Air quality in pullet barns

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Glennon, C. R., McQuitty, J. B., Clark, P. C. and Feddes, J. J. R. 1989. **Air quality in pullet barns.** Can. Agric. Eng. **31**: 233–237. Air quality and contaminant production rates were determined in two commercial poultry rearing barns by monitoring the ventilation rates and concentrations of carbon dioxide, ammonia, hydrogen sulphide and dust for 24-h periods during each month of the 18- to 20-wk winter rearing cycle. One barn was representative of the cage-rearing system and the other of on-floor rearing. Air quality in the cage unit remained fairly constant and was superior to that in the on-floor operation, where air quality decreased over time. Carbon dioxide concentrations in the two barns ranged from 1670 to 2890 ppm. In the on-floor unit, ammonia concentration and production rate increased over the rearing cycle, with the concentration rising from a daily average of 0–25 ppm and production from 0 to 19 mL/(h.bird). Ammonia concentration and production data from the cage-rearing system showed no significant trends, the overall mean concentration being 11 ppm and production of 6.1 mL/(h.bird), respectively. Dust levels in the on-floor unit were very high, reaching a daily average of 100 particles/mL of size less than 5 μm, and an average during the light hours of 150 particles/mL. Hydrogen sulphide concentrations were detected only in the cage unit and never exceeded 142 ppb.

Table I. Summary of management data for the two barns

	Barn A	Barn B
Number of birds:		
start/finish	5800/2300†	14000/13580
% mortality	8.3	3.0
Strain of birds	HY-Line-W-77	Shaver S288
Birds per cage	NA	24 (12)‡
Size of cage (cm^2)	NA	91 × 61
Cage area per bird (cm^2/bird)	NA	240 (450)‡
Bird density‡ (birds/m^2 floor area)	24	27
Building construction	Wood-frame Metal roof	Wood-frame Metal roof
Building dimensions (m)	6 × 40 × 2.3	9 × 50 × 2.4
Waterer type	Fountain	Low-pressure cups
Ration type	Wheat-based	Wheat-based
Protein content (%)	16–20	16–19
Feed energy (MJ/kg ME)	12.8	11.7
Feeder type	Chain-in-trough	Chain-in-trough
Feedings per day	7	2
Feeder period (min)	5	15
Lighting type	Incandescent	Incandescent
Lights on/off (time)	0700/1700	0700/1800
Hours light	11	11

†3000 birds removed from upper storey after 6 wk to reduce density.
‡After 6 wk.

INTRODUCTION

Air quality is recognized as having a significant effect on animal health, performance, and product quality in intensive animal confinement operations. From the viewpoint of occupational health, the air quality in confinement animal housing needs to be quantified, as the combination of particulate and gaseous contaminants may pose a respiratory health hazard. Background levels of air contaminants under different management regimes must be known if a compromise is to be established between the energy savings realized by reduced ventilation and possible adverse effects of poor air quality.

Accordingly, a study was undertaken, the results of which are presented here, during the period from September to April (1983-1984) to determine the concentrations and production rates of the primary air quality contaminants in two commercial poultry rearing barns over the 18- to 20-wk rearing period. Cage-rearing systems represent the predominant method of raising pullets in Alberta, but floor-rearing systems are still utilized and so, for comparative purposes, a barn representative of each system was studied in this project. This work was carried out concurrently with another study of heat and moisture loads in poultry rearing facilities (Glennon et al. 1989).

EXPERIMENTAL FACILITIES AND METHODOLOGY

The two replacement pullet barns monitored have been described elsewhere (Glennon et et al. 1989). The relevant management data for the barns are given in Table I. Barns A and B were located within 80 km of Edmonton, Alberta. Barn A was a double-storey, on-floor replacement pullet unit; only one storey was monitored. Barn B was a single-story unit and utilized six rows of double-deck rearing cages. Barns A and B started initially with 5800 and 14 000 chicks, respectively. At 6 wk of age, over half the birds in Barn A were removed to the lower level.

Both barns utilized negative pressure ventilation systems, with fans located along one wall. Fresh air was introduced into the barns through slotted air inlets located as shown in Figs. 1 and 2. A fan-operated space heater in Barn A provided additional air mixing while air mixing in Barn B was dependent entirely on inlet air velocities.

The equipment utilized in this study to monitor and record air contaminant concentrations, temperatures and ventilation rates in each barn was developed by Feddes and McQuitty (1977), and described previously by McQuitty et al. (1985). Rapidly-changing parameters, such as fan speed, were monitored every 4 min. Parameters which had a slower time constant, such as ambient temperature, were measured every 20 min. Concentrations of carbon dioxide (CO_2), ammonia (NH_3), hydrogen sulphide (H_2S), and dust particles were measured at five sampling locations in Barn A and six in Barn B, twice per hour during each 24-h monitoring period. These locations were at the center of each half of the air space, at bird height and in the exhaust air at each operating fan. Dust concentrations were sampled at a representative central location in each barn for one 16-min period of each hour. Gas production rates of CO_2 and NH_3 were determined on the basis of mean hourly concentrations and ventilation rates, which were calculated from

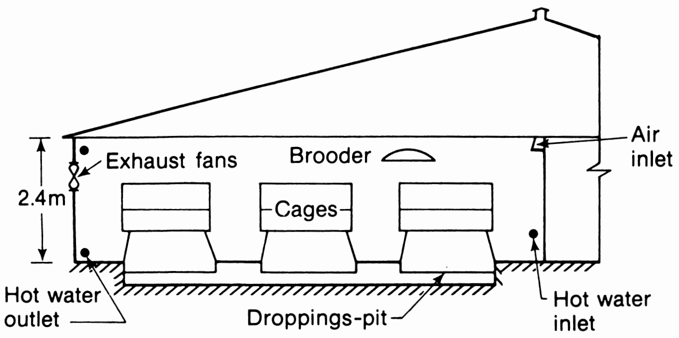

Figure 1. Schematic elevation of on-floor pullet rearing unit (Barn A).

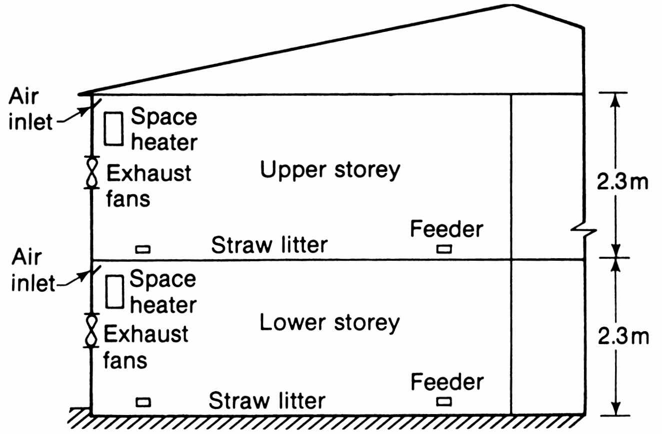

Figure 2. Schematic elevation of caged pullet rearing unit (Barn B).

4-min fan speed data that had been previously correlated to mean air velocity measurements taken in a calibration duct on each fan (Glennon et al. 1989).

The CO_2 and NH_3 concentrations were measured by non-dispersive infrared gas analyzers. Hydrogen sulphide concentrations were measured by a sulphur analyzer. Calibration gases were used to check the zero and span of each instrument before, and several times during, each data-recording period.

Environmental Conditions

The ambient temperature in both barns was controlled at 30–32°C when the chicks were introduced to the start of the rearing cycle. Over the 18- to 20-wk rearing period, the inside ambient temperature was decreased gradually to approximately 11 and 19°C for Barns A and B, respectively, being below the recommended temperatures in Barn A (Hy-Line Commercial Management Guide 1982; Shaver Commercial Management Guide 1982). The hourly ambient temperature throughout the monitoring period in Barn A ranged from 7 to 32°C and from 13 to 26°C in Barn B. Mean daily ambient temperatures for both barns are presented in Table II.

The measured ventilation rates for each 24-h monitoring period ranged from 0.08 to 0.24 L/(s.bird) (10-118 d) and from 0.05 to 0.42 L/(s. bird) (6-134 d) for Barns A and B, respectively. The recommended inside relative humidities for pullet facilities are a minimum of 50% and a maximum of 75%, (Associate Committee on the National Building Code 1977; American Society of Agricultural Engineers 1984). The measured relative humidities were found to have a mean value of 53.0 (range 36.5–63.8) percent for Barn A and 43.7)range 38.7–47.9) percent for Barn B. Therefore, the values in the ambient air in Barn B were, for every run, below the minimum recommended levels, suggesting that the barn was somewhat over-ventilated for moisture control, at least. Ventilation rates in Barn B were higher than in Barn B (Table II). Building latent heat production also was less in Barn A (Glennon et al. 1989). As a result, no supplemental heat was required after 6 d in Barn B.

RESULTS AND DISCUSSION

Carbon Dioxide

The mean CO_2 concentrations measured in this study were not great enough to be considered a health hazard to either birds or humans. They did not exceed the values of 3000 ppm suggested as the maximum concentrations for animal housing (Scottish Farm Building Investigation Unit (SFBIU)) 1984, nor the 5000 ppm threshold limit value (TLV) recommended for the human workplace for an 8-h, 40-h week (American Conference of Governmental Industrial Hygenists (ACGIH) 1984). The daily mean ambient CO_2 concentrations ranged from 1970 to 2880 ppm and from 1670 to 2890 ppm for Barns A and B, respectively (Table II). The CO_2 concentrations at the exhaust fan locations and at ambient locations were similar for Barn A and different for Barn B (Table III). The additional air mixing provided by the heater in Barn A ensured a uniform concentration throughout the air space, whereas some stratification of CO_2 occurred in Barn B as a result of inadequate mixing of the air space.

On the basis of bodyweight, Leonard et al. (1984) found that CO_2 production rates in two broiler barns averaged 2.8 L/(h.kg) while McQuitty et al. (1985) reported mean daily rates of 1.0 L/(h.kg) in three layer units. The means in Barns A and B were 2.4 and 2.3 L/(h.kg) respectively, using bird target weights with age from the Hy-Line and Shaver Commercial Management Guides (1982), respectively. The trends in all these CO_2 data followed similar trends found in the bird total heat production rates (Glennon et al. 1989).

The lighting schedule and resultant activity influences metabolic rate and, in turn CO_2 production rate. Diurnal fluctuations in CO_2 production were observed, with a larger drop in production from the light to the dark period in Barn B than in Barn A. The mean reduction in CO_2 production rates from day to night was 39 and 30 percent for Barns A and B, respectively (Table III). McQuitty et al. (1985) reported a mean reduction in CO_2 production rates from day to night of 30% for layers. The findings of these authors related favorable to those measured in this study.

Ammonia

Daily mean ambient concentrations of NH_3, ventilation rates, and the resultant production rates of NH_3 are given in Table II. The daily mean concentration of NH_3 recorded in Barn A ranged from 0 to 25 ppm in Barn A, and was above the acceptable level of 20 ppm suggested for poultry (Sainsbury 1980; SFBIU 1984) during the last two runs. The NH_3 TLV for workers is 25 ppm for an 8-hour day, 40-hour week, with short-term exposures allowed to reach 40 ppm (ACGIH 1984). In combination with other air contaminants, the atmosphere in Barn A could be considered borderline with respect to human health. The concentrations in Barn B ranged from 4 to 38 ppm, with the one abnormally high value occurring during the second monitoring period due to the droppings pits cleaned out just prior to monitoring.

Production rates for NH_3 measured in this study increased markedly with litter age similar to findings of Leonard et al. (1984) in broiler barns, and ranged from 0.0 to 19 mL/(h.bird)

Table II. Daily mean data for the gases monitored in two barns

Bird age (d)	CO_2† (ppm)	NH_3 (ppm)	H_2S (ppb)	VENT (L/(s.bird))	CO_2 (mL/(h.bird))	NH_3 (mL/(h.bird))	Temp. (C)	HR (%)
Barn A								
10	1970	0	< 10	0.083	440	0.0	28.5	36.5
36	2010	5	< 10	0.148	804	2.7	18.3	53.7
61	2070	16	< 10	0.204	1154	12.0	17.2	59.6
90	2880	25	< 10	0.182	1560	16.0	15.4	51.4
118	2760	22	< 10	0.240	1952	19.0	10.5	63.8
Barn B								
6	2830	8	70	0.05	341	1.5	24.4	43.0
35	2890	38	142	0.10	896	14.0	22.4	46.0
63	2150	7	69	0.19	1256	5.1	20.3	41.0
93	1870	4	58	0.33	1766	5.0	17.1	45.6
113	1800	4	36	0.36	1921	5.2	16.4	47.9
134	1670	4	10	0.42	2093	6.0	18.6	38.7

†Includes 500 ppm CO_2 in outside air.
‡Based on concentration in exhaust air, weighted by capacity of operating fans.

Table III. Overall mean carbon dioxide and ammonia data during day and night periods

	Barn A		Barn B	
	Day	Night	Day	Night
CO_2 concentration†				
Ambient† (ppm)	2460	2020	2260	2160
Exhaust‡ (ppm)	2490	2010	2560	2560
CO_2 production‡				
mL/(h.bird)	1430	864	1622	1173
(range)	(667/1940)	(430/1280)	(466/2538)	(235/1870)
% reduction, day to night	39		30	
NH_3 concentration				
Ambient (ppm)	15	13	9	11
Exhaust (ppm)	15	12	12	15
NH_3 production‡				
mL (h.bird)	9.6	7.0	7.1	5.9
range	(0/15.4)	(0/13.0)	(2.1/15.7)	(1.0/16.6)
% reduction, day to night	27		17	

†Includes 500 ppm CO_2 in outside air.
‡Based on concentration of exhaust air, weighted by capacity of operating fans.

for Barn A. The production rate of NH_3 was relatively constant at 5.3 mL/(h.bird) in Barn B after run 2 (Table II). In Barn A, the rate of increase was reduced when half the birds were removed at 6 wk of age. The frequent removal of the droppings from the droppings pits in Barn B indicated that NH_3 production reached a maximum production rate of 5–6 mL/(h.bird). The rate of production in Barn A up to 6 wk of age appeared to follow a trend similar to that found by Leonard et al. (1984) in two broiler barns. These authors established an exponential relationship for the above two parameters over the broiler production cycle. A similar pattern was observed by McQuitty et al. (1985) for the first 5 wk after droppings removal in a shallow-gutter, cage-layer facility.

These data illustrated the importance of removing the litter on which replacement pullets have been reared previously. Several authors, including Reece (1979), and Moulsley (1977), observed that young chickens were less resistant to disease due to the use of old litter. The NH_3 production rates did show some diurnal fluctuation. This may be due to the birds voiding their droppings mainly during the light hours. This is in contrast to results reported by McQuitty et al. (1985) for cage layers, where no variations were found in NH_3 concentration or production due to the lighting schedule. In this study, the overall mean ambient concentrations of NH_3 measured were 15 and 9 ppm during the day and 13 and 11 ppm during the night for Barns A and B, respectively (Table III). The different ambient and exhaust NH_3 concentrations (Table III) indicated that air mixing in Barn A was superior to that in Barn B, thus confirming this finding suggested by the CO_2 data.

Hydrogen Sulphide

The sulphur analyzer sampled the air in the two rearing units for approximately 20 min during each run. This analyzer was capable of measuring H_2S concentrations as low as 10 ppb. Hydrogen sulphide concentrations were undetectable in Barn A during any of the trial runs (Table II).

The mean concentrations of H_2S recorded in Barn B ranged from 10 to 142 ppb. The highest concentrations found in Barn B occurred during the second monitoring period. This also coincided with the highest NH_3 concentrations found during this same period in which the contents of the droppings pits were agitated. Higher H_2S concentrations were expected in Barn B than in Barn A due to anaerobic decomposition of the semi-liquid droppings in the pits and frequent disturbance of these stored droppings. Due to the frequency of cleaning, and to the method of handling the droppings, any danger due to H_2S was considered to be minimal in this cage facility.

Dust

Dust particle counts were measured in five group sizes, i.e., greater than 0.5, 1, 2, 5, and 10 μm. These groups were combined in the respirable range (less than 5 μm). As a result of high concentrations of dust and the adhesive nature of the dust, the particle counter (Climet Instruments, Redlands, Calif.) suffered repeated calibration problems. The data were not collected with the pullets at the same stage of growth in the two barns. Dust data were obtained for the first and last run in Barn A and for a total of three runs in Barn B (Table IV).

Table IV. Daily mean dust concentrations in two barns (particles/mL)

Bird age (d)	Light <5 μm	Light >5 μm	Dark <5 μm	Dark >5 μm	Daily <5 μm	Daily >5 μm
Barn A						
10	52.0	1.4	22.0	0.3	36.0	0.8
118	150.0	34.0	62.0	7.3	100.0	19.0
Barn B						
63	3.5	0.5	3.0	0.5	3.2	0.5
93	13.0	1.3	13.0	1.3	13.0	1.3
134	8.3	0.9	28.3	1.2	18.9	1.1

Barn A was found to have high dust particle concentrations over the monitoring period, particularly in the size range less than 5 μm. For this size range, the mean daily concentrations ranged from 36 to 100 particles/mL and from 3.2 to 18.9 particles/mL for Barns A and B, respectively. For particles greater than 5 μm the mean daily concentrations ranged from 0.8 to 19.0 particles/mL and from 0.5 to 1.3 particles/mL for Barns A and B, respectively. Leonard et al. (1984) reported a maximum daily mean concentration of dust less than 5 μm of 6.8 particles/mL and that of particles greater than 5 μm of 1.3 particles/mL in a study involving commercial broiler facilities under winter conditions. In three cage-layer facilities, McQuitty et al. (1985) found mean daily concentrations of 7.9 and 0.3 particles/mL for sizes less than and greater than 5 μm respectively.

In Barn A, the dust concentrations during the night, in both size categories, were found to be less than half the daytime values while those in Barn B remained relatively constant. The birds in Barn A were always in contact with the dry litter and were noted to be very flighty. Their activity resulted in litter particles becoming airborne. The caged birds (Barn B) when active could only release particles such as feed, skin or feathers to the air space. Mean dust levels for the caged pullets were higher than those for caged layers due to the flighty behavior of the moving birds. The pullets raised on litter also generated more dust than broilers, again, as a result of their much more active nature. In Barn A, the mean daytime concentration of particles less than 5 μm in diameter was 150 particles/mL. In both barns, periodic extremes were measured, with maximum values approaching or exceeding the TLVs for nuisance particulates or grain dust (ACGIH 1984), expecially in Barn A. Lack of information on dust composition makes direct comparison with documented TLVs difficult. However, dust concentrations measured in Barn A exceeded values found in any other confinement housing facility to date in Alberta by researchers in the Department of Agricultural Engineering, University of Alberta.

SUMMARY AND CONCLUSIONS

Based on the results obtained in this study, the following summary of results and related conclusions were drawn:

1. Carbon dioxide concentrations were considered to be low in terms of health hazards, ranging from 1670 to 2890 ppm.
2. Ammonia concentrations reached potentially unhealthy levels in the unit with on-floor rearing, exceeding 20 ppm for over half the production cycle.
3. Ammonia production increased exponentially for the first 6 wk in the on-floor unit but leveled off after a reduction in stocking density at 6 wk of age.
4. In the on-floor and the cage rearing units, ammonia production was 19 and 6 mL/(h.bird), respectively, at the end of the production cycle.
5. In the on-floor and the cage rearing units, carbon dioxide production was 1950 and 2093 mL/(h.bird) at 118 and 134 dy, respectively.
6. Hydrogen sulphide concentrations were detected only in the cage unit and at very low values.
7. Maximum daily mean dust concentrations in the on-floor and cage rearing units were 100 and 19 particles/mL, respectively, for particles less than 5 μm.
8. Significant diurnal changes in dust concentrations were measured in the on-floor unit while dust concentrations in the cage unit remained relatively constant at low levels.
9. A mean concentration of 150 particles/mL less than 5 μ in diameter was observed over the light hours in the on-floor unit.
10. The synergistic effect of NH_3 and dust concentrations in the on-floor unit may have represented a potentially hazardous environment.

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