The Effect of Different Levels of Relative Humidity and Air Movement on Litter Conditions, Ammonia Levels, Growth, and Carcass Quality for Broiler Chickens

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(Received for publication June 13, 1990)

ABSTRACT An experiment using 4,800 commercial broiler males (Ross × Ross) was conducted in 12 climatic chambers. Three levels of relative humidity (RH) (45, 40 to 80, and 75%) and two levels of internal air circulation (7.7 to 9.9 and 17.8 to 24.5 cm/s), with each level replicated and, therefore, forming a 3 × 2 × 2 factorial arrangement of treatments, were imposed as the main effects. Broilers were group weighed and feed efficiencies calculated at 14, 28, and 42 days of age. Percentage dry matter of the litter and a subjective evaluation of general litter conditions (moisture and caking) were scored weekly, with the percentage nitrogen and total quantity of litter produced in each chamber measured at the conclusion of the study. Ammonia levels were measured in each chamber every second day. A sample of birds (36) from each chamber was processed at 42 days and scored for litter spots and ammonia burns on the breast and for the incidence and severity of twisted legs, crooked toes, and infected and calloused hocks and foot pads.

Mean body weight was significantly greater (32 g) at 42 days of age in birds exposed to 45% RH compared with the two higher regimens of RH. Both the incidence and severity of ammonia burns on the breast and infected foot pads were significantly higher with 75 versus 45% RH. Increases in RH significantly increased caking and litter moisture and reduced the percentage of dry matter and the percentage of nitrogen found in the litter. Ammonia levels were more variable but generally increased with increases in RH. The two levels of air movement within the chambers produced less influence on the environment than RH, although the scores for both litter moisture and caking were significantly lower with increased levels of internal air circulation. (*Key words*: broilers, relative humidity, air movement, breast and leg defects, litter conditions)

1991 Poultry Science 70:746–755

INTRODUCTION

The environment maintained in broiler houses has a major impact on the health and performance of broiler chickens. Caretakers are increasingly challenged in the operation of systems designed to remove both respired and excreted moisture produced by the birds under management schemes where the kilograms of meat produced per square meter continues to escalate.

Atmospheric ammonia, which is produced by microbial activity on the excreted uric acid in the presence of water and normal brooding and growing temperatures, is detrimental to broilers. A number of investigators cited in a review article by Carlile (1984) have reported reduced growth rates and feed efficiencies when ammonia concentrations ranged from 25 to 100 ppm. Based on these findings, Reece *et al.* (1980) suggested that ammonia levels should not exceed 25 ppm for broilers. Furthermore, as little as 10 ppm of ammonia have been shown to damage the tracheal mucous membranes in turkeys (Nagaraja *et al.*, 1983); 20 ppm ammonia increased the rate of infections from Newcastle disease vaccination in chickens (Anderson *et al.*, 1964; Moum *et al.*, 1969).

Several methods have been used to decrease the production of ammonia in poultry houses. Litter additives such as monobasic calcium phosphate (superphosphate) (Reece *et al.*, 1979), phosphoric acid (Reece *et al.*, 1979; Malone, 1987), propionic acid (Parkhurst *et al.*, 1974), and ferrous sulfate (Huff *et al.*, 1984; Malone, 1987) act by reducing litter pH, which in turn reduces enzymatic and microbial

[1]Research was conducted while on sabbatical leave at the Spelderholt Centre.

activities and increases the solubility (binding) of ammonia in water. However, such treatments only provided short-term reductions in the production of ammonia, because litter pH and ammonia levels reached control levels by 3 wk after application.

Possibly the most common method for controlling ammonia production in broiler houses is to control litter moisture with mechanical ventilation. Valentine (1964) observed that when four different ventilation rates were used, both the levels of ammonia and relative humidity (RH) were reduced as the rates of air exchange in the test chambers increased.

Carr and Nicholson (1980), using three ventilation rates, labeled low, medium, and high, reported significant increases in body weight and reductions in litter moisture and concentrations of ammonia with each increase in the rate of ventilation. Only the high rate of ventilation, which ranged from .047 to .422 m^3/s per 1,000 broilers from 0 to 7 wk of age, was adequate to maintain litter moisture below 30% and ammonia level below 35 ppm.

Poor litter conditions have also been associated with lowered carcass quality and increased leg and foot abnormalities. Both May and Noles (1965) and Wisman and Beane (1965) observed a significant increase in the incidence of breast blisters at market age between broilers grown on dry and wet litter. These researchers reported a level of breast blisters between 2 and 6% on dry litter and between 12 and 19% on litter that had been artificially wetted during the production cycle. Harms *et al.* (1977) reported a significant increase in foot pad dermatitis among broilers grown on wet versus dry litter; the incidence of the lesion ranged between 66 and 91% on wet and between 5 and 20% on dry litter.

The objectives of the present study were to determine the effects of two ventilation schemes and three levels of RH on litter conditions and ammonia levels in climatic chambers stocked with broiler chickens. The effects of the different environments on litter conditions and ammonia levels, bird growth and feed efficiency, leg and foot abnormalities, and carcass quality were measured.

[2]AM-600 detector head, Number GGA235, Wallac, Turku 10, Finland.

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MATERIALS AND METHODS

General Husbandry

Forty-eight hundred 1-day-old male broiler chickens (Ross × Ross) were evenly distributed among 12 climatic chambers (4.46 × 6.90 m) in a computer-controlled test facility. A wire partition was used in each chamber to confine the birds in an area of 4.46 × 5.13 m, which provided a stocking density of 17.5 broilers per square meter. Pine shavings, spread evenly to a depth of 10 cm were used for bedding. Four bell-shaped waterers (36 cm in diameter) and five tube feeders (43 cm in diameter) were used in each chamber. Brooding temperature started at 33 C and was lowered 1 C every 3 days until 21 C was reached at 36 days of age. Temperature was maintained at this level until the conclusion of the study at 42 days. Illumination was provided by incandescent lamps, which produced an intensity of 50 lx at bird level for the 1st wk, and then was reduced 10 lx weekly until 20 lx was reached, which was maintained until the end of the study.

Ventilation (air exchange) rates were based on 400 broilers started in each chamber and provided .85 m^3/h per bird for the first 21 days. The rates were then increased to 1.19, 1.65, and 1.80 m^3/h per bird at 22, 32, and 37 days of age, respectively. Ventilation rates were increased equally in all chambers over the course of the study. The chambers were operated under positive pressure with increases in ventilation rate accomplished by increasing fan speed. Rates were measured with a thermo hot wire anemometer.[2] The apparatus was placed over the air outlet, where air speed was measured in meters per second and converted to cubic meters per hour based on the known dimensions of the detector.

Practical diets containing ingredients locally available in The Netherlands were used in the study. A crumbled starter diet containing 22.6% protein and 3,133 kcal of ME/kg was fed from 0 to 21 days of age. Grower and finisher diets were offered in pellet form, contained 22.6% protein and 3,317 kcal of ME/kg, and were fed from 22 to 35 and 36 to 42 days, respectively. All diets were formulated to meet the minimum nutritional requirements for broiler chickens as set forth by the National Research Council (1984). Additionally all diets contained zinc bacitracin®[3] (50 mg/kg) and the starter and grower diets contained Narasin®[4] (coccidiostat) (710 mg/kg).

Treatments

The study was conducted as a 2 × 3 × 2 factorial arrangement of treatments with two levels of internal air movement and three levels of RH considered as the main effects. All treatments were replicated.

The positive pressure ventilation system associated with the climatic chambers produced a minimum rate of air movement in all units. When measured 10 cm above the floor, these rates were 7.7 and 9.9 cm/s at the low (.85 m^3/h per bird) and high (1.80 m^3/h per bird) air exchange rates, respectively. This level was considered as the low rate of air movement (low). Internal air movement rates were increased in six chambers by adding two axial circulation fans per chamber. The fans increased the circulation rate to 17.8 and 29.5 cm/s for the low (.85 m^3/h per bird) and high (1.80 m^3/h per bird) air exchange rates, respectively, and constituted the high rate of air movement (high). All internal air speeds were measured with a hot-wire anemometer[5] and represented the mean of 10 predetermined locations. The propeller on each circulation fan was 24.5 cm in diameter and was capable of moving air at the rate at 25 m^3/min. The fans were suspended .95 m below the ceiling, 1.55 m above the floor, 3.10 m apart, and were located directly above the wire partition in each chamber. The fan motor shaft was used as a reference point when making all measurements. Each fan was directed down in a manner that allowed the propeller to form an angle of 30° with the vertical axis. Fans were also equipped with an oscillating device that permitted them to traverse an angle of 75°, and fans were operated continuously from 7 days to the end of the study.

Relative humidity was maintained at either 45 or 75% or was increased from 40 to 80% in increments of 8% each week. The environmental equipment used to control the temperature and relative humidity in each chamber was capable of adding and removing both heat and moisture to (or from) the incoming air to maintain desired conditions.

Measurements

Birds were weighed on a chamber basis, and feed efficiencies were calculated, after adjusting for mortality, at 14, 28, and 42 days of age. Birds found dead each day were weighed and recorded.

Atmospheric ammonia levels were measured in each chamber every other day, starting at 5 days of age. One measurement was taken in the center of each chamber, 15 cm above the litter, using a Drager® pump[6] and Drager® ammonia detection tubes[7] (range 0 to 100 ppm).

Litter conditions were evaluated weekly starting at 2 wk by first numerically scoring the litter in each chamber and then by determining percentage dry matter. Six evaluators scored the level of litter caking on a scale of 1 to 5 and the general moisture level of the litter and cakes on a scale of 1 to 10. Scores of 1 indicated no caking while a score of 5 indicated total caking. A moisture score of 1 indicated extremely dry litter or cakes (<20% moisture), and a score of 10 indicated extremely wet litter (>70% moisture). Five scores for each variable (caking and moisture), one in the region of each of the four water fountains and one representing the rest of the chamber, were taken by each evaluator in each chamber. Weekly scores from the six evaluators, were then combined to produce one caking and one litter moisture score for each chamber.

Litter samples were taken weekly from the top 5 cm in 10 predetermined locations in each chamber, placed in an air-tight plastic bag, and mixed thoroughly prior to moisture extraction. Samples were then weighed, freeze-dried, and reweighed to determine percentage of dry matter. Percentage and total nitrogen in the litter was also measured at 42 days of age. A 450-g portion of the last litter sample was immediately fixed with 550 mL of a .1*N* solution of H_2SO_4 to prevent any loss of ammonium nitrogen. Standard Kjeldahl procedures were used to estimate percentage nitrogen. The total quantity of litter (bedding material plus manure) on an "as is" basis in each chamber was weighed at the conclusion of the study and was expressed as kilograms of litter per bird.

Carcass quality and foot and leg conditions were measured using a random sample of 36 birds from each chamber at the conclusion of the study. Two previously trained evaluators scored the breasts of processed carcasses for both litter spots and ammonia burns. Litter spots were

[4]Elanco Products Co., Indianapolis, IN 46285.
[5]Lambrecht Therm Anemometer 642, Wilh Lambrecht, Gottingen, Germany.
[6]Drager Model 21-31, Dragerwerk, Lubeck, Germany.
[7]Model 5a.

defined as "brownish to black-brown discolorations and possible damage to the skin in the breast area." and ammonia burns were defined as "local swelling and damage to the epidermis, with or without discoloration in the breast area" (Daniels *et al.*, 1989). Both incidence and severity of the conditions were determined; a score of 0 indicated a condition was not present and a score of 1 to 4 indicated both presence and the level of severity. Scores from the two evaluators were combined for each variable prior to analysis.

Leg and foot conditions were evaluated for both the incidence and severity of twisted legs, crooked toes, and infected and calloused hocks and foot pads. Carcasses were scored from 0 to 4 for all conditions. A score of 0 indicated no defects; 1, a slight to moderate defect on one foot or leg; 2, slight to moderate defects on both feet or legs; 3, a severe defect on one foot or leg and a slight to moderate defect on the other foot or leg; and 4, severe defects on both feet and legs. Incidence was scored from 1 to 4, indicating lesions and abnormalities, and a score of 0, indicating no lesions.

Statistical Analyses

Differences in treatment means were determined by subjecting data to analysis of variance. When significant differences ($P \leq .05$) were found, means were partitioned by using least significant differences. Percentage data were transformed to arc sine coefficients prior to analyses. The mathematical model used for body weights, feed efficiencies, percentage mortality, breast irritations, foot and leg conditions, total litter per chamber, and percentage nitrogen was

$$Y_{ijk} = \mu + H_i + A_j + r_k + (HA)_{ij} + e_{ijk}$$

where μ = overall mean; H_i = relative humidity effect, $i = 1, 2, 3$; A_j = air circulation effect, $j = 1, 2$; r_k = replications, $k = 1, 2$; $(HA)_{ij}$ = interaction of relative humidity and air circulation; e_{ijk} = error term. Because of the lack of independence associated with litter moistures and litter scores, these data were analyzed using a split-plot model of the analysis of variance. The mathematical model used was

$$Y_{ijkl} = \mu + H_i + A_j + r_k + (HA)_{ij} + e_{ijk} + W_l + (HAW)_{ijl} + e_{ijkl}$$

where W_l = weeks, $l = 1, 2, \ldots 6$; $(HAW)_{ijl}$ = interaction of relative humidity, air circulation and weeks; and e_{ijkl} = error term.

RESULTS

Body Weight, Feed Efficiency, and Mortality Rate

Body weight was significantly higher at 42 days of age for broilers grown under 45% RH compared with those provided the two higher levels of RH (Table 1). Under the lower RH regimen, broilers were an average of 32 g heavier at the conclusion of the study than birds grown under higher RH. Body weights were not different among the RH treatments at 14 or 28 days or between the two air movement schemes at any age. Air movement and RH had no effect on feed efficiency or mortality rate except at 14 days of age when mortality rate was significantly higher in the high air movement group. The difference noted in mortality rate at 2 wk was actually attributed to differences during the 1st wk, which was prior to the start of the increased level of air movement.

Percentage Dry Matter of Litter

Relative humidity had a significant effect on the percentage dry matter of the litter starting at 7 days of age and continuing to the end of the study (Table 2). Relative humidity of 75% caused a reduction in the level of dry matter throughout the trial with the regimen of 40 to 80% being immediate and significantly different from the other two regimens at 42 days. The two levels of internal air movement had no effect on the percentage dry matter of the litter during any of the time periods measured.

Litter Conditions

Mean scores for both litter moisture and litter caking were significantly different for each of the three levels of RH with 75% having the highest, 40 to 80% being intermediate, and 45% having the lowest values (Table 3). Furthermore, a significant interaction occurred between weeks and both measures of litter conditions. Litter scores were higher for the 75% RH regimen than for the other two treatments during the earlier portion of the production cycle. However, as RH was increased in the 40 to 80% regimen, litter scores in these chambers increased more rapidly than under low RH and scores for moisture and

TABLE 1. *Effects of relative humidity and air movement on body weight, feed efficiency, and mortality for broilers at 14, 28, and 42 days of age*

Treatment	Age, days		
	14	28	42
	Body weight (g)		
Relative humidity			
45%	428[a]	1,295[a]	2,277[a]
40 to 80%	423[a]	1,289[a]	2,237[b]
75%	423[a]	1,293[a]	2,253[b]
Air movement			
7.7 to 9.9 cm/s (low)	423[a]	1,292[a]	2,251[a]
17.8 to 24.5 cm/s (high)	426[a]	1,293[a]	2,260[a]
	Feed efficiency, weight:feed (g:g)		
Relative humidity			
45%	.88[a]	.70[a]	.59[a]
40 to 80%	.88[a]	.70[a]	.58[a]
75%	.88[a]	.70[a]	.59[a]
Air movement			
7.7 to 9.9 cm/s (low)	.88[a]	.70[a]	.59[a]
17.8 to 24.5 cm/s (high)	.88[a]	.70[a]	.59[a]
	Mortality (%)		
Relative humidity			
45%	3.5[a]	5.2[a]	6.8[a]
40 to 80%	3.1[a]	4.7[a]	6.3[a]
75%	2.3[a]	4.1[a]	5.5[a]
Air movement			
7.7 to 9.9 cm/s (low)	2.5[b]	4.3[a]	5.7[a]
17.8 to 24.5 cm/s (high)	3.4[a]	5.0[a]	6.7[a]

[a,b]Means within treatment and column with different superscripts are significantly different ($P \leq .05$).

caking became aligned with those in the 75% chambers by 28 and 35 days, respectively.

An increase in the rate of internal air movement significantly reduced the cumulative scores for litter moisture and litter caking (Table 3). Even though scores were lower in all cases for the high air movement regimen, there were no significant differences noted in weekly scores for either litter moisture or caking between the two air movement schemes.

Ammonia Levels

The concentrations of ammonia for the three levels of RH and the two levels of air movement are presented in Figures 1 and 2. Generally, through 30 days of age, the rates of increase in the levels of ammonia corresponded with increases in RH; the concentration of ammonia was the highest under the 75% RH and lowest under the 45% RH regimens. However, at 28

TABLE 2. *Effects of relative humidity and air movement on the percentage dry matter of the litter*

Treatment	Age, days						
	7	14	21	28	35	42	$\bar{x}$
	(%)						
Relative humidity							
45%	87[a]	82[a]	72[a]	61[a]	62[a]	59[a]	71[a]
40 to 80%	88[a]	83[a]	70[a]	58[ab]	60[a]	55[b]	69[b]
75%	82[b]	75[b]	63[b]	55[b]	55[b]	51[c]	64[c]
Air movement							
7.7 to 9.9 cm/s (low)	86[a]	81[a]	68[a]	57[a]	61[a]	54[a]	68[a]
17.8 to 24.5 cm/s (high)	85[a]	80[a]	69[a]	59[a]	58[a]	56[a]	68[a]

[a–c]Means within treatment and column with no common superscripts are different ($P \leq .05$).

TABLE 3. *Effects of relative humidity and air movement on litter conditions*

Age (days)	Relative humidity, %			Air movement, cm/s	
	45	40 to 80	75	Low	High
			Litter moisture[1]		
14	1.15[b]	1.12[b]	2.01[a]	1.58[a]	1.27[a]
21	2.22[b]	2.33[b]	3.39[a]	2.90[a]	2.40[a]
28	4.27[b]	5.49[a]	6.17[a]	5.67[a]	4.95[a]
35	4.34[b]	5.88[a]	6.26[a]	5.85[a]	5.13[a]
42	5.52[b]	7.55[a]	7.67[a]	7.15[a]	6.68[a]
$\bar{x}$	3.50[c]	4.47[b]	5.10[a]	4.63[a]	4.09[b]
			Caking[2]		
14	1.01[b]	1.01[b]	1.40[a]	1.18[a]	1.08[a]
21	1.56[b]	1.55[b]	1.95[a]	1.76[a]	1.61[a]
28	2.24[c]	2.75[b]	3.12[a]	2.85[a]	2.55[a]
35	1.92[b]	2.35[a]	2.30[a]	2.29[a]	2.09[a]
42	1.97[b]	2.35[a]	2.37[a]	2.23[a]	2.20[a]
$\bar{x}$	1.74[c]	2.00[b]	2.23[a]	2.06[a]	1.91[b]

[a–c]Means within treatment and week with no common superscripts are significantly different ($P \leq .05$).

[1]Individual scores ranging from 1 to 10 with 1 representing dry and 10 representing extremely wet litter.

[2]Individual scores ranging from 1 to 5 with 1 representing no caking and 5 representing severe caking of the litter.

days of age the amount of litter caking (Table 3) increased substantially, especially in the units with the two higher levels of RH, which suppressed the release of ammonia in those chambers. The level of ammonia was relatively low in all units throughout the study, with no value being above 20 ppm.

The two levels of air movement had little effect on the release of ammonia through 33 days of age (Figure 2). However, from 35 days to the conclusion of the study levels of ammonia were actually lower in chambers with lower interval air movement. Again this may be explained by the increased levels of caking (nonsignificant) for chambers with the lower level of air movement from 28 days of age (Table 3).

Production of Manure and Nitrogen

Both the percentage and the total quantity of nitrogen produced per bird were significantly higher under the 45% RH regimen than under the 75% regimen; the level under the 40 to 80% treatment was intermediate and not significant (Table 4). The quantity of nitrogen was 9% higher with the lower RH and accounted for an increase of 5 mg of this element per bird. The different levels of air movement had no measurable effect on either the percentage or total

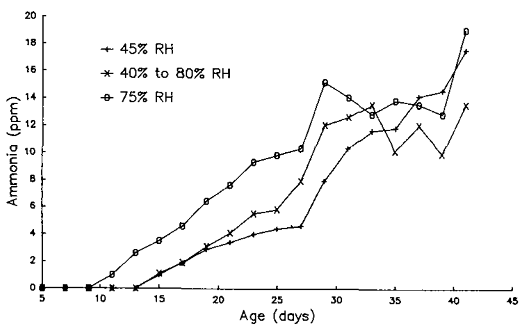

FIGURE 1. The effect of relative humidity (RH) on the level of ammonia.

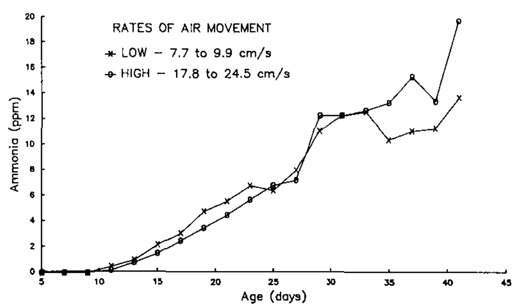

FIGURE 2. The effect of air movement on the level of ammonia.

TABLE 4. *Effects of relative humidity and air movement on nitrogen and total litter produced at 42 days of age*

Treatments	Nitrogen[1] Percentage	Per bird (mg)[1]	Total litter[1] per bird (kg)
Relative humidity			
45%	2.46^{a}	27.2^{a}	1.67^{a}
40 to 80%	2.29^{ab}	24.2^{ab}	1.71^{a}
75%	2.24^{b}	22.2^{b}	1.72^{a}
Air movement			
7.7 to 9.9 cm/s (low)	2.30^{a}	23.8^{a}	1.73^{a}
17.8 to 24.5 cm/s (high)	2.35^{a}	25.3^{a}	1.68^{b}

^{a,b}Means within treatments and columns with no common superscripts are significantly different ($P\leq.05$).

[1]Calculations based on 400 broilers per chamber.

quantity of nitrogen produced; however, the total quantity of litter produced was significantly reduced under the higher level of air movement when compared with the lower level of air movement. This difference is probably associated with the reduction in litter moisture observed in the former pens (Table 3).

Ammonia Burns and Litter Spots

Both the incidence and severity of ammonia burns were significantly lower under 45% RH when compared with 75% RH (Table 5). The percentage of carcasses having ammonia burns was increased approximately threefold (5.6 versus 16.3%) for broilers reared under the low RH when compared with the high RH regimens. Litter spots were not affected by RH.

The incidence of litter spots was significantly higher under the high versus the low air movement scheme (Table 5). No other differences were noted between treatments for air movement and the measures of carcass quality.

Foot and Leg Lesions

The incidence and severity of swollen, calloused foot pads was significantly higher for the 75% RH than for the 45% RH regimens (Table 6). Approximately 54% of the broilers grown under high RH experienced at least some foot pad abnormalities, whereas under low humidity, less than 14% demonstrated lesions. The severity of the foot pad lesions was also significantly increased for the lower versus the higher air movement regimen. Other than a significant increase (47%) in the severity of crooked toes under low versus high air movement schemes, neither RH nor air movement had any effect on the incidence or severity of infected hocks, twisted legs, or crooked toes.

TABLE 5. *Effects of relative humidity and air movement on ammonia burns and litter spots for broilers at 42 days of age*

Treatments	Ammonia burns Incidence (%)	Ammonia burns Severity[1]	Litter spots Incidence (%)	Litter spots Severity[1]
Relative humidity				
45%	5.6^{b}	.06^{b}	13.7^{a}	.15^{a}
40 to 80%	11.5^{ab}	.15^{ab}	13.2^{a}	.16^{a}
75%	16.3^{a}	.27^{a}	13.5^{a}	.15^{a}
Air movement				
7.7 to 9.9 cm/s (low)	12.5^{a}	.17^{a}	10.3^{b}	.12^{a}
17.8 to 24.5 cm/s (high)	9.7^{a}	.15^{a}	16.7^{a}	.19^{a}

^{a,b}Means within treatment and column with no common superscripts are significantly different ($P\leq.05$).

[1]Based on a score from 0 to 4, with 0 representing no irritation and 4 representing severe irritations.

TABLE 6. *The effects of relative humidity and air movement on infected foot pads and hocks, and twisted legs and crooked toes for broilers at 42 days*

	Foot pads		Hocks	
Treatments	Incidence (%)	Severity[1]	Incidence (%)	Severity[1]
Relative humidity				
45%	13.9[b]	.28[b]	89.5[a]	1.80[a]
40 to 80%	44.4[ab]	.92[a]	93.1[a]	2.16[a]
75%	53.5[a]	1.11[a]	100.0[a]	2.42[a]
Air movement				
7.7 to 9.9 cm/s (low)	42.2[a]	.94[a]	96.7[a]	2.22[a]
17.8 to 24.5 cm/s (high)	32.4[a]	.60[b]	91.7[a]	2.03[a]
	Twisted legs		Crooked toes	
	Incidence (%)	Severity[1]	Incidence (%)	Severity[1]
Relative humidity				
45%	9.1[a]	.11[a]	25.2[a]	.43[a]
40 to 80%	8.3[a]	.10[a]	27.1[a]	.41[a]
75%	6.3[a]	.08[a]	33.3[a]	.56[a]
Air movement				
7.7 to 9.9 cm/s (low)	7.9[a]	.09[a]	37.1[a]	.56[a]
17.8 to 24.5 cm/s (high)	7.9[a]	.10[a]	25.0[a]	.38[b]

[a,b]Means within treatment and column with no common superscripts are significantly different ($P \leq .05$).

[1]Based on a score from 0 to 4, with 0 representing normal and 4 representing severe abnormalities.

DISCUSSION

Several investigators have reported that broilers can tolerate a wide range of RH and still perform efficiently (Prince *et al.*, 1965; Winn and Godfrey, 1967; Peterson *et al.*, 1971; Harris *et al.*, 1974). However, in the present study broilers were significantly heavier under a regimen that provided a low (45%) RH (Table 1). It is suggested that the differences in body weight between the levels of RH in the current study were not directly related to moisture differences in the atmosphere but to differences in litter conditions and ammonia levels, which were influenced by the differences in RH. Elevations in the level of atmospheric ammonia and poorer litter conditions, which were indicated by reduced percentages of dry matter and increased litter scores, are generally indicative of reduced growth, and help explain lower body weight under the higher RH. Increases in both percentage and quantity of nitrogen produced under the lower level of RH (Table 4) further support the findings of lower levels of ammonia in the dryer chambers. Furthermore, the ability to lower the level of ammonia emissions will become increasingly more important in the future in areas where limits are placed on the quantity of this gas that can be released into the atmosphere.

Possibly litter moisture and caking scores (Table 3) provide an even more graphic description of how rapidly changes in RH can influence litter conditions. For example, the 40 to 80% RH regimen was designed to provide moisture conditions during the first portion of the growing cycle that were similar to those in the 45% regimen, and during the final portion of the cycle similar to those in the 75% regimen. Interestingly, scores for both measures of litter conditions (litter moisture and caking) under the increasing RH regimen were closely aligned with the low RH schedule earlier in the production cycle and with the high schedule later in the cycle. The elevated litter scores under high RH, which were reflective of poorer litter conditions, were also associated with increased ammonia burns on the breasts and swollen foot pads. These findings indicate that changes in RH can rapidly influence litter conditions, carcass quality, and body weight; and they suggest that means of direct measurement and control of RH should be included in the design of systems for ventilating poultry houses in cool weather.

Researchers have reported that chicks can rapidly loose weight through dehydration when they are held in the incubator at 37 C for several hours after hatching (Hager and Beane, 1983; Wyatt *et al.*, 1985). In one experiment, compensation for the early loss in weight did not occur by market time. These findings have led investigators to speculate that low RH during the early stages of brooding may have a negative impact on growth. Findings in the present study do not support this hypothesis, as body weight, feed efficiency, and mortality were similar between the low and high RH regimens at 14 days (Table 1).

The ability to reduce the influence of RH on the general environment by increasing the rate of internal circulation in the chambers was partially successful. Even though increases in air movement lowered litter moisture and caking scores, reduced the total quantity of litter produced per bird (which was associated with a reduction in litter moisture), and caused a reduction in the severity of foot pad lesions, the actual effects of internal air circulation were less critical in the present study than those associated with changes in RH. Apparent inconsistencies are illustrated in Tables 2 and 3, respectively, as no difference was found in the actual level of moisture in core litter samples, but differences were noted in the more subjective litter moisture and caking scores for the two internal air circulation regimens.

The initial concern when increasing the velocity of air movement over birds is its effect on thermoregulation, and consequently, its possible influence on performance. However, no reductions in growth or feed efficiency, or increases in mortality, were noted between the air movement schemes. This suggests that internal rates of air circulation higher than the 2.4 fold increase used in the present study (maximum of 24.5 cm/s) should be considered. In future studies, investigators should consider varying the rate of air exchange (ventilation rate) in combination with different rates of internal air circulation to measure possible relationships between these two methods for moisture removal.

ACKNOWLEDGMENTS

The authors would like to express their sincere appreciation to E. J. de Weerd for caring for the birds, P.F.G. Vereijken for providing assistance with statistical analysis, R. Steunenberg for providing technical assistance in operating the climatic chambers, and C.L.M. Gerritsen for taking and analyzing the litter samples.

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