0	0.0	1	0.6	0	0.0	0	0.0
7	0.75	10	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
8	0.90	20	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
9	0.45	15	0	1	0.7	0	0.0	0	0.0	0	0.0	0	0.0
10	0.60	15	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	0.45	10	0	0	0.0	0	0.0	1	0.4	0	0.0	0	0.0
12	0.90	5	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
13	0.45	20	0	0	0.0	0	0.0	1	0.4	0	0.0	0	0.0
14	0.60	10	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
15	0.75	10	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
16	0.90	20	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
33	0.45	5	0	0	0.0	0	0.0	1	0.4	0	0.0	0	0.0
34	0.60	5	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
35	0.75	15	0	1	0.7	0	0.0	0	0.0	0	0.0	0	0.0
36	0.90	15	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
37	0.45	20	0	0	0.0	0	0.0	0	0.0	1	0.4	0	0.0
38	0.60	10	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
39	0.75	20	0	0	0.0	0	0.0	0	0.0	1	0.7	0	0.0
40	0.90	10	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
41	0.45	15	0	0	0.0	0	0.0	1	0.4	0	0.0	0	0.0
42	0.60	15	0	0	0.0	0	0.0	1	0.6	0	0.0	0	0.0
43	0.75	5	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
44	0.90	5	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
45	0.45	10	0	0	0.0	0	0.0	2	0.8	0	0.0	0	0.0
46	0.60	20	0	2	1.1	0	0.0	0	0.0	0	0.0	0	0.0
47	0.75	20	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
48	0.90	10	1	1	0.8	1	0.8	0	0.0	0	0.0	0	0.0
Total/Average			3	8	0.16	1	0.03	16	0.25	3	0.05	0	0.00

				Condemnations					Mortality Report			
Pen	STDEN	NIPP	mutilation	mutilation %	Other	Other %	SDS	SDS %	Ascites	Ascites %	Valgus Legs	Valgus Legs %
1	0.45	5	0	0.0	0	0.0	3	23.1	1	7.7	3	23.1
2	0.60	5	1	0.6	0	0.0	2	50.0	0	0.0	1	25.0
3	0.75	15	0	0.0	0	0.0	3	75.0	0	0.0	4	100.0
4	0.90	15	0	0.0	0	0.0	1	20.0	0	0.0	2	40.0
5	0.75	5	0	0.0	1	0.7	0	0.0	0	0.0	1	50.0
6	0.60	20	0	0.0	0	0.0	0	0.0	0	0.0	3	100.0
7	0.75	10	0	0.0	0	0.0	1	25.0	0	0.0	1	25.0
8	0.90	20	0	0.0	0	0.0	0	0.0	0	0.0	3	100.0
9	0.45	15	0	0.0	0	0.0	1	16.7	2	33.3	1	16.7
10	0.60	15	0	0.0	0	0.0	4	57.1	0	0.0	1	14.3
11	0.45	10	0	0.0	0	0.0	2	40.0	0	0.0	1	20.0
12	0.90	5	0	0.0	0	0.0	0	0.0	1	33.3	3	100.0
13	0.45	20	0	0.0	0	0.0	2	40.0	0	0.0	2	40.0
14	0.60	10	0	0.0	0	0.0	1	33.3	1	33.3	1	33.3
15	0.75	10	0	0.0	0	0.0	1	50.0	0	0.0	1	50.0
16	0.90	20	0	0.0	0	0.0	1	100.0	0	0.0	1	100.0
33	0.45	5	0	0.0	0	0.0	1	16.7	1	16.7	3	50.0
34	0.60	5	0	0.0	0	0.0	1	33.3	0	0.0	0	0.0
35	0.75	15	0	0.0	0	0.0	3	50.0	1	16.7	2	33.3
36	0.90	15	0	0.0	0	0.0	0	0.0	0	0.0	1	100.0
37	0.45	20	0	0.0	0	0.0	1	50.0	0	0.0	0	0.0
38	0.60	10	0	0.0	0	0.0	1	100.0	0	0.0	0	0.0
39	0.75	20	0	0.0	0	0.0	2	40.0	1	20.0	2	40.0
40	0.90	10	0	0.0	0	0.0	1	50.0	0	0.0	0	0.0
41	0.45	15	0	0.0	0	0.0	1	16.7	0	0.0	2	33.3
42	0.60	15	0	0.0	0	0.0	1	20.0	0	0.0	2	40.0
43	0.75	5	0	0.0	0	0.0	3	100.0	0	0.0	0	0.0
44	0.90	5	0	0.0	0	0.0	1	50.0	0	0.0	0	0.0
45	0.45	10	0	0.0	0	0.0	4	66.7	0	0.0	1	16.7
46	0.60	20	0	0.0	0	0.0	2	66.7	0	0.0	1	33.3
47	0.75	20	0	0.0	0	0.0	2	100.0	0	0.0	0	0.0
48	0.90	10	0	0.0	0	0.0	1	100.0	0	0.0	0	0.0
Total/Average			1	0.02	1	0.02	47	43.4	8	5.0	43	37.0

Mortality Report

Pen	STDEN	NIPP	Septacemia	Septacemia %	Omphalitis	Omphalitis %	Dehydration	Dehydration %	Other	Other %
1	0.45	5	0	0.0	0	0.0	0	0.0	4	30.8
2	0.60	5	0	0.0	0	0.0	0	0.0	1	25.0
3	0.75	15	0	0.0	0	0.0	0	0.0	1	25.0
4	0.90	15	0	0.0	0	0.0	1	20.0	1	20.0
5	0.75	5	0	0.0	0	0.0	1	50.0	2	100.0
6	0.60	20	0	0.0	0	0.0	0	0.0	1	33.3
7	0.75	10	1	25.0	0	0.0	0	0.0	2	50.0
8	0.90	20	0	0.0	0	0.0	0	0.0	0	0.0
9	0.45	15	0	0.0	1	16.7	0	0.0	3	50.0
10	0.60	15	1	14.3	0	0.0	1	14.3	3	42.9
11	0.45	10	0	0.0	0	0.0	0	0.0	0	0.0
12	0.90	5	0	0.0	0	0.0	0	0.0	0	0.0
13	0.45	20	0	0.0	0	0.0	1	20.0	3	60.0
14	0.60	10	0	0.0	0	0.0	0	0.0	3	100.0
15	0.75	10	0	0.0	0	0.0	0	0.0	0	0.0
16	0.90	20	0	0.0	0	0.0	0	0.0	2	200.0
33	0.45	5	0	0.0	0	0.0	1	16.7	0	0.0
34	0.60	5	0	0.0	0	0.0	0	0.0	1	33.3
35	0.75	15	0	0.0	0	0.0	0	0.0	1	16.7
36	0.90	15	0	0.0	0	0.0	0	0.0	0	0.0
37	0.45	20	0	0.0	0	0.0	1	50.0	0	0.0
38	0.60	10	0	0.0	0	0.0	0	0.0	1	100.0
39	0.75	20	0	0.0	0	0.0	0	0.0	0	0.0
40	0.90	10	0	0.0	0	0.0	1	50.0	1	50.0
41	0.45	15	1	16.7	0	0.0	1	16.7	1	16.7
42	0.60	15	0	0.0	0	0.0	0	0.0	2	40.0
43	0.75	5	0	0.0	0	0.0	0	0.0	0	0.0
44	0.90	5	0	0.0	0	0.0	0	0.0	2	100.0
45	0.45	10	0	0.0	0	0.0	0	0.0	3	50.0
46	0.60	20	0	0.0	0	0.0	0	0.0	0	0.0
47	0.75	20	0	0.0	0	0.0	0	0.0	0	0.0
48	0.90	10	0	0.0	0	0.0	0	0.0	0	0.0
Total/Average			3	1.7	1	0.5	8	7.4	38	35.7

Summary Trial 2

Pen	STDEN	NIPP	Placed	kg/m^2	Culls	Males	MJZProc	Deads	Birds weighed day 40	Count day 40	ShipLily day 42	Estimated Count	Count Lilydale
1	0.37	5	313	53.1	0	0	7	17	299	301	294	268	270
2	0.60	5	199	33.4	0	0	7	13	186	189	186	163	158
3	0.75	15	159	28.1	0	0	7	4	153	156	155	142	142
4	0.90	15	133	22.4	2	0	7	4	126	129	126	114	108
5	0.75	5	159	28.8	0	0	6	3	156	153	153	137	133
6	0.60	20	199	32.4	4	0	6	9	190	191	185	170	165
7	0.75	10	159	29.1	0	0	8	9	155	154	154	127	137
8	0.90	20	133	21.3	4	0	8	5	128	128	124	110	107
9	0.45	15	265	44.8	0	0	8	15	248	250	249	221	220
10	0.60	15	199	33.2	0	0	8	8	191	191	191	170	166
11	0.45	10	265	42.9	0	0	6	13	253	253	253	233	227
12	0.90	5	133	22.9	0	0	6	10	127	128	126	107	110
13	0.45	20	265	45.6	2	0	7	19	245	246	241	223	215
14	0.60	10	199	34.8	0	0	7	12	190	190	188	169	170
15	0.75	10	159	28.3	0	0	7	4	156	156	156	141	138
16	0.90	20	133	23.1	0	0	7	6	126	126	126	105	108
33	0.45	5	265	47.2	0	0	7	19	247	248	244	208	218
34	0.60	5	199	34.8	0	0	7	6	191	191	191	171	169
35	0.75	15	159	29.1	0	0	7	8	152	153	153	133	120
36	0.90	15	133	23.3	0	0	7	6	128	131	130	109	108
37	0.45	20	265	46.3	0	0	6	8	256	258	258	225	216
38	0.60	10	199	35.0	0	0	6	4	195	194	194	178	175
39	0.75	20	159	27.7	0	0	8	5	156	154	154	136	135
40	0.90	10	133	22.3	0	0	8	6	126	126	126	112	105
41	0.45	15	265	44.5	1	0	8	10	256	256	254	230	221
42	0.60	15	199	35.9	0	0	8	12	187	189	187	169	166
43	0.75	5	159	28.5	0	0	6	4	154	155	155	137	130
44	0.90	5	133	23.5	3	0	6	4	129	129	126	114	109
45	0.45	10	265	45.7	2	0	7	13	253	254	251	224	221
46	0.60	20	199	35.7	0	0	7	9	190	190	189	171	170
47	0.75	20	159	28.4	0	0	7	3	150	156	156	137	134
48	0.90	10	133	24.1	0	0	7	5	127	129	128	112	110
Total/Average			6096	33.0	18	0	224	273	5826	5854	5803	5166	5081

Pen	STDEN	NIPP	Penwt7	BW7	PenWt40	PenWt40c	BW40	CV	EvisBW42	EvCV	Gain	Gainc
			kg	g	kg	kg	g/bird	%	g/bird		kg	kg
1	0.37	5	46.2	147.6	545.6	549.3	1825	11.8	1412	12.6	499.4	503.1
2	0.60	5	28.4	142.7	346.4	351.9	1862	15.5	1422	15.4	318.0	323.5
3	0.75	15	23.6	148.4	299.2	305.1	1956	14.1	1488	15.9	275.6	281.5
4	0.90	15	19	142.9	236.5	242.1	1877	16.7	1433	14.6	217.5	223.1
5	0.75	5	23.2	145.9	313.0	306.9	2006	13.4	1507	15.1	289.8	283.7
6	0.60	20	27.9	140.2	343.4	345.3	1808	16.8	1392	14.4	315.5	317.4
7	0.75	10	23.3	146.5	314.1	312.1	2027	12.9	1521	12.5	290.8	288.8
8	0.90	20	18.7	140.6	228.1	228.1	1782	19.4	1378	17.0	209.4	209.4
9	0.45	15	37.6	141.9	464.8	468.5	1874	13.2	1400	14.3	427.2	430.9
10	0.60	15	28.4	142.7	353.0	353.0	1848	15.4	1408	18.5	324.6	324.6
11	0.45	10	39.1	147.5	453.7	453.7	1793	14.6	1375	14.1	414.6	414.6
12	0.90	5	19.8	148.9	243.4	245.3	1917	16.2	1473	15.2	223.6	225.5
13	0.45	20	39.5	149.1	467.5	469.4	1908	13.5	1426	14.6	428.0	429.9
14	0.60	10	30.2	151.8	368.9	368.9	1942	13.7	1481	13.5	338.7	338.7
15	0.75	10	23.4	147.2	307.6	307.6	1972	12.5	1473	12.2	284.2	284.2
16	0.90	20	19.6	147.4	243.0	243.0	1928	15.5	1461	16.3	223.4	223.4
33	0.45	5	38.7	146.0	487.7	489.7	1974	14.0	1491	15.0	449.0	451.0
34	0.60	5	30.7	154.3	370.6	370.6	1941	14.1	1450	14.0	339.9	339.9
35	0.75	15	23.3	146.5	308.5	310.5	2030	13.6	1514	13.9	285.2	287.2
36	0.90	15	19.9	149.6	249.2	255.0	1947	15.6	1476	19.8	229.3	235.1
37	0.45	20	40	150.9	495.5	499.3	1935	12.6	1461	13.1	455.5	459.3
38	0.60	10	30	150.8	380.0	378.0	1949	12.9	1468	13.2	350.0	348.0
39	0.75	20	24.4	153.5	301.0	297.1	1929	14.4	1422	17.1	276.6	272.7
40	0.90	10	20.5	154.1	234.8	234.8	1864	16.9	1377	17.6	214.3	214.3
41	0.45	15	41.5	156.6	476.3	476.3	1861	14.7	1379	14.5	434.8	434.8
42	0.60	15	30.1	151.3	373.8	377.8	1999	9.8	1517	11.2	343.7	347.7
43	0.75	5	24.7	155.3	305.5	307.5	1984	14.6	1476	14.4	280.8	282.8
44	0.90	5	20.2	151.9	253.1	253.1	1962	16.6	1478	13.9	232.9	232.9
45	0.45	10	41.7	157.4	483.0	484.9	1909	15.0	1420	14.6	441.3	443.2
46	0.60	20	30.4	152.8	378.0	378.0	1990	14.1	1450	15.7	347.6	347.6
47	0.75	20	23.8	149.7	296.8	308.6	1979	12.8	1486	13.7	273.0	284.8
48	0.90	10	20.5	154.1	256.4	260.5	2019	14.3	1490	13.3	235.9	240.0
Total/Average			28.4	148.9	349.3	351.0	1924.8	14.4	1450.2	14.7	320.9	322.6

Pen	STDEN	NIPP	Pen feed	Dead feed	Feed/bd	PenWater (L)	mL/bird	water/feed	FCR
			kg	kg	g/bird				
1	0.37	5	996.1	8.72	3309	1659	5512	1.67	**1.98**
2	0.60	5	613.9	24.28	3248	958	5069	1.56	**1.90**
3	0.75	15	478.6	0.867	3068	764	4897	1.60	**1.70**
4	0.90	15	373.6	5.86	2896	600	4651	1.61	**1.67**
5	0.75	5	496.5	2.57	3245	797	5209	1.61	**1.75**
6	0.60	20	591.2	13.98	3095	887	4644	1.50	**1.86**
7	0.75	10	572.6	16.95	3718	823	5344	1.44	**1.98**
8	0.90	20	349.4	3.46	2730	576	4500	1.65	**1.67**
9	0.45	15	815.3	19.92	3261	1393	5572	1.71	**1.89**
10	0.60	15	625.5	5.88	3275	1016	5319	1.62	**1.93**
11	0.45	10	805.1	12.18	3182	1392	5502	1.73	**1.94**
12	0.90	5	454.4	7.30	3550	697	5445	1.53	**2.01**
13	0.45	20	730.6	13.16	2970	1368	5561	1.87	**1.70**
14	0.60	10	643.1	7.65	3385	1048	5516	1.63	**1.90**
15	0.75	10	549.1	3.73	3520	838	5372	1.53	**1.93**
16	0.90	20	447.8	5.25	3554	681	5405	1.52	**2.01**
33	0.45	5	770.2	24.17	3106	1462	5895	1.90	**1.71**
34	0.60	5	578.6	4.56	3030	1012	5298	1.75	**1.70**
35	0.75	15	490.1	7.62	3203	846	5529	1.73	**1.71**
36	0.90	15	387.2	9.59	2956	672	5130	1.74	**1.65**
37	0.45	20	785.7	10.46	3046	1398	5419	1.78	**1.71**
38	0.60	10	584.9	5.01	3015	1048	5402	1.79	**1.68**
39	0.75	20	463.8	3.14	3011	803	5214	1.73	**1.70**
40	0.90	10	370.8	14.10	2943	648	5143	1.75	**1.73**
41	0.45	15	682.0	9.75	2664	1435	5605	2.10	**1.57**
42	0.60	15	595.0	9.83	3148	1213	6418	2.04	**1.71**
43	0.75	5	477.6	2.82	3081	840	5419	1.76	**1.69**
44	0.90	5	324.0	2.56	2512	706	5473	2.18	**1.39**
45	0.45	10	741.4	16.17	2919	1450	5709	1.96	**1.67**
46	0.60	20	519.6	6.95	2735	1050	5526	2.02	**1.49**
47	0.75	20	452.6	2.94	2901	843	5404	1.86	**1.59**
48	0.90	10	400.5	4.84	3104	700	5426	1.75	**1.67**
Total/Average			567.7	8.9	3105.7	988.2	5360.3	1.7	1.8

						Scratches		
Pen	STDEN	NIPP	Light	Light %	Severe	Severe %	Total	Total %
1	0.37	5	15	5.6	49	18.1	64.0	23.7
2	0.60	5	5	3.2	32	20.3	37.0	23.4
3	0.75	15	7	4.9	14	9.9	21.0	14.8
4	0.90	15	8	7.4	14	13.0	22.0	20.4
5	0.75	5	11	8.3	22	16.5	33.0	24.8
6	0.60	20	14	8.5	35	21.2	49.0	29.7
7	0.75	10	18	13.1	17	12.4	35.0	25.5
8	0.90	20	10	9.3	14	13.1	24.0	22.4
9	0.45	15	14	6.4	64	29.1	78.0	35.5
10	0.60	15	20	12.0	53	31.9	73.0	44.0
11	0.45	10	22	9.7	41	18.1	63.0	27.8
12	0.90	5	5	4.5	18	16.4	23.0	20.9
13	0.45	20	26	12.1	63	29.3	89.0	41.4
14	0.60	10	17	10.0	24	14.1	41.0	24.1
15	0.75	10	14	10.1	20	14.5	34.0	24.6
16	0.90	20	19	17.6	22	20.4	41.0	38.0
33	0.45	5	24	11.0	57	26.1	81.0	37.2
34	0.60	5	41	24.3	56	33.1	97.0	57.4
35	0.75	15	16	13.3	11	9.2	27.0	22.5
36	0.90	15	22	20.4	67	62.0	89.0	82.4
37	0.45	20	17	7.9	23	10.6	40.0	18.5
38	0.60	10	0	0.0	0	0.0	0.0	0.0
39	0.75	20	11	8.1	16	11.9	27.0	20.0
40	0.90	10	18	17.1	20	19.0	38.0	36.2
41	0.45	15	9	4.1	106	48.0	115.0	52.0
42	0.60	15	17	10.2	42	25.3	59.0	35.5
43	0.75	5	24	18.5	37	28.5	61.0	46.9
44	0.90	5	13	11.9	29	26.6	42.0	38.5
45	0.45	10	53	24.0	43	19.5	96.0	43.4
46	0.60	20	29	17.1	30	17.6	59.0	34.7
47	0.75	20	12	9.0	24	17.9	36.0	26.9
48	0.90	10	17	15.5	20	18.2	37.0	33.6
Total/Average			548.0	11.1	1083.0	21.0	51.0	32.1

Pen	STDEN	NIPP	Contamination Red	Contamination White	Contamination Blue	Red White Blue Removed	Red White Blue %	Overall gr A	% Grade A
1	0.37	5	14	6	1	21	7.8	81	87.4
2	0.60	5	8	5	3	16	10.1	79	86.7
3	0.75	15	0	2	4	6	4.2	45	46.5
4	0.90	15	3	3	0	6	5.6	82	86.1
5	0.75	5	3	10	0	13	9.8	75	82.7
6	0.60	20	0	10	0	10	6.1	79	83.6
7	0.75	10	2	13	0	15	10.9	72	79.6
8	0.90	20	0	5	1	6	5.6	76	80.4
9	0.45	15	9	11	1	21	9.5	78	85.9
10	0.60	15	5	8	0	13	7.8	73	78.3
11	0.45	10	9	2	2	13	5.7	80	84.1
12	0.90	5	1	8	1	10	9.1	77	83.6
13	0.45	20	8	4	2	14	6.5	73	78.1
14	0.60	10	5	6	0	11	6.5	82	87.1
15	0.75	10	1	6	0	7	5.1	75	78.3
16	0.90	20	11	3	1	15	13.9	60	68.5
33	0.45	5	11	13	7	31	14.2	59	67.4
34	0.60	5	7	7	1	15	8.9	65	70.4
35	0.75	15	1	9	1	11	9.2	63	69.2
36	0.90	15	5	6	0	11	10.2	66	72.2
37	0.45	20	18	8	0	26	12.0	72	80.6
38	0.60	10	1	7	3	11	6.3	77	82.3
39	0.75	20	0	2	8	10	7.4	93	100
40	0.90	10	1	3	3	7	6.7	94	100
41	0.45	15	6	5	5	16	7.2	93	100
42	0.60	15	3	4	3	10	6.0	94	100
43	0.75	5	4	2	6	12	9.2	75	81.5
44	0.90	5	1	0	5	6	5.5	61	64.2
45	0.45	10	8	7	4	19	8.6	62	67.4
46	0.60	20	1	5	6	12	7.1	59	62.9
47	0.75	20	0	2	10	12	9.0	65	70.9
48	0.90	10	3	1	5	9	8.2	65	70
Total/Average			149.0	183.0	83.0	415.0	8.1	73.4	79.2

								Condemnations			
Pen	STDEN	NIPP	DOA	Ascites	Ascites %	Bruising	Bruising %	Cellulitis	Cellulitis %	contamination	contamination %
1	0.37	5	0	0	0.0	0	0.0	6	2.2	7	2.6
2	0.60	5	0	0	0.0	0	0.0	4	2.5	4	2.5
3	0.75	15	1	0	0.0	0	0.0	0	0.0	0	0.0
4	0.90	15	0	0	0.0	0	0.0	0	0.0	2	1.9
5	0.75	5	1	0	0.0	0	0.0	0	0.0	3	2.3
6	0.60	20	0	0	0.0	0	0.0	0	0.0	0	0.0
7	0.75	10	0	0	0.0	0	0.0	0	0.0	2	1.5
8	0.90	20	0	0	0.0	0	0.0	0	0.0	0	0.0
9	0.45	15	0	0	0.0	0	0.0	3	1.4	6	2.7
10	0.60	15	0	0	0.0	0	0.0	0	0.0	5	3.0
11	0.45	10	0	0	0.0	0	0.0	3	1.3	6	2.6
12	0.90	5	0	0	0.0	0	0.0	0	0.0	1	0.9
13	0.45	20	0	0	0.0	0	0.0	3	1.4	4	1.9
14	0.60	10	0	0	0.0	0	0.0	3	1.8	2	1.2
15	0.75	10	0	0	0.0	0	0.0	0	0.0	1	0.7
16	0.90	20	0	0	0.0	0	0.0	0	0.0	11	10.2
33	0.45	5	1	0	0.0	0	0.0	9	4.1	2	0.9
34	0.60	5	0	0	0.0	0	0.0	0	0.0	7	4.1
35	0.75	15	1	0	0.0	0	0.0	1	0.8	0	0.0
36	0.90	15	0	0	0.0	0	0.0	1	0.9	4	3.7
37	0.45	20	1	0	0.0	0	0.0	4	1.9	14	6.5
38	0.60	10	0	0	0.0	0	0.0	0	0.0	1	0.6
39	0.75	20	0	0	0.0	0	0.0	0	0.0	0	0.0
40	0.90	10	0	0	0.0	0	0.0	0	0.0	1	1.0
41	0.45	15	0	0	0.0	0	0.0	2	0.9	4	1.8
42	0.60	15	0	0	0.0	0	0.0	1	0.6	2	1.2
43	0.75	5	0	2	1.5	0	0.0	2	1.5	0	0.0
44	0.90	5	0	0	0.0	0	0.0	1	0.9	0	0.0
45	0.45	10	0	0	0.0	0	0.0	2	0.9	6	2.7
46	0.60	20	1	0	0.0	0	0.0	0	0.0	1	0.6
47	0.75	20	0	0	0.0	0	0.0	0	0.0	0	0.0
48	0.90	10	1	0	0.0	0	0.0	1	0.9	2	1.8
Total/Average			7.0	2.0	0.0	0.0	0.0	46.0	0.8	98.0	1.8

					Condemnations						Mortality Report			
Pen	STDEN	NIPP	Cyanosis	Cyanosis %	Mutilation	Mutilation %	Other	Other %	SDS	SDS %	Ascites	Ascites %	Valgus Legs	Valgus Legs %
1	0.37	5	0	0.0	0	0.0	1	0.4	7	41.2	5	29.4	3	17.6
2	0.60	5	0	0.0	0	0.0	0	0.0	1	7.7	1	7.7	3	23.1
3	0.75	15	0	0.0	0	0.0	0	0.0	1	25.0	1	25.0	1	25.0
4	0.90	15	0	0.0	0	0.0	1	0.9	0	0.0	0	0.0	0	0.0
5	0.75	5	0	0.0	0	0.0	0	0.0	1	33.3	1	33.3	0	0.0
6	0.60	20	0	0.0	0	0.0	0	0.0	5	55.6	0	0.0	0	0.0
7	0.75	10	0	0.0	0	0.0	0	0.0	4	44.4	1	11.1	0	0.0
8	0.90	20	0	0.0	0	0.0	0	0.0	3	60.0	1	20.0	0	0.0
9	0.45	15	0	0.0	0	0.0	0	0.0	5	33.3	0	0.0	5	33.3
10	0.60	15	0	0.0	0	0.0	0	0.0	2	25.0	2	25.0	1	12.5
11	0.45	10	0	0.0	0	0.0	0	0.0	7	53.8	1	7.7	1	7.7
12	0.90	5	0	0.0	0	0.0	0	0.0	3	30.0	1	10.0	1	10.0
13	0.45	20	0	0.0	0	0.0	1	0.5	3	15.8	0	0.0	1	5.3
14	0.60	10	0	0.0	0	0.0	0	0.0	5	41.7	0	0.0	2	16.7
15	0.75	10	0	0.0	0	0.0	0	0.0	1	25.0	0	0.0	0	0.0
16	0.90	20	0	0.0	0	0.0	0	0.0	0	0.0	2	33.3	0	0.0
33	0.45	5	0	0.0	0	0.0	1	0.5	4	21.1	2	10.5	3	15.8
34	0.60	5	0	0.0	0	0.0	0	0.0	3	50.0	2	33.3	1	16.7
35	0.75	15	0	0.0	0	0.0	0	0.0	2	25.0	0	0.0	1	12.5
36	0.90	15	0	0.0	0	0.0	0	0.0	2	33.3	0	0.0	2	33.3
37	0.45	20	0	0.0	0	0.0	0	0.0	2	25.0	1	12.5	1	12.5
38	0.60	10	0	0.0	0	0.0	0	0.0	1	25.0	0	0.0	0	0.0
39	0.75	20	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	40.0
40	0.90	10	0	0.0	0	0.0	0	0.0	3	50.0	1	16.7	3	50.0
41	0.45	15	0	0.0	0	0.0	0	0.0	2	20.0	2	20.0	1	10.0
42	0.60	15	0	0.0	0	0.0	0	0.0	5	41.7	0	0.0	3	25.0
43	0.75	5	0	0.0	0	0.0	0	0.0	0	0.0	1	25.0	1	25.0
44	0.90	5	0	0.0	0	0.0	0	0.0	2	50.0	0	0.0	1	25.0
45	0.45	10	0	0.0	0	0.0	0	0.0	4	30.8	1	7.7	0	0.0
46	0.60	20	0	0.0	0	0.0	0	0.0	4	44.4	1	11.1	2	22.2
47	0.75	20	0	0.0	0	0.0	0	0.0	1	33.3	0	0.0	3	100.0
48	0.90	10	0	0.0	0	0.0	0	0.0	3	60.0	0	0.0	1	20.0
Total/Average			0.0	0.0	0.0	0.0	4.0	0.1	86.0	31.3	27.0	10.6	43.0	17.5

Mortality Report

Pen	STDEN	NIPP	Septacemia	Septacemia %	Dehydration	Dehydration %	Other	Other %
1	0.37	5	0	0.0	1	5.9	4	23.5
2	0.60	5	1	7.7	0	0.0	5	38.5
3	0.75	15	0	0.0	0	0.0	0	0.0
4	0.90	15	0	0.0	0	0.0	4	100.0
5	0.75	5	0	0.0	0	0.0	3	100.0
6	0.60	20	0	0.0	0	0.0	3	33.3
7	0.75	10	0	0.0	0	0.0	4	44.4
8	0.90	20	0	0.0	0	0.0	1	20.0
9	0.45	15	1	6.7	0	0.0	3	20.0
10	0.60	15	0	0.0	0	0.0	2	25.0
11	0.45	10	0	0.0	0	0.0	5	38.5
12	0.90	5	1	10.0	0	0.0	3	30.0
13	0.45	20	2	10.5	6	31.6	8	42.1
14	0.60	10	0	0.0	0	0.0	5	41.7
15	0.75	10	1	25.0	1	25.0	2	50.0
16	0.90	20	2	33.3	0	0.0	1	16.7
33	0.45	5	0	0.0	1	5.3	10	52.6
34	0.60	5	0	0.0	1	16.7	1	16.7
35	0.75	15	0	0.0	1	12.5	3	37.5
36	0.90	15	1	16.7	1	16.7	0	0.0
37	0.45	20	0	0.0	0	0.0	4	50.0
38	0.60	10	1	25.0	1	25.0	2	50.0
39	0.75	20	1	20.0	0	0.0	2	40.0
40	0.90	10	0	0.0	0	0.0	0	0.0
41	0.45	15	1	10.0	0	0.0	4	40.0
42	0.60	15	0	0.0	0	0.0	3	25.0
43	0.75	5	0	0.0	0	0.0	1	25.0
44	0.90	5	0	0.0	0	0.0	1	25.0
45	0.45	10	2	15.4	0	0.0	8	61.5
46	0.60	20	0	0.0	0	0.0	3	33.3
47	0.75	20	0	0.0	0	0.0	0	0.0
48	0.90	10	1	20.0	0	0.0	1	20.0
Total/Average			15.0	6.3	13.0	4.3	96.0	34.4

Appendix 2

Broiler Performance Summary Trials 1 & 2 Data Experiment 1

LA – refers to Low Air speed circulation

HA – refers to High Air speed circulation

MF – refers to Manual Feeding

AF – refers to Automatic Feeding (feed Auger)

d7 – refers to day 7

d41 – refers to day 41

FCR – Feed Conversion Ratio

Red White Blue

Red – condemned carcass

White – trimmed carcass

Blue – internal contamination

Summary Data - Experiment 2-Trial 1

pen	vent	air speed	disturb	Placed	kg/m2	Analysis	Deads	Deads %	Culls	Birds wt day 41	BW41 g/bird	CV %	Penwt-d7 kg	BW7 g	PenWt-d41 kg
1	low	LA	MF	214	37.3	4	11	5.1	5	198	1734	14.9	22.5	107.1	343.3
2	low	HA	AF	219	36.7	4	15	6.8	8	196	1703	14.5	23	109.5	333.8
3	low	LA	AF	215	37.4	4	20	9.3	11	184	1739	12.9	22.9	109.0	320.0
4	low	HA	MF	217	37.4	4	8	3.7	5	204	1737	15.0	23.3	111.0	354.3
5	low	LA	MF	214	35.9	4	9	4.2	1	204	1669	14.8	22.6	107.6	340.5
6	low	HA	AF	219	36.2	4	16	7.3	6	197	1681	14.0	23.2	110.5	331.2
7	low	LA	AF	216	36.2	4	9	4.2	5	202	1681	13.1	23.2	110.5	339.6
8	low	HA	MF	215	37.1	4	17	7.9	7	191	1725	13.1	22.7	108.1	329.5
9	high	LA	MF	216	35.7	4	17	7.9	10	189	1656	16.4	22.5	107.1	313.0
10	high	HA	AF	219	34.7	4	22	10.0	13	184	1611	16.3	21.6	108.5	296.4
11	high	LA	AF	216	36.6	4	10	4.6	2	204	1698	14.1	23	109.5	346.4
12	high	HA	MF	220	37.1	4	9	4.1	3	208	1723	13.9	23.3	111.0	358.4
13	high	LA	MF	215	37.1	4	9	4.2	4	202	1722	15.0	23.2	110.5	347.8
14	high	HA	AF	217	36.2	4	12	5.5	5	200	1681	13.2	22.4	106.7	336.2
15	high	LA	AF	218	37.0	4	9	4.1	6	203	1719	14.7	22.4	106.7	349.0
16	high	HA	MF	215	38.5	4	4	1.9	0	211	1788	11.9	23.3	111.0	377.3
33	high	LA	MF	222	36.3	4	11	5.0	2	209	1688	15.2	22.2	105.7	352.8
34	high	HA	AF	221	37.2	4	16	7.2	7	198	1727	13.3	22.7	108.1	341.9
35	high	LA	AF	216	36.6	4	13	6.0	3	200	1702	13.8	22.3	106.2	340.4
36	high	HA	MF	217	36.1	4	11	5.1	4	202	1676	14.1	21.6	108.5	338.6
37	high	LA	MF	221	35.7	4	17	7.7	8	196	1657	15.3	23.3	111.0	324.8
38	high	HA	AF	220	37.2	4	7	3.2	2	211	1727	14.0	23.3	111.0	364.4
39	high	LA	AF	216	34.9	4	19	8.8	8	189	1623	13.6	22.3	106.2	306.7
40	high	HA	MF	215	36.3	4	9	4.2	3	203	1688	14.0	21.6	108.5	342.7
41	low	LA	MF	217	34.6	4	12	5.5	4	201	1605	14.8	22.9	109.0	322.6
42	low	HA	AF	218	35.4	4	16	7.3	8	194	1646	14.7	22.8	108.6	319.3
43	low	LA	AF	214	35.4	4	11	5.1	4	199	1645	13.7	22.3	106.2	327.4
44	low	HA	MF	217	34.4	4	16	7.4	10	191	1598	15.7	22.9	109.0	305.2
45	low	LA	MF	216	37.8	4	12	5.6	6	198	1755	12.6	22.7	108.1	347.5
46	low	HA	AF	211	35.2	4	10	4.7	6	195	1635	15.2	22.2	105.7	318.8
47	low	LA	AF	216	36.6	4	10	4.6	6	200	1700	14.2	22.7	108.1	340.0
48	low	HA	MF	215	36.3	4	18	8.4	5	192	1688	15.3	22.4	106.7	324.1
		Total/Average		6937	36.3	128	405	5.8	177	6355	1688.3	14.3	22.7	108.5	335.4

pen	vent	air speed	disturb	Gain	pen feed	dead bird intake	Corrected Pen feed	Feed/bd	PenWater (L)	ml/bird	water/feed	FCR
				kg	kg	kg	kg	g/bird				
1	low	LA	MF	320.8	739.8	16.9	722.9	3651	1203	6076	1.66	**2.25**
2	low	HA	AF	310.8	691.5	28.0	663.5	3385	1283	6546	1.93	**2.14**
3	low	LA	AF	297.1	655.0	39.4	615.6	3346	1244	6761	2.02	**2.07**
4	low	HA	MF	331.0	737.6	12.3	725.3	3555	1272	6235	1.75	**2.19**
5	low	LA	MF	317.9	713.3	11.9	701.4	3438	1169	5730	1.67	**2.21**
6	low	HA	AF	308.0	648.8	20.8	628.0	3188	1212	6152	1.93	**2.04**
7	low	LA	AF	316.4	681.4	17.6	663.8	3286	1273	6302	1.92	**2.10**
8	low	HA	MF	306.8	718.1	28.8	689.3	3609	1245	6518	1.81	**2.25**
9	high	LA	MF	290.5	726.9	24.0	702.9	3719	1171	6196	1.67	**2.42**
10	high	HA	AF	274.8	684.3	24.2	660.1	3588	1154	6272	1.75	**2.40**
11	high	LA	AF	323.4	731.3	18.0	713.3	3496	1189	5828	1.67	**2.21**
12	high	HA	MF	335.1	758.2	27.0	731.2	3515	1270	6106	1.74	**2.18**
13	high	LA	MF	324.6	726.0	20.7	705.3	3492	1178	5832	1.67	**2.17**
14	high	HA	AF	313.8	722.7	21.0	701.7	3508	1237	6185	1.76	**2.24**
15	high	LA	AF	326.6	734.2	10.4	723.8	3566	1153	5680	1.59	**2.22**
16	high	HA	MF	354.0	759.1	9.1	750.0	3554	1236	5858	1.65	**2.12**
33	high	LA	MF	330.6	714.1	15.7	698.4	3342	1185	5670	1.70	**2.11**
34	high	HA	AF	319.2	723.6	23.7	699.9	3535	1342	6778	1.92	**2.19**
35	high	LA	AF	318.1	704.7	16.2	688.5	3442	1121	5605	1.63	**2.16**
36	high	HA	MF	317.0	700.6	20.5	680.1	3367	1158	5733	1.70	**2.15**
37	high	LA	MF	301.5	698.8	30.6	668.2	3409	1163	5934	1.74	**2.22**
38	high	HA	AF	341.1	740.4	4.8	735.6	3486	1177	5578	1.60	**2.16**
39	high	LA	AF	284.4	696.6	30.6	666.0	3524	1148	6074	1.72	**2.34**
40	high	HA	MF	321.1	699.7	12.2	687.5	3387	1134	5586	1.65	**2.14**
41	low	LA	MF	299.7	702.4	18.1	684.3	3405	1241	6174	1.81	**2.28**
42	low	HA	AF	296.5	717.2	29.0	688.2	3547	1227	6325	1.78	**2.32**
43	low	LA	AF	305.1	707.5	17.1	690.4	3469	1186	5960	1.72	**2.26**
44	low	HA	MF	282.3	698.5	22.6	675.9	3539	1183	6194	1.75	**2.39**
45	low	LA	MF	324.8	736.1	15.9	720.2	3637	1165	5884	1.62	**2.22**
46	low	HA	AF	296.6	710.9	13.6	697.3	3576	1159	5944	1.66	**2.35**
47	low	LA	AF	317.3	680.2	17.1	663.1	3316	1262	6310	1.90	**2.09**
48	low	HA	MF	301.7	709.8	22.9	686.9	3577	1155	6016	1.68	**2.28**
		Total/Average		312.8	711.5	20.0	691.5	3483.0	1203.0	6063.7	1.74	2.21

							Contamination						
pen	vent	air speed	disturb	% Grade A	Red white blue	Red white blue	Red	Red	White	White	Blue	Blue	Total
					Removed	%	%		%		%		
1	low	LA	MF	81	34	17.2	**5.1**	10	3.5	7	8.6	17	34
2	low	HA	AF	88	22	11.2	**2.0**	4	0.5	1	8.7	17	22
3	low	LA	AF	90	17	9.2	**1.6**	3	0.0	0	7.6	14	17
4	low	HA	MF	87	25	12.3	**1.0**	2	1.0	2	10.3	21	25
5	low	LA	MF	84	26	12.7	**2.9**	6	2.0	4	7.8	16	26
6	low	HA	AF	92	10	5.1	**1.5**	3	0.5	1	3.0	6	10
7	low	LA	AF	92	15	7.4	**0.5**	1	0.0	0	6.9	14	15
8	low	HA	MF	88	16	8.4	**1.6**	3	0.5	1	6.3	12	16
9	high	LA	MF	89	16	8.5	**0.5**	1	0.0	0	7.9	15	16
10	high	HA	AF	90	17	9.2	**0.5**	1	0.5	1	8.2	15	17
11	high	LA	AF	91	12	5.9	**0.5**	1	0.0	0	5.4	11	12
12	high	HA	MF	86	25	12.0	**2.9**	6	1.0	2	8.2	17	25
13	high	LA	MF	92	16	7.9	**0.5**	1	0.5	1	6.9	14	16
14	high	HA	AF	90	21	10.5	**0.5**	1	1.0	2	9.0	18	21
15	high	LA	AF	94	12	5.9	**0.5**	1	0.5	1	4.9	10	12
16	high	HA	MF	90	21	10.0	**1.9**	4	0.5	1	7.6	16	21
33	high	LA	MF	89	18	8.6	**2.4**	5	0.0	0	6.2	13	18
34	high	HA	AF	90	19	9.6	**3.0**	6	.	0	6.6	13	19
35	high	LA	AF	82	32	16.0	**0.5**	1	.	0	15.5	31	32
36	high	HA	MF	74	49	24.3	**3.0**	6	0.5	1	20.8	42	49
37	high	LA	MF	82	35	17.9	**1.5**	3	1.5	3	14.8	29	35
38	high	HA	AF	80	42	19.9	**2.4**	5	0.0	0	17.5	37	42
39	high	LA	AF	83	30	15.9	**1.1**	2	0.0	0	14.8	28	30
40	high	HA	MF	86	27	13.3	**2.5**	5	0.0	0	10.8	22	27
41	low	LA	MF	91	17	8.5	**2.5**	5	0.0	0	6.0	12	17
42	low	HA	AF	89	17	8.8	**1.5**	3	0.0	0	7.2	14	17
43	low	LA	AF	86	26	13.1	**2.5**	5	1.0	2	9.5	19	26
44	low	HA	MF	87	16	8.4	**0.5**	1	0.0	0	7.9	15	16
45	low	LA	MF	89	20	10.1	**2.0**	4	1.0	2	7.1	14	20
46	low	HA	AF	90	19	9.7	**1.5**	3	0.5	1	7.7	15	19
47	low	LA	AF	85	28	14.0	**1.0**	2	2.5	5	10.5	21	28
48	low	HA	MF	88	24	12.5	**1.0**	2	0.5	1	10.9	21	24
		Total/Average		87.4	724	11.4	1.7	3.3	0.7	1.2	9.1	18.1	

								Scratches					
pen	vent	air speed	disturb	old light	old Light	Old Severe	Old Severe	New Light	New light	New Severe	New Severe	Total	Total
				%		%		%		%		%	
1	low	LA	MF	37.4	74.0	21.2	42	4.0	8	0.5	1	58.6	116.0
2	low	HA	AF	16.8	33.0	14.3	28	0.0	0	0.0	0	31.1	61.0
3	low	LA	AF	21.7	40.0	12.5	23	3.8	7	0.5	1	34.2	63.0
4	low	HA	MF	12.3	25.0	16.7	34	3.4	7	1.5	3	28.9	59.0
5	low	LA	MF	13.2	27.0	25.0	51	0.5	1	0.0	0	38.2	78.0
6	low	HA	AF	13.7	27.0	21.3	42	0.5	1	0.0	0	35.0	69.0
7	low	LA	AF	13.4	27.0	27.7	56	0.5	1	0.5	1	41.1	83.0
8	low	HA	MF	19.4	37.0	15.2	29	0.0	0	1.6	3	34.6	66.0
9	high	LA	MF	13.8	26.0	18.0	34	3.7	7	0.0	0	31.7	60.0
10	high	HA	AF	16.3	30.0	32.1	59	0.5	1	0.0	0	48.4	89.0
11	high	LA	AF	25.0	51.0	23.0	47	0.0	0	0.0	0	48.0	98.0
12	high	HA	MF	19.2	40.0	22.6	47	2.4	5	0.5	1	41.8	87.0
13	high	LA	MF	26.2	53.0	23.3	47	0.0	0	0.0	0	49.5	100.0
14	high	HA	AF	18.0	36.0	26.0	52	2.0	4	0.5	1	44.0	88.0
15	high	LA	AF	20.2	41.0	19.2	39	1.5	3	0.5	1	39.4	80.0
16	high	HA	MF	14.7	31.0	10.4	22	0.0	0	0.9	2	25.1	53.0
33	high	LA	MF	13.9	29.0	13.9	29	1.0	2	0.0	0	27.8	58.0
34	high	HA	AF	.	.	.	.	.	.	.	.	.	.
35	high	LA	AF	.	.	.	.	.	.	.	.	.	.
36	high	HA	MF	16.3	33.0	9.4	19	3.0	6	1.5	3	25.7	52.0
37	high	LA	MF	13.3	26.0	12.2	24	1.5	3	1.5	3	25.5	50.0
38	high	HA	AF	17.5	37.0	11.4	24	2.8	6	0.0	0	28.9	61.0
39	high	LA	AF	18.5	35.0	18.0	34	1.6	3	0.5	1	36.5	69.0
40	high	HA	MF	15.3	31.0	27.6	56	1.0	2	0.5	1	42.9	87.0
41	low	LA	MF	16.9	34.0	17.4	35	0.0	0	0.0	0	34.3	69.0
42	low	HA	AF	24.2	47.0	28.9	56	0.0	0	0.0	0	53.1	103.0
43	low	LA	AF	19.1	38.0	24.6	49	1.0	2	1.5	3	43.7	87.0
44	low	HA	MF	27.7	53.0	23.0	44	1.0	2	1.0	2	50.8	97.0
45	low	LA	MF	27.8	55.0	24.2	48	0.5	1	0.0	0	52.0	103.0
46	low	HA	AF	19.0	37.0	40.5	79	0.0	0	0.0	0	59.5	116.0
47	low	LA	AF	20.5	41.0	19.0	38	0.0	0	0.0	0	39.5	79.0
48	low	HA	MF	26.6	51.0	10.9	21	0.0	0	0.0	0	37.5	72.0
		Total/Average		19.3	1145.0	20.3	1208.0	1.2	72.0	0.5	27.0	39.6	78.4

										Condemnations						
pan	vent	air speed	disturb	DOA	Ascites	Ascites	Bruising	Bruising	Cellulitis	Cellulitis	Contamination	Contamination	Cyanosis	Mutilation	other	Other
					%		%		%		%				%	
1	low	LA	MF		0.51	1	0.51	1	0.0	0	0.0	0	1	0	0.5	1
2	low	HA	AF		0.00	0	0.00	0	0.0	0	0.0	0	1	0	0.5	1
3	low	LA	AF		0.00	0	0.00	0	0.0	0	0.0	0	0	0	0.5	1
4	low	HA	MF		0.00	0	0.49	1	0.0	0	0.0	0	0	0	0.0	0
5	low	LA	MF		0.00	0	0.00	0	2.5	5	0.0	0	0	0	0.5	1
6	low	HA	AF		0.00	0	0.00	0	0.5	1	0.0	0	1	0	1.5	3
7	low	LA	AF		0.00	0	0.00	0	0.5	1	0.0	0	0	0	0.5	1
8	low	HA	MF		0.00	0	0.00	0	1.0	2	0.0	0	0	0	2.6	5
9	high	LA	MF		0.00	0	0.00	0	0.5	1	0.0	0	2	0	0.5	1
10	high	HA	AF		0.54	1	0.00	0	0.0	0	0.0	0	1	0	0.0	0
11	high	LA	AF		0.49	1	0.00	0	0.0	0	0.0	0	0	1	2.0	4
12	high	HA	MF		0.00	0	0.00	0	1.4	3	0.0	0	0	0	0.5	1
13	high	LA	MF		0.00	0	0.00	0	0.0	0	0.0	0	0	0	0.0	0
14	high	HA	AF		0.00	0	0.00	0	0.0	0	0.0	0	0	0	0.0	0
15	high	LA	AF		0.00	0	0.00	0	0.0	0	0.0	0	0	0	0.0	0
16	high	HA	MF		0.00	0	0.00	0	0.0	0	0.0	0	0	0	0.0	0
33	high	LA	MF		0.00	0	0.00	0	1.4	3	0.5	1	0	0	0.0	0
34	high	HA	AF		0.00	0	0.00	0	0.0	0	0.0	0	1	0	0.0	0
35	high	LA	AF		0.00	0	0.00	0	0.5	1	0.0	0	1	0	1.0	2
36	high	HA	MF		0.00	0	0.00	0	0.5	1	0.0	0	1	0	0.5	1
37	high	LA	MF		0.00	0	0.00	0	0.0	0	0.0	0	0	0	0.0	0
38	high	HA	AF		0.00	0	0.47	1	0.0	0	0.0	0	0	0	0.0	0
39	high	LA	AF		0.00	0	0.00	0	0.5	1	0.0	0	1	0	0.0	0
40	high	HA	MF		0.00	0	0.49	1	0.5	1	0.0	0	0	0	0.0	0
41	low	LA	MF		0.00	0	0.00	0	0.0	0	0.0	0	1	0	0.0	0
42	low	HA	AF		0.00	0	0.00	0	0.5	1	0.5	1	1	0	0.5	1
43	low	LA	AF		0.00	0	0.00	0	0.5	1	0.0	0	0	0	0.0	0
44	low	HA	MF		1.05	2	0.00	0	0.0	0	0.5	1	4	0	0.5	1
45	low	LA	MF		0.00	0	0.00	0	0.5	1	0.5	1	0	0	0.0	0
46	low	HA	AF		0.00	0	0.00	0	0.0	0	0.0	0	1	0	0.0	0
47	low	LA	AF		0.50	1	0.00	0	0.5	1	0.0	0	1	0	0.0	0
48	low	HA	MF		0.00	0	0.00	0	0.0	0	0.0	0	0	0	0.0	0
		Total/Average			0.10	6.0	0.1	4.0	0.4	24.0	0.1	4.0	18.0	1.0	0.4	24.0

Summary Data - Experiment 2-Trial 2

pen	vent	Air speed	disturb	Placed	kg/m2	Culls	Analysis	Deads	Deads %	Birds weighed day 40	BW41 g/bird	CV %	Penwt-d7 kg
1	low	LA	MF	218	39.0	5	4	8	3.7	205	1810	12.6	24.3
2	low	HA	AF	225	39.2	2	4	5	2.2	218	1820	13.7	24.2
3	low	LA	AF	222	38.5	1	4	11	5.0	210	1790	12.4	24.2
4	low	HA	MF	222	38.8	6	4	6	2.7	210	1800	15.4	24.4
5	low	LA	MF	223	38.5	1	4	2	0.9	220	1790	13.8	24.4
6	low	HA	AF	227	39.8	1	4	8	3.5	218	1850	12.9	24.1
7	low	LA	AF	223	38.3	5	4	5	2.2	213	1780	12.5	23
8	low	HA	MF	220	38.8	5	4	5	2.3	210	1800	15.3	24.3
9	high	LA	MF	222	36.4	1	4	5	2.3	216	1690	17.3	22.8
10	high	HA	AF	225	39.6	1	4	5	2.2	219	1840	12.0	24
11	high	LA	AF	225	37.5	1	4	2	0.9	222	1740	15.5	23.4
12	high	HA	MF	222	40.9	2	4	5	2.3	215	1900	11.5	22.8
13	high	LA	MF	224	38.3	1	4	9	4.0	214	1780	15.9	23.8
14	high	HA	AF	223	39.4	2	4	11	4.9	210	1830	14.8	23.7
15	high	LA	AF	222	39.8	0	4	4	1.8	218	1850	15.1	22.9
16	high	HA	MF	220	40.7	1	4	5	2.3	214	1890	13.4	23.4
33	high	LA	MF	224	39.8	1	4	2	0.9	221	1850	13.9	24.1
34	high	HA	AF	223	41.3	1	4	4	1.8	218	1920	12.7	24.1
35	high	LA	AF	224	39.4	3	4	3	1.3	218	1830	13.9	23.1
36	high	HA	MF	222	39.8	1	4	5	2.3	216	1850	14.7	23.4
37	high	LA	MF	225	38.8	3	4	7	3.1	215	1800	13.5	23.8
38	high	HA	AF	222	40.3	1	4	7	3.2	214	1870	12.3	22.1
39	high	LA	AF	223	38.1	1	4	6	2.7	216	1770	12.4	23.3
40	high	HA	MF	221	38.3	2	4	5	2.3	214	1780	15.5	23.2
41	low	LA	MF	226	36.2	2	4	5	2.2	219	1680	14.0	23.9
42	low	HA	AF	223	39.4	0	4	2	0.9	221	1830	14.5	24.7
43	low	LA	AF	227	37.2	6	4	4	1.8	217	1730	14.6	23.7
44	low	HA	MF	220	39.2	4	4	3	1.4	213	1820	15.2	23.2
45	low	LA	MF	209	39.4	2	4	6	2.9	201	1830	11.2	22.1
46	low	HA	AF	223	38.5	2	4	4	1.8	217	1790	13.5	23.5
47	low	LA	AF	222	40.5	2	4	6	2.7	214	1880	12.2	23.6
48	low	HA	MF	226	41.1	2	4	2	0.9	222	1910	15.1	23.6
Total/Average				7123	39.1	68	128	167	2.3	6888	1815.6	13.9	23.6

pen	vent	Air speed	disturb	Gain	pen feed	Dead bird intak	Corrected pen fe	Feed/bd	PenWater (L)	ml/bird
				kg	kg	kg	kg	g/bird		
1	low	LA	MF	346.8	764.0	20.7	743.3	3626	1292	6302
2	low	HA	AF	372.6	780.6	8.9	771.7	3540	1321	6060
3	low	LA	AF	351.7	752.3	25.3	727.0	3462	1283	6110
4	low	HA	MF	353.6	770.4	19.4	751.0	3576	1266	6029
5	low	LA	MF	369.4	758.7	4.9	753.8	3426	1298	5900
6	low	HA	AF	379.2	775.9	10.3	765.6	3512	1287	5904
7	low	LA	AF	356.1	744.3	14.0	730.3	3429	1317	6183
8	low	HA	MF	353.7	750.6	7.4	743.2	3539	1249	5948
9	high	LA	MF	342.2	723.7	6.2	717.5	3322	1241	5745
10	high	HA	AF	379.0	774.0	10.2	763.8	3488	1353	6178
11	high	LA	AF	362.9	742.7	5.7	737.0	3320	1240	5586
12	high	HA	MF	385.7	723.6	3.8	719.8	3348	1343	6247
13	high	LA	MF	357.1	743.9	14.7	729.2	3407	1218	5692
14	high	HA	AF	360.6	761.9	20.4	741.5	3531	1258	5990
15	high	LA	AF	380.4	734.5	5.1	729.4	3346	1224	5615
16	high	HA	MF	381.1	769.4	13.3	756.1	3533	1262	5897
33	high	LA	MF	384.8	712.7	0.4	712.3	3223	1286	5819
34	high	HA	AF	394.5	730.3	7.6	722.7	3315	1391	6381
35	high	LA	AF	375.8	689.8	7.0	682.9	3132	1209	5546
36	high	HA	MF	376.2	702.1	10.1	692.0	3204	1267	5866
37	high	LA	MF	363.2	689.4	10.6	678.8	3157	1280	5953
38	high	HA	AF	378.1	683.6	14.4	669.2	3127	1238	5785
39	high	LA	AF	359.0	666.9	12.6	654.3	3029	1248	5778
40	high	HA	MF	357.7	681.1	9.1	672.0	3140	1206	5636
41	low	LA	MF	344.0	649.5	10.8	638.7	2916	1282	5854
42	low	HA	AF	379.7	684.6	9.3	675.3	3056	1331	6023
43	low	LA	AF	351.7	735.8	16.6	719.2	3314	1279	5894
44	low	HA	MF	364.5	673.2	12.6	660.6	3102	1241	5826
45	low	LA	MF	345.7	663.0	8.4	654.6	3257	1232	6129
46	low	HA	AF	364.9	744.1	5.0	739.1	3406	1225	5645
47	low	LA	AF	378.7	782.7	8.0	774.7	3620	1293	6042
48	low	HA	MF	400.4	729.1	5.3	723.8	3260	1238	5577
Total/Average				367.2	727.8	10.6	717.2	3333.3	1271.8	5910.5

						Contamination						
pen	vent	Air speed	disturb	% Grade A	Red white blue Removed	Red white blue %	Red %	Red	White %	White	Blue %	Blue
1	low	LA	MF	95	10	4.9	**0.0**	0	0.0	0	0.6	10
2	low	HA	AF	90	19	8.7	**0.1**	1	0.1	2	0.9	16
3	low	LA	AF	94	11	5.2	**0.0**	0	0.0	0	0.6	11
4	low	HA	MF	88	23	11.0	**0.1**	1	0.3	5	0.9	17
5	low	LA	MF	92	15	6.8	**0.1**	1	0.1	2	0.7	12
6	low	HA	AF	90	20	9.2	**0.0**	0	0.1	1	1.0	19
7	low	LA	AF	88	22	10.3	**0.3**	5	0.3	5	0.7	12
8	low	HA	MF	88	25	11.9	**0.1**	1	0.4	7	0.9	17
9	high	LA	MF	89	21	9.7	**0.2**	3	0.1	1	1.0	17
10	high	HA	AF	93	16	7.3	**0.0**	0	0.3	6	0.5	10
11	high	LA	AF	89	23	10.4	**0.0**	0	0.1	1	1.3	22
12	high	HA	MF	94	9	4.2	**0.2**	3	0.0	0	0.3	6
13	high	LA	MF	90	20	9.3	**0.1**	1	0.1	1	1.0	18
14	high	HA	AF	88	20	9.5	**0.2**	3	0.3	5	0.7	12
15	high	LA	AF	93	15	6.9	**0.1**	1	0.2	3	0.6	11
16	high	HA	MF	91	19	8.9	**0.2**	4	0.2	3	0.6	12
33	high	LA	MF	94	13	5.9	**0.1**	1	0.2	3	0.5	9
34	high	HA	AF	96	9	4.1	**0.1**	2	0.1	1	0.3	6
35	high	LA	AF	96	7	3.2	**0.1**	2	0.1	1	0.2	4
36	high	HA	MF	95	9	4.2	**0.1**	1	0.0	0	0.4	8
37	high	LA	MF	91	20	9.3	**0.0**	0	0.4	8	0.7	12
38	high	HA	AF	82	35	16.4	**0.3**	6	1.0	19	0.5	10
39	high	LA	AF	88	23	10.6	**0.2**	3	0.1	2	1.0	18
40	high	HA	MF	94	12	5.6	**0.1**	1	0.1	1	0.6	10
41	low	LA	MF	89	22	10.0	**0.1**	2	0.3	5	0.9	15
42	low	HA	AF	94	10	4.5	**0.1**	2	0.1	1	0.4	7
43	low	LA	AF	91	19	8.8	**0.1**	2	0.3	5	0.7	12
44	low	HA	MF	95	9	4.2	**0.1**	1	0.0	0	0.4	8
45	low	LA	MF	89	21	10.4	**0.1**	2	0.4	7	0.7	12
46	low	HA	AF	95	11	5.1	**0.1**	1	0.1	1	0.5	9
47	low	LA	AF	89	17	7.9	**0.2**	3	0.1	2	0.6	12
48	low	HA	MF	94	11	5.0	**0.1**	1	0.0	0	0.5	10
Total/Average				91.4	536	7.8	0.1	1.7	0.2	3.1	0.7	12.0

								Scratches		
pen	vent	Air speed	disturb	Old light	Old Light	Old Severe	Old Severe	New Light	New Light	New Severe
				%		%		%		%
1	low	LA	MF	1.7	31.0	3.4	61	0.1	2	0.0
2	low	HA	AF	3.2	58.0	2.2	40	0.1	2	0.2
3	low	LA	AF	2.5	45.0	1.8	33	0.2	4	0.1
4	low	HA	MF	1.8	32.0	2.4	44	0.1	1	0.1
5	low	LA	MF	1.5	27.0	3.7	66	0.0	0	0.1
6	low	HA	AF	1.0	18.0	6.3	117	0.1	1	0.0
7	low	LA	AF	2.9	51.0	4.3	76	0.4	7	0.0
8	low	HA	MF	2.3	42.0	4.1	74	0.1	2	0.0
9	high	LA	MF	2.9	49.0	2.5	43	0.1	2	0.0
10	high	HA	AF	1.5	28.0	5.4	99	0.1	2	0.1
11	high	LA	AF	1.7	29.0	4.1	71	0.2	4	0.0
12	high	HA	MF	1.7	33.0	4.7	89	0.1	1	0.0
13	high	LA	MF	2.4	42.0	3.3	58	0.4	8	0.0
14	high	HA	AF	1.7	32.0	3.7	67	0.1	2	0.0
15	high	LA	AF	1.7	32.0	4.3	79	0.0	0	0.0
16	high	HA	MF	2.0	38.0	3.0	56	0.1	2	0.0
33	high	LA	MF	1.9	35.0	3.0	55	0.0	0	0.0
34	high	HA	AF	1.5	28.0	4.3	82	0.1	1	0.1
35	high	LA	AF	2.3	43.0	3.3	61	0.0	0	0.0
36	high	HA	MF	1.2	22.0	4.3	80	0.2	3	0.0
37	high	LA	MF	1.6	29.0	6.2	112	0.1	1	0.0
38	high	HA	AF	2.5	46.0	2.6	48	0.2	3	0.0
39	high	LA	AF	3.1	55.0	2.4	43	0.1	1	0.0
40	high	HA	MF	1.2	22.0	3.1	56	0.0	0	0.0
41	low	LA	MF	1.4	24.0	3.4	57	0.3	5	0.0
42	low	HA	AF	2.4	44.0	1.3	23	0.3	5	0.0
43	low	LA	AF	2.3	39.0	3.4	58	0.1	1	0.0
44	low	HA	MF	1.6	30.0	5.7	104	0.0	0	0.0
45	low	LA	MF	2.7	50.0	3.8	69	0.0	0	0.0
46	low	HA	AF	2.8	50.0	3.0	54	0.1	1	0.0
47	low	LA	AF	1.8	33.0	4.6	86	0.0	0	0.0
48	low	HA	MF	2.5	47.0	4.4	84	0.0	0	0.0
Total/Average				2.0	37.0	3.7	67.0	0.1	1.9	0.0

									Condemnations		
Pen	vent	Air Speed	disturb	DOA	Ascites %	Ascites	Bruising %	Bruising	Cellulitis %	Cellulitis	Contamination
1	low	LA	MF	0	0.10	1	0	0	0.0	0	0
2	low	HA	AF	0	0	0	0	0	0.0	0	0
3	low	LA	AF	0	0	0	0	0	0.1	1	0
4	low	HA	MF	0	0.10	1	0	0	0.1	1	0
5	low	LA	MF	0	0.00	0	0	0	0.1	1	0
6	low	HA	AF	0	0.10	1	0	0	0.1	1	0
7	low	LA	AF	0	0.00	0	0	0	0.1	1	0
8	low	HA	MF	0	0.00	0	0	0	0.1	1	0
9	high	LA	MF	0	0.00	0	0	0	0.0	0	0
10	high	HA	AF	0	0.00	0	0	0	0.0	0	0
11	high	LA	AF	0	0.00	0	0	0	0.0	0	0
12	high	HA	MF	0	0.00	0	0	0	0.2	3	0
13	high	LA	MF	0	0.00	0	0.1	1	0.0	0	0
14	high	HA	AF	0	0.00	0	0	0	1.9	4	0
15	high	LA	AF	0	0.00	0	0	0	0.2	0	0
16	high	HA	MF	0	0.00	0	0	0	0.1	1	0
33	high	LA	MF	0	0.00	0	0	0	0.1	1	0
34	high	HA	AF	0	0.00	0	0	0	0.0	0	0
35	high	LA	AF	0	0.10	1	0	0	0.5	1	0
36	high	HA	MF	0	0.00	0	0	0	0.0	0	0
37	high	LA	MF	0	0.00	0	0	0	0.0	0	0
38	high	HA	AF	0	0.10	1	0	0	0.1	2	0
39	high	LA	AF	0	0.10	1	0	0	0.1	2	0
40	high	HA	MF	0	0.00	0	0	0	0.0	0	0
41	low	LA	MF	0	0.00	0	0	0	0.1	1	0
42	low	HA	AF	0	0.10	1	0.1	1	0.1	2	0
43	low	LA	AF	0	0.00	0	0	0	0.0	0	0
44	low	HA	MF	0	0.00	0	0	0	0.1	2	0
45	low	LA	MF	0	0.00	0	0	0	0.1	1	0
46	low	HA	AF	0	0.00	0	0	0	0.0	0	0
47	low	LA	AF	0	0.00	0	0	0	0.3	6	0
48	low	HA	MF	0	0.00	0	0	0	0.2	3	0
Total/Average				0.0	0.0	0.2	0.0	2.0	0.1	1.1	0.0

						Condemnations			
pen	vent	Air speed	disturb	Cyanosis %	Cyanosis	Mutilation %	Mutilation	Other %	Other
1	low	LA	MF	0.0	0	0.0	0	0.0	0
2	low	HA	AF	0.0	0	0.0	0	0.1	2
3	low	LA	AF	0.0	0	0.0	0	0.0	0
4	low	HA	MF	0.1	1	0.0	0	0.0	0
5	low	LA	MF	0.0	0	0.0	0	0.1	1
6	low	HA	AF	0.0	0	0.0	0	0.0	0
7	low	LA	AF	0.1	2	0.5	1	0.1	2
8	low	HA	MF	0.0	0	0.0	0	0.0	0
9	high	LA	MF	0.0	0	0.5	1	0.1	2
10	high	HA	AF	0.0	0	0.0	0	0.0	0
11	high	LA	AF	0.1	1	0.0	0	0.1	1
12	high	HA	MF	0.0	0	0.0	0	0.0	0
13	high	LA	MF	0.0	0	0.0	0	0.0	0
14	high	HA	AF	0.0	0	0.5	1	0.0	0
15	high	LA	AF	0.0	0	0.0	0	0.0	0
16	high	HA	MF	0.1	1	0.0	0	0.0	0
33	high	LA	MF	0.1	1	0.0	0	0.0	0
34	high	HA	AF	0.0	0	0.0	0	0.0	0
35	high	LA	AF	0.0	0	0.0	0	0.0	0
36	high	HA	MF	0.0	0	0.5	1	0.0	0
37	high	LA	MF	0.0	0	0.0	0	0.0	0
38	high	HA	AF	0.2	3	0.0	0	0.0	0
39	high	LA	AF	0.0	0	0.0	0	0.0	0
40	high	HA	MF	0.0	0	0.0	0	0.1	1
41	low	LA	MF	0.0	0	0.0	0	0.0	0
42	low	HA	AF	0.0	0	0.0	0	0.0	0
43	low	LA	AF	0.0	0	0.0	0	0.0	0
44	low	HA	MF	0.0	0	0.0	0	0.0	0
45	low	LA	MF	0.0	0	0.0	0	0.0	0
46	low	HA	AF	0.0	0	0.0	0	0.0	0
47	low	LA	AF	0.0	0	0.0	0	0.0	0
48	low	HA	MF	0.0	0	0.0	0	0.0	0
Total/Average				0.0	0.3	0.1	0.1	0.0	0.3

Appendix 3 – Pen Heat Index

Experiment 1 & 2

Temperature Chart Experiment 1-Trial 1

Day	Average Barn Temperature	Recommended	Heat Index Pen Intercept 4.1°C
20	23	27.0	2.00
21	24.5	26.8	38.50
22	27	26.5	101.20
23	27	26.3	110.40
24	27	26.2	117.30
25	25.5	25.4	104.58
26	27	24.7	165.97
27	25	24.5	124.65
28	26	24.1	169.05
29	28.5	24.0	248.19
30	30	23.3	323.61
31	26	23.3	210.80
32	25.5	23.2	205.47
33	25	23.0	201.30
34	24	22.9	175.53
35	22.5	22.5	143.50
36	23.5	21.5	219.60
37	26	21.0	336.70
38	25.5	20.5	345.80
39	25.5	20.3	361.40
40	26.5	19.5	444.00
		Total Heat Index	**4150**

Temperature Chart Experiment 1-Trial 2

Day	Average Barn Temperature	Recommended	Heat Index Pen Intercept 4.1°C
20	29.5	27.0	132.00
21	30.5	26.8	164.50
22	33.5	26.5	244.20
23	37	26.3	340.40
24	32	26.2	237.30
25	32.5	25.4	279.58
26	32	24.7	295.97
27	32	24.5	313.65
28	28	24.1	225.05
29	28.5	24.0	248.19
30	28.5	23.3	278.61
31	29	23.3	303.80
32	29	23.2	317.47
33	25.5	23.0	217.80
34	27.5	22.9	294.53
35	24	22.5	196.00
36	23	21.5	201.60
37	26	21.0	336.70
38	31.1	20.5	558.60
39	27.5	20.3	439.40
		Total Heat Index	**5625**

Experiment 2 Trial 2

Temperature Chart - 2 L/s (section 1)				Temperature Chart - 2 L/s (section 4)			
Day	Recommended	Average Pen Temperature	Pen Heat Index	Day	Recommended	Average Pen Temperature	Pen Heat Index
8	32.0	.	.	8	32.0	.	.
9	31.3	.	.	9	31.3	.	.
10	31.0	.	.	10	31.0	.	.
11	30.4	.	.	11	30.4	.	.
12	29.6	.	.	12	29.6	.	.
13	29.5	.	.	13	29.5	.	.
14	29.1	.	.	14	29.1	.	.
15	29.2	25.9	.	15	29.2	27.4	.
16	28.6	27.7	.	16	28.6	29.1	.
17	28.1	23.9	.	17	28.1	26.3	.
18	27.8	18.9	.	18	27.8	23.7	.
19	27.4	25.3	.	19	27.4	25.4	.
20	27.0	26.4	0.0	20	27.0	28.9	0
21	26.8	27.1	5.5	21	26.8	27.8	20
22	26.5	27.2	15.1	22	26.5	28.7	48
23	26.3	28.4	0.0	23	26.3	26.3	0
24	26.2	22.0	0.0	24	26.2	24.0	0
25	25.4	20.0	0.0	25	25.4	21.0	0
26	24.7	21.0	0.0	26	24.7	23.0	0
27	24.5	26.0	40.5	27	24.5	26.0	41
28	24.1	27.1	88.0	28	24.1	28.5	128
29	24.0	28.9	143.2	29	24.0	29.1	149
30	23.3	28.4	154.1	30	23.3	28.8	164
31	23.3	27.0	114.7	31	23.3	28.0	146
32	23.2	25.0	57.6	32	23.2	26.0	90
33	23.0	21.1	0.0	33	23.0	24.0	38
34	22.9	27.6	160.7	34	22.9	29.0	207
35	22.5	26.0	122.5	35	22.5	27.0	158
36	21.5	24.0	90.0	36	21.5	25.0	126
37	21.0	27.0	222.0	37	21.0	25.3	157
38	20.5	27.0	247.0	38	20.5	27.0	247
39	20.3	21.0	27.3	39	20.3	23.0	105
40	19.5	21.0	60.0	40	19.5	21.0	60
		Total Heat Index	1548			Total Heat Index	1873

Experiment 2 Trial 2

Temperature Chart - 34 L/s (…m2)				Temperature Chart - 34 L/s (…m3)			
		Average				Average	
Day	Recorded	Rn Temperature	Rn Hatchrate	Day	Recorded	Rn Temperature	Rn Hatchrate
8	320	.	.	8	320	.	.
9	313	.	.	9	313	.	.
10	310	.	.	10	310	.	.
11	304	.	.	11	304	.	.
12	296	.	.	12	296	.	.
13	295	.	.	13	295	.	.
14	291	.	.	14	291	.	.
15	292	263	.	15	292	261	.
16	286	289	.	16	286	279	.
17	281	288	.	17	281	274	.
18	278	240	.	18	278	222	.
19	274	286	.	19	274	288	.
20	270	270	0	20	270	257	0
21	268	266	0	21	268	274	12
22	265	281	34	22	265	281	36
23	263	241	-61	23	263	241	0
24	262	197	0	24	262	220	0
25	254	182	0	25	254	200	0
26	247	181	0	26	247	220	0
27	245	238	0	27	245	250	14
28	241	234	121	28	241	281	113
29	240	234	168	29	240	291	147
30	233	220	171	30	233	291	173
31	233	233	163	31	233	281	148
32	232	223	0	32	232	250	58
33	230	206	0	33	230	230	0
34	229	281	178	34	229	279	171
35	225	237	42	35	225	250	88
36	215	225	36	36	215	250	126
37	210	250	148	37	210	253	167
38	205	246	167	38	205	270	247
39	203	201	0	39	203	230	105
40	195	210	60	40	195	210	60
		Total Hatchrate	1276			Total Hatchrate	1358

Experiment 2 Trial 1

Day	Recommended	Average Pen Temperature	Pen Heat Index		Day	Recommended	Average Pen Temperature	Pen Heat Index
Temperature Chart - 13/s (section 1)					Temperature Chart - 13/s (section 4)			
8	320	.	.		8	320	.	.
9	313	.	.		9	313	.	.
10	310	.	.		10	310	.	.
11	304	.	.		11	304	.	.
12	296	.	.		12	296	.	.
13	295	.	.		13	295	.	.
14	291	.	.		14	291	.	.
15	292	.	.		15	292	.	.
16	286	.	.		16	286	.	.
17	281	.	.		17	281	.	.
18	278	.	.		18	278	.	.
19	274	.	.		19	274	.	.
20	270	.	.		20	270	.	.
21	268	261	0		21	268	251	0
22	265	246	0		22	265	222	0
23	263	253	0		23	263	253	0
24	262	221	0		24	262	235	0
25	254	242	0		25	254	253	0
26	247	204	0		26	247	241	0
27	245	239	0		27	245	211	0
28	241	236	98		28	241	238	49
29	240	200	0		29	240	232	38
30	233	246	39		30	233	230	51
31	233	233	0		31	233	253	60
32	232	236	45		32	232	244	0
33	230	244	45		33	230	238	25
34	229	271	140		34	229	231	174
35	225	239	235		35	225	278	186
36	215	235	222		36	215	233	238
37	210	254	201		37	210	239	200
38	205	235	322		38	205	222	300
39	203	231	109		39	203	231	109
40	195	238	200		40	195	238	200
		Total Heat Index	1707				Total Heat Index	1830

			Experiment 2 Trial 1					
	Temperature Chart - 34 lbs (section 2)					Temperature Chart - 34 lbs (section 3)		
		Average					Average	
Day	Recommended	Pen Temperature	Pen Heat Index		Day	Recommended	Pen Temperature	Pen Heat Index
8	320	.	.		8	320	.	.
9	313	.	.		9	313	.	.
10	310	.	.		10	310	.	.
11	304	.	.		11	304	.	.
12	296	.	.		12	296	.	.
13	295	.	.		13	295	.	.
14	291	.	.		14	291	.	.
15	292	.	.		15	292	.	.
16	286	.	.		16	286	.	.
17	281	.	.		17	281	.	.
18	278	.	.		18	278	.	.
19	274	.	.		19	274	.	.
20	270	.	.		20	270	.	.
21	268	224	0		21	268	226	0
22	265	246	0		22	265	220	0
23	263	244	0		23	263	246	0
24	262	262	0		24	262	220	0
25	254	266	0		25	254	234	0
26	247	230	0		26	247	220	0
27	245	240	0		27	245	220	0
28	241	253	0		28	241	230	0
29	240	240	0		29	240	220	0
30	233	230	0		30	233	230	0
31	233	238	0		31	233	230	0
32	232	240	26		32	232	220	0
33	230	238	25		33	230	230	66
34	229	257	128		34	229	230	104
35	225	230	128		35	225	261	127
36	225	269	166		36	225	264	176
37	220	230	148		37	220	244	125
38	205	234	229		38	205	234	322
39	203	230	122		39	203	230	104
40	195	230	230		40	195	230	230
		Total Heat Index	1166				Total Heat Index	1228

Appendix 4 – Effects of Ventilation and Air speed on Litter Temperature

Effect of air speed on surface litter

Pen	air speed	week	ambient pen	Surface litter	Litter temp - ambient	avg difference
46	HA	3	25.5	23.1	-2.4	
38	HA	3	24.5	23.5	-1.0	-1.5
14	HA	3	26.8	25.4	-1.4	
6	HA	3	21	19.8	-1.3	
41	LA	3	27	24.8	-2.3	
33	LA	3	25.5	23.3	-2.3	-1.9
9	LA	3	25.5	23.8	-1.7	
1	LA	3	22	20.5	-1.5	
46	HA	4	28.	26.	-1.8	
38	HA	4	28	28.3	0.3	
14	HA	4	27	26.4	-0.6	-0.5
6	HA	4	24.	24.	-0.2	
41	LA	4	30	29.	-0.2	
33	LA	4	26.5	26.0	-0.5	
9	LA	4	26.4	26.8	0.3	-0.3
1	LA	4	24.7	23.	-0.9	
46	HA	5	22.3	25.2	2.9	
38	HA	5	21.7	24.8	3.1	
14	HA	5	21.6	24.7	3.1	3.1
6	HA	5	21.7	25.0	3.3	
41	LA	5	22.5	26.3	3.8	
33	LA	5	20.8	24.7	3.9	3.5
9	LA	5	21.8	25.3	3.6	
1	LA	5	20.5	23.4	2.9	

Effect of ventilation rate on surface litter temperature

Pen	vent	week	ambient pen temperature	Surface litter Temperature	Litter temp - ambient temp	avg difference
33	high	3	25.5	23.3	-2.3	
38	high	3	24.5	23.5	-1.0	-1.6
14	high	3	26.8	25.4	-1.4	
9	high	3	25.5	23.8	-1.7	
46	low	3	25.5	23.1	-2.4	
41	low	3	27	24.8	-2.3	-1.9
6	low	3	21	19.8	-1.3	
1	low	3	22	20.5	-1.5	
33	high	4	26.5	26.0	-0.5	
38	high	4	28	28.3	0.3	-0.1
14	high	4	27	26.4	-0.6	
9	high	4	26.4	26.8	0.3	
46	low	4	28.2	26.4	-1.8	
41	low	4	30	29.8	-0.2	-0.8
6	low	4	24.6	24.4	-0.2	
1	low	4	24.75	23.8	-0.9	
33	high	5	20.8	24.7	3.9	
38	high	5	21.7	24.8	3.1	3.4
14	high	5	21.6	24.7	3.1	
9	high	5	21.8	25.3	3.6	
46	low	5	22.3	25.2	2.9	
41	low	5	22.5	26.3	3.8	3.2
6	low	5	21.7	25.0	3.3	
1	low	5	20.5	23.4	2.9	