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Abstract

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Keywords

Aerial ammonia, Broiler, Energy, House clean-out, Minimum ventilation

Disciplines

Agriculture | Bioresource and Agricultural Engineering

Comments

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MINIMUM VENTILATION REQUIREMENT AND ASSOCIATED ENERGY COST FOR AERIAL AMMONIA CONTROL IN BROILER HOUSES

H. Xin, I. L. Berry, G. T. Tabler

ABSTRACT. *Minimum ventilation rate (MVR) and bird performance of four commercial-scale broiler houses were monitored for 16 consecutive growouts. A complete house clean-out was conducted after the 7th growout and again after the 13th growout. Between the clean-outs, only caked litter was removed, and new bedding was added to the old litter.*

*The MVR needed to control indoor aerial ammonia to within 25 to 30 ppm (MVR_a), for growouts raised on old litter, largely exceeded the normal MVR (MVR_n) needed for moisture control during the first week of brooding. In particular, MVR_a averaged nine times MVR_n on day one, and declined exponentially with bird age. Elevated MVR_a during a two-week brooding period requires additional propane fuel use of 136 L (36 gal) and 57 L (15 gal) per 1,000 birds, at an outside temperature of -17.8°C (0°F) and 10°C (50°F), respectively. This extra fuel or heat requirement should be considered in designing supplemental heating capacity for broiler houses using old litter. Moreover, the results obtained from this study suggest that broilers raised on old litter are more likely to have higher carcass condemnation rate than those raised on new litter. Heating broiler houses at 35°C (95°F) for two days before chick placement seems helpful in extracting ammonia from old litter, but may not be cost-effective. Thus, whenever possible, house cleaning after each growout is desirable to improve energy use efficiency and indoor air quality. In particular, partial cleaning of the brooding end only would be cost-effective and is recommended. **Keywords.** Aerial ammonia, Broiler, Energy, House clean-out, Minimum ventilation.*

Aerial ammonia (NH_3) in poultry housing adversely affects bird performance such as growth rate, feed efficiency, carcass quality, and susceptibility to disease challenge (Charlie, 1984). To minimize these adverse effects on bird performance and worker's health, broiler producers have been advised to keep their house ammonia level under 25 ppm. It has been a typical practice of the broiler industry to raise birds on old litter for one year or longer before conducting a complete house clean-out. Between house clean-outs, only caked litter is removed at the end of the growout, and fresh bedding is generally added to the old litter (a practice commonly referred to as top dressing).

To reduce ammonia release from broiler litter, numerous chemical additives that reduce litter pH level have been studied, as cited by Weaver and Meijerhof (1991). Several commercial litter and feed additives are currently on the market. However, such treatments tend to provide only

short-term ammonia reduction. Moreover, material and labor costs often prohibit application of these additives.

The easiest and the most popular method which poultry producers use to control aerial ammonia is control of the ventilation rate. This can be done by simply adjusting the minimum ventilation timer or the variable speed fan. Increasing the ventilation rate generally dilutes the aerial ammonia concentration and keeps the litter dry, thus reducing ammonia release. However, increased minimum ventilation also escalates building heat loss, which will result in more fuel use and requirement of larger heating capacity. Through a computer simulation, Elliott and Collins (1982) stated that maintaining a safe ammonia level of < 25 ppm during the first week for flocks grown on old litter requires ventilation rates 10 times the normal rates. However, there is limited field data to demonstrate the relationships among ammonia-control minimum ventilation rate (MVR), bird performance, and litter conditions in modern broiler houses.

The objective of this study was to determine MVR for ammonia control, resultant energy expenditures, and bird performance as influenced by litter conditions in modern commercial-scale broiler houses.

MATERIALS AND METHODS

BROILER HOUSES

The four broiler houses used in this study were representative of current broiler housing systems. These research houses were owned by the University of Arkansas and located 20 km (13 mile) west of Fayetteville, Arkansas. The broiler houses, each measuring 12×121 m (40×400 ft), used earthen floors, curtain-sided windows 75 cm (2.5 ft) in height, nipple drinkers, and pan feeders. Two of

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the four houses used conventional cross-ventilation. The other two houses used tunnel ventilation. One house of each ventilation style used steel trusses with rigid-board insulation of 1.76 m²·° C/W (R-10) along the roof line. The other house used wooden trusses with loose-fill insulation of 3.35 m²·° C/W (R-19) over a dropped-ceiling vapor barrier. Supplemental heating was provided by pancake brooders and space heaters with a total capacity of 404 kW (1.38 million BTU/h) per house. Summer cooling was provided by fans and foggers in the conventional houses, and fans and evaporative cooling pads in the tunnel houses. Minimum ventilation was achieved by 0.9-m (36-in.) diameter fans in the conventional houses and 1.2 m (48-in.) diameter fans in the tunnel houses. Five-minute timers were used to control the minimum ventilation fans. More detailed descriptions of the broiler housing systems are given by Berry et al. (1991) and Xin et al. (1993).

BROILER AND LITTER MANAGEMENT

The same production management practices were used in all four houses. Cobb × Cobb male broilers were placed at a stocking density of 18,800/house, and raised to eight weeks of age (2.6 kg or 5.8 lb in body weight). The birds were fed standard production rations as supplied by the integrator. The birds were brooded in half of the house during the first two weeks to conserve energy, which is typical for the broiler industry. House temperature setpoints during the half-housing brooding period are listed in table 1. Relative humidity was in the range of 30 to 50% during the same period.

Commercial poultry bedding that consisted of rice hulls, sawdust, and wood shavings was used. For the new house conditions and after each clean-out, a layer of fresh bedding approximately 10 cm (4 in.) thick was spread on the earthen floor. Between clean-outs, caked litter was removed, and a layer of fresh bedding about 2.5 cm (1 in.) thick was added to the top of the old litter (i.e., top dressing). During the three-year study period, the houses were cleaned out twice, once after the 7th growout and again after the 13th growout. Litter samples were collected and analyzed for each clean-out.

Prior to the arrival of the chicks, the aerial ammonia level inside each house was checked with colorimetric ammonia detector tubes (Sensidyne, 16333 Bay Vista Drive, Clearwater, FL 34620). Minimum ventilation rate was adjusted until aerial ammonia at the bird level was in the range of 25 to 30 ppm. The same procedure was used to adjust the daily timer setting and thus the minimum ventilation rate. In addition, for some growouts raised on old litter, the houses were preheated at 35°C (95°F) for two days in an attempt to drive off ammonia from the litter.

DETERMINATION OF MVR AND EXTRA ENERGY USE FOR AMMONIA CONTROL DURING BROODING

The MVR was estimated based on the airflow rates and operating time of the exhaust fans at the static pressure of 12 Pa (0.05 in H₂O). The airflow rates of 4.72 m³/s

(10,000 CFM) for 0.9-m (36-in.) diameter fans and 8.97 m³/s (19,000 CFM) for 1.2-m (48-in.) diameter fans were verified by using airflow traverses. The MVR for growouts with new litter bedding (average values of growouts 8 and 14) was used as the baseline to compare the MVR for growouts with old litter during the cool and cold weather seasons (average values of growouts 6, 7, 11, 12, and 13). The first growout (new houses) was excluded from this analysis because the houses were overventilated, and no ammonia problem was observed. The warm/hot weather growouts were also excluded because of uncertainty in determination of the natural ventilation rate with open curtains. The extra daily heat loss from the building and the propane fuel use resulting from the elevated ammonia-control MVR were calculated as the following:

$$\Delta\text{DBHL} = C_p \cdot \rho \cdot (\text{MVR}_a - \text{MVR}_n) (t_i - t_o) \cdot 24 \quad (1)$$

$$\Delta\text{PFU} = \Delta\text{DBHL} / (V \cdot E) \quad (2)$$

where

- ΔDBHL = extra daily building heat loss [kJ·d⁻¹ (BTU·d⁻¹)]
- C_p = specific heat of air [1.00 kJ·kg⁻¹·° K⁻¹ (0.24 Btu·lb⁻¹·° F⁻¹)]
- ρ = air density [1.20 kg·m⁻³ (0.074 lb·ft⁻³)]
- MVR_a = minimum ventilation rate for ammonia control of old litter [m³·h⁻¹ (ft³·h⁻¹)]
- MVR_n = minimum ventilation rate for moisture control of new litter [m³·h⁻¹ (ft³·h⁻¹)]
- t_i, t_o = daily average inside and outside air temperature [°C (°F)]
- 24 = h/d
- ΔPFU = extra daily propane fuel use of the house [L·d⁻¹ (gal·d⁻¹)]
- V = propane fuel heat content [25.52 MJ·L⁻¹ (91,550 Btu·gal⁻¹)]
- E = efficiency of the heating system (0.80)

RESULTS AND DISCUSSION

Bird performance and litter management practice between growouts for the 16 growouts are listed in table 2. Because bird performance was similar in all houses for each growout (Xin et al., 1994), farm averages are reported here. As indicated in table 2, growouts raised on old litter tended to coincide with higher condemnation than those grown on new bedding. In particular, condemnation for growouts that used new bedding (nos. 1, 8, and 14) averaged 0.69%, as compared with 1.04% for the remaining growouts that used old litter. The higher condemnation rate of broilers exposed to elevated ammonia levels had been reported by Quarles and King (1974). Because the bird performance could also have been affected by other uncontrollable factors such as chick quality, health, and the production season, statistical significance was not tested in this study.

In an effort to extract ammonia from the old litter before brooding started, the houses were preheated. Keeping house temperature at 35°C (95°F) two days before chick placement and then lowering it to the brooding level of 31°C (87°F) seemed somewhat effective. However,

Table 1. House temperature setpoints during the half-house brooding period

Bird age	Day:	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temperature °C		31	31	31	30	29	29	28	28	27	27	27	27	27	26
setpoint*	°F	87	87	87	86	85	84	83	82	81	80	80	80	80	79

* Setpoints in degree °C are rounded-off values of those in °F.

Table 2. Production performance of eight-week old broilers and litter treatment between growouts

Flock	Start Date (mm-dd-yy)	Age Day	BW* (kg)	FC† (%)	Live‡ (%)	Cond.§ (%)	Litter Treatment Between Growouts
1	11-19-90	56	2.65	2.04	94.60	0.72	New bedding
2	02-01-91	56	2.57	2.06	92.98	0.55	Cake removal and dressing
3	04-15-91	56	2.50	2.10	92.85	0.76	Cake removal and dressing
4	06-20-91	60	2.43	2.42	91.10	1.52	Cake removal and dressing
5	08-29-91	56	2.64	2.05	95.94	0.94	Two-day heating at 35°C
6#	11-12-91	57	2.71	2.10	95.74	1.49	Cake removal and dressing
7#	01-23-92	54	2.57	2.04	91.56	0.81	14-day warming at 10°C, one-day heating at 21°C and one-day heating at 30°C (used 1,058 gal propane for the farm)
8**	04-02-92	50	2.35	1.94	90.53	0.60	New bedding
9	06-08-92	53	2.44	2.02	92.19	0.76	Cake removal and dressing
10	08-07-92	56	2.75	2.11	92.32	2.06	Cake removal and dressing
11#	10-15-92	57	2.84	2.15	95.09	0.91	Two-day heating at 35°C
12#	12-21-92	58	—	2.05	94.63	0.84	Tilted litter in two houses and applied litter treatment in other two houses
13#	03-02-93	56	2.81	2.21	94.09	1.28	Two-day heating at 35°C
14**	05-11-93	56	2.71	2.07	93.59	0.74	New bedding
15	07-07-93	56	2.58	2.13	93.60	0.98	Cake removal and dressing
16	09-17-93	—	—	2.10	95.87	0.98	Two-day heating at 35°C

* Body weight of the bird.

† Feed conversion of the bird, i.e., feed consumption per unit marketed live body weight.

‡ Liveability at harvesting time, percent of total chicks placed.

§ Carcass condemnation rate at processing plant, percentage of total marketed weight.

|| House heating or warming was conducted to extract ammonia from the litter before brooding started. The house ventilation rate during this period was generally set at 0.3 m³/s (650 cfm). Caked litter was removed after each growout and fresh bedding added to the top of old litter (i.e., top dressing). The fresh commercial poultry bedding consisted of rice hulls, wood shavings, and sawdust.

Used to determine ammonia-control MVR.

** Used to establish baseline MVR for comparison of ammonia-control MVR.

keeping the houses at some moderate temperatures before brooding and then increasing it to the brooding level, as was the case with flock 7, had little or no effect on ammonia reduction. Depending upon weather conditions, propane fuel use in preheating the houses varied from 57 L (15 gal) per house in summer to 1 135 L (300 gal) per house in winter.

Figure 1 presents the MVR values associated with new and old litter during the two-week brooding period. Minimum ventilation rate for growouts with new litter was the same during the first week as that recommended by Midwest Plan Service (1990), and slightly higher during the second week. By comparison, MVR for growouts with old litter averaged nine times the MVR for new litter on day one, and declined exponentially with age. This result was also obtained by Elliott and Collins (1982), who noted that 6 to 10 times the normal ventilation rate was required

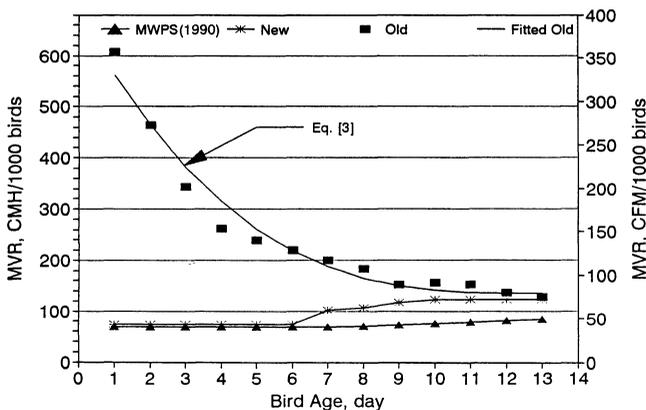


Figure 1—MVR for moisture and ammonia removal of broiler houses as influenced by litter condition (CMH/1000 and CFM/1000 stand for m³/h and ft³/min of air movement per 1,000 birds, respectively).

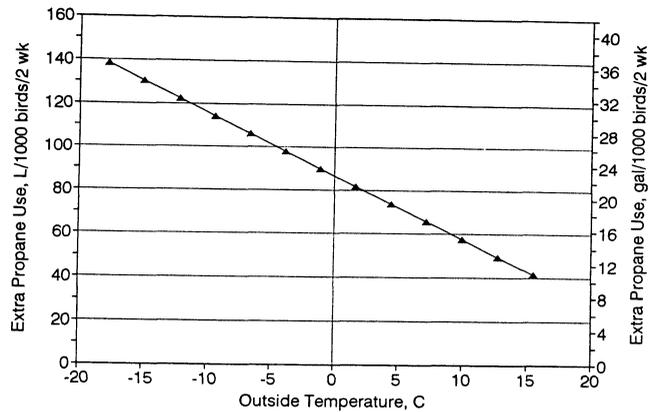


Figure 2—Extra propane fuel use during the two-week brooding period caused by elevated ammonia-control minimum ventilation rate as a function of outside air temperature (assuming 80% efficiency of the heating system).

to maintain a safe ammonia level of < 25 ppm during the first week for flocks grown on old litter. However, litter moisture content (16 to 24% on “as-is” weight basis) and pH value (7.2 to 7.7) found in the present study were lower than those used by Elliott and Collins (18 to 33% and 8.5 pH) in their simulation. The reduced litter moisture content in the present study was presumably due to increased ventilation, and the correlation between litter moisture content and ventilation was demonstrated by Carr and Nicholson (1980). The ammonia-control MVR (MVR_a) during the two-week brooding period was related to bird age by the following regression equation:

$$\text{MVR}_a [\text{m}^3/\text{h}/1,000 \text{ birds}] = 134 + 0.2474 \times (13 - \text{age})^3$$

$$(R^2 = 0.97) \quad (3a)$$

or

$$\text{MVR}_a [\text{ft}^3/\text{min}/1,000 \text{ birds}] = 79 + 0.1456 \times (13 - \text{age})^3$$

$$(R^2 = 0.97) \quad (3b)$$

Extra fuel use for ammonia control during the two-week brooding period at various outside temperatures (T₀) is presented in figure 2. This extra supplemental heat demand must be taken into account when designing heating capacity. Otherwise, birds raised on old litter could experience one of two undesirable environments: adequate house temperature but excessive ammonia because of insufficient ventilation, or acceptable ammonia level but cold temperature because of insufficient heating capacity. In fact, the latter condition had been encountered more than once during the study period.

Table 3 lists the extra fuel costs during the two-week brooding period for a 20,000 broiler house (40 × 400 ft) that uses old litter bedding. This information can be used to determine the economic benefits of house clean-out for a specific climatic condition and cost of new bedding. For example, a spreader load of poultry bedding currently costs approximately \$110, and four loads are generally needed to cover the floor of a 12- × 121-m (40- × 400-ft) house. According to table 3, the cost of new bedding can be offset by savings of fuel that would be consumed by old litter if

Table 3. Extra propane fuel costs for ammonia control during the two-week brooding period in a 20,000-broiler house (12 × 121 m or 40 × 400 ft) that has old litter bedding (assuming 80% heating efficiency)

T _o , °C*	-17.8	-15.0	-12.2	-9.4	-6.7	-3.9	-1.1	1.7	4.4	7.2	10.0
T _o , °F	0	5	10	15	20	25	30	35	40	45	50
EPF†	731	688	646	603	561	518	475	433	390	348	305
\$0.50‡	<u>\$365</u>	<u>\$344</u>	<u>\$323</u>	<u>\$302</u>	<u>\$280</u>	<u>\$259</u>	<u>\$238</u>	\$216	\$195	\$174	\$153
\$0.60‡	<u>\$438</u>	<u>\$413</u>	<u>\$387</u>	<u>\$362</u>	<u>\$336</u>	<u>\$311</u>	<u>\$285</u>	<u>\$260</u>	<u>\$234</u>	<u>\$209</u>	<u>\$183</u>
\$0.07‡	<u>\$511</u>	<u>\$482</u>	<u>\$452</u>	<u>\$422</u>	<u>\$392</u>	<u>\$363</u>	<u>\$333</u>	<u>\$303</u>	<u>\$273</u>	<u>\$243</u>	<u>\$214</u>

* T_o = outside temperature, °C or °F.

† EPF = extra propane fuel use during the two-week brooding period, gal (1 gal = 3.785 L).

‡ \$0.50, \$0.60, and \$0.70 are propane prices per gallon. The underlined dollar values correspond to the outside temperatures at which net savings can be realized if half-house cleaning of the brooding end only is used, assuming two spreader loads of new bedding at \$110 each load (i.e., \$220 worth of new bedding) are applied.

the outside temperature is -18°C (0°F) and propane costs \$0.60/gal. Moreover, birds raised on new bedding is likely to perform better (e.g., lower carcass condemnation). Although it is not a common practice, half-house cleaning of the brooding end only would be a more cost-effective option to reduce ammonia and conserve energy during the brooding period while reducing the cost of new bedding by 50%. Such a practice would result in significant energy savings for a wider range of outside temperatures (table 3).

CONCLUSIONS

- The MVR needed to control ammonia within 25 to 30 ppm for broiler growouts on old litter largely exceeds the normal MVR needed for moisture control for the first week. The MVR for ammonia control averaged nine times the normal MVR, and decreased exponentially with time during the first two weeks.
- The elevated ammonia-control MVR requires an extra propane use of 136 L (36 gal) and 57 L (15 gal) per 1,000 birds at an outside temperature of -17.8°C (0°F) and -10°C (50°F), respectively.
- Design of heating capacity for broiler houses using old litter should take into account the elevated supplemental heat requirement for ammonia control.
- Preheating broiler houses at 35°C (95°F) and then reducing to brooding temperature (30°C or 86°F) seems helpful in extracting ammonia from old litter, but may not be cost effective.

- If conditions permit, house cleaning after each growout is desirable to improve energy efficiency and bird performance. Specifically, partial house cleaning of the brooding end only would be most cost-effective.

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