Air quality and contaminant loads in three commercial b breeder barns

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O'Connor, J. M., McQuitty, J. B., and Clark, P. C. 1988. **Air quality and contaminant loads in three commercial broiler breeder barns.** Can. Agric. Eng. 30: 273–276. The quality of the broiler breeder environment in three barns was evaluated by establishing ranges of background concentrations for the primary air contaminants — ammonia, carbon dioxide, hydrogen sulphide and dust. Mean daily ambient ammonia concentrations ranging from 17 to 123 ppm were considered to be potentially hazardous to both operators and birds relative to occupational health standards. The highest respirable dust concentration recorded was 80 particles/mL, with the maximum concentrations for light and dark periods being 69 and 26 particles/mL, respectively. The combined effect of ammonia and dust resulted in an unacceptable and unhealthy environment. Overall mean production rates of ammonia ranged from 73.4 to 128 mL/(h.bird) over the three barns, while values for carbon dioxide ranged from 3.61 to 3.77 L/(h.bird). Only trace concentrations of hydrogen sulphide were recorded.

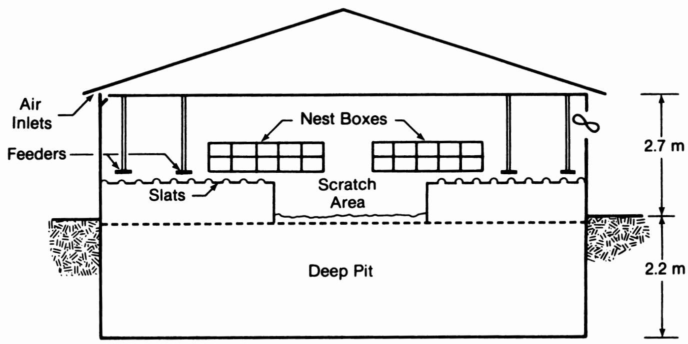

Figure 1. Cross-sectional view of broiler breeder barns (Barns A and B, shallow pits; Barn C, deep pit).

INTRODUCTION

If the animal environment is a composite of all the factors that affect the animal, then the quality of the air which the animal breathes must be considered as an important component of the environment as it can have a direct or indirect effect on the animal's performance (Curtis 1981). However, there is a notable lack of definitive data on air quality within commercial-scale animal housing and on the combined effects of the air contaminants in such housing on animal health and performance (McQuitty 1985). Specifically, there is a need to determine the production rates of contaminants and on the effects of management practices and housing systems on these rates (Scott et al. 1983). Such data are required for design purposes if concentrations of particular contaminants are not to exceed acceptable upper limits within the animal's environment. The suggested animal threshold limit values (TLVs) for ammonia (NH_3), carbon dioxide (CO_2) and hydrogen sulphide (H_2S) are 20, 3000 and 5 ppm, respectively (Scottish Farm Building Investigation Unit (SFBIU) 1984). The corresponding TLVs recommended for humans are 25, 5000 and 10 ppm, respectively and 1060 respirable particles/mL (American Conference of Governmental Industrial Hygienists (ACGIH) 1985).

No data are available on the production rates or concentrations of aerial contaminants as they occur in commercial broiler housing. Accordingly, a study was initiated to establish production rates and/or concentrations of these contaminants in such units and to determine the possible effects on these rates of droppings storage systems and management practices in Alberta. This study was carried out concurrently with another study involving heat and moisture loads in the same facilities (O'Connor et al. 1988).

Experimental Facilities, Equipment and Procedures

The three barns involved in this study have been described in detail elsewhere (O'Connor et al. 1988). The barns employed a 1/3 litter, 2/3 slatted floor system, with the raised slatted portion being situated on either side of a central passageway/scratch area. The bird droppings were permitted to accumulate in each barn throughout the production cycle before removal. Two of the barns (Barns A and B) utilized shallow pits for droppings storage, whereas the third (Barn C) employed the deep-pit system (Fig. 1). All three barns were of similar construction and levels of thermal insulation and had similar feeding and watering systems. Ventilation in each unit was provided by a cross-flow, negative pressure, mechanical exhaust system.

The instrumentation and methodology used to establish the concentrations of CO_2, NH_3, H_2S and dust, and of the rates of production of CO_2 and NH_3, within these barns, were the same as those utilized in air quality studies in broiler and layer barns and described by Leonard et al. (1984) and McQuitty et al. (1985), respectively. Gas and dust concentrations were monitored for 24-h periods at intervals of approximately 3-4 wk during the production cycle in each barn. Air samples were drawn via sampling lines from these equally-spaced locations along the centerline of each barn just above bird height, from the incoming fresh air and at each fan location by an automatic-sequencing sampler to the appropriate instruments housed in a mobile laboratory (Feddes and McQuitty 1977).

The CO_2 and NH_3 concentrations were measured three times every hour at each location, using nondispersive gas analyzers (Model 315A, Beckman, Fullerton, Calif.). The instruments were calibrated with certified gases (Matheson Gas Products, Edmonton, Alberta). Concentrations of H_2S were measured for

. Management data for the three broiler breeder barns [illegible]g the study period

	Barn		
	A	B	C
Barn location	Ardrossen	Edberg	New Norway
Barn size (m)	10 × 38 × 2.7	12 × 52 × 2.7	9 × 68 × 2.7
Raised slats (m)	0.83	0.61	0.65
Additional pit depth (m)			1.55
Number of birds			
— at start	2600	4831	4908
— at end	2338	4442	4766
Mortality (%)	10	8	3
Bird age (wk)			
— at start	31	27	33
— at end	57	55	49
Floor area (m^2/bird)	0.155	0.134	0.118
Egg collection	Manual	Manual	Manual
time (h, approximate)	7:00 11:00 15:00	7:00 11:00 15:00	7:00 11:00 15:00
Feed schedules time (h)	5:00 6:15	8:00 8:30	6:30 7:15 8:00
Time lights on (h)	4:00	4:30	4:00
Time lights off (h)	18:00	18:30	18:00

20 min each monitoring day using a sulphur analyzer which utilized a flame-photometric, detection process (Melroy Laboratories, Springfield, VA.). Ambient concentration was calculated as the mean of the concentrations measured at bird height. The production rates of CO_2 and NH_3 were calculated by summing the production rate at each fan. The rates were a function of the difference between inlet and exhaust concentrations and the respective airflow rate.

Atmospheric dust concentrations were measured immediately above bird level in the center of each barn for 15 min of each hour. The measured aerosols could include feed, litter, and bird matter, but the source was not identified in this study. Sample air was drawn through an iso-kinetic probe into a photometric particle counter (Climat Instruments, Redlands, Calif.). The total number of particles greater than 0.5, 1.0, 2.0, 5.0, and 10 μm in diameter were obtained every 3 min.

Management data for the three barns are tabulated in Table I. Feeder space was approximately 18 birds/m while one waterer was provided per 100 birds. Feed was restricted to 2.0 MJ metabolizable energy per day per bird. A summary of measured outside and ambient temperatures, relative humidity and ventilation rates are presented in Table II. The ventilation rates were higher than the 0.29 L/(s.bird) recommended under Alberta winter condition (Winchell 1982). This resulted in relative humidities lower than recommended maximum levels of 80%.

Experimental procedures and equipment used in collecting and processing of data are outlined elsewhere (O'Connor et al. 1988).

RESULTS AND DISCUSSION

Carbon Dioxide

The overall mean CO_2 concentrations for each barn, including the range of daily mean and light/dark period concentrations,

Table II. Summary of operational parameters — overall mean measured values*

Parameter	Barn A	Barn B	Barn C
Outside temperature (°C)			
Mean	−3.1	−2.2	1.7
Range	−24/15	−17/4	0/4
Ambient temperature (°C)			
Mean	17.5	18.9	18.8
Range	15/20	15/22	18/20
Humidity (%)			
Mean	55	58	60
Range	50/70	51/75	52/71
Ventilation rate (L/(s.bird))			
Mean	0.85	0.65	0.82
Range	0.5/1.8	0.5/0.9	0.7/1.0

are given in Table III. The overall means for ambient CO_2 concentrations over the entire monitoring cycle were 1953, 2241 and 2013 ppm, for Barns A, B and C, respectively. The maximum daily ambient concentration at 2727 ppm, recorded in Barn B, was lower than the human TLV of 5000 ppm recommended by ACGIH (1985) and the animal TLV of 3000 ppm recommended by SFBIU (1984). Ambient concentrations were 11, 22 and 16% lower during the dark hours than the light period for Barns A, B and C, respectively.

Carbon dioxide production rates (L/(h.bird)) were calculated as daily means, and means for light and dark periods. The three barns showed close agreement in CO_2 rates, the overall means being 3.61, 3.62 and 3.77 L/(h.bird) for Barns A, B and C, respectively. This indicated similar metabolic activity. The magnitude of the reduction in CO_2 production from light to dark hours was similar for all three barns, with a 26% reduction for Barn A and 28% reductions for Barns B and C.

Ammonia

The overall mean ambient NH_3 concentrations were 33, 78 and 45 ppm for Barns A, B and C, respectively (Table III). Based on the TLV of 25 ppm recommended by ACGIH (1985) for time-limited exposures, the NH_3 concentrations measured in this study indicated the existence of a potential health hazard to operators exposed to these barn environments for extended periods of time. Indeed, the short-term exposure limit of 35 ppm (ACGIH 1985), based on a 15-min exposure time not repeated more than four times daily, was exceeded throughout much of the production cycles in all three barns, indicating the existence of a health hazard to operators exposed to these environments for even short periods of time.

Based on an acceptable upper limit of 20 ppm for poultry as recommended by Sainsbury (1980) and SFBIU (1984), concerns also must be expressed for bird health and performance, because of the continuous exposures to high NH_3 concentrations (Table III). The concentrations recorded in Barn B give particular cause for concern, with the mean daily values briefly reaching as high as 123 ppm. Although production was maintained at a satisfactory level in Barn B, the same producer obtained better performance in Barn C, possibly due to the lower NH_3 concentrations in that barn.

The overall mean NH_3 production rates were 73.4, 128.5 and 96.7 mL/(h.bird) for Barns A, B and C, respectively. The daily mean production rate in Barn C (deep pit) showed the least variation over the production cycle, ranging from 95 to 105 mL/(h.bird). The daily means for Barns A and B, ranged from 27.0

Table III. Overall mean aerial contaminant production and concentration data during the breeder production cycle

	Barn A			Barn B			Barn C		
	Daily	Light	Dark	Daily	Light	Dark	Daily	Light	Dark
CO_2 concentration, ambient (ppm)	1953	2089	1763	2241	2406	2017	2013	2135	1843
CO_2 production (L/(h.bird))	3.61	4.07	3.01	3.62	4.28	3.08	3.77	4.25	3.05
% reduction, day to night		26			28			28	
NH_3 concentration									
Ambient (range) (ppm)		33 (23/42)			78 (17/123)			45 (33/53)	
Exhaust		25			61			34	
NH_3 production (mL/(h.bird)) (range)		73.4 (27/127)			128.5 (45/160)			96.7 (95/105)	
Dust concentration (particles/mL)									
Respirable	27.2	40.0	12.0	26.4	37.5	10.8	7.9	16.6	3.7
Nonrespirable	9.4	15.2	2.4	7.9	12.0	2.3	2.5	4.0	0.8
Range of total		6–67.8			10.8–55.7			3.6–23.4	

to 126.5 mL/(h.bird) and from 45.3 to 171.8 mL/(h.bird), respectively. The large variation among the daily means in Barns A and B were likely due to the droppings in the shallow pits being more susceptible to changes in temperature and humidity. The ambient temperatures in Barns A and B did fluctuate more than those of Barn C (Table II). The observed dry litter conditions in Barn A, due to higher ventilation rates, explained the difference in the NH_3 production rates for these two units. Because of the relatively large difference in NH_3 production for the two shallow-pit barns, the effect of the droppings storage system on NH_3 production was not evident in this study. The effects due to the prevailing environmental conditions in each barn on production rates appeared to be the primary reasons for the variation in NH_3 production.

Although no other data are apparently available on the quality of the air environment in broiler breeder facilities, the overall mean NH_3 concentration in Barn B was shown to exceed the overall mean NH_3 concentrations recorded in layer barns under winter conditions in Alberta, as reported by McQuitty et al. (1985). The existence of such high ambient NH_3 concentrations in all of the barns monitored, despite ventilation rates in excess of those recommended by Winchell (1982), demonstrated the inadequacy of these recommended values for NH_3 control. The maintenance of satisfactory relative humidities by the ventilation systems indicated that NH_3 control rather than moisture control should have been the criterion on which the design of minimum ventilation rate was based in each of these three barns.

To eliminate potential hazards to operator health due to long-term and short-term exposures to high NH_3 concentrations as well as to optimize bird health and performance requires either (a) increasing the ventilation rate, causing an associated increase in supplemental heating demand, or (b) reducing the rate of NH_3 production. The latter possibility could be achieved by increasing the frequency of manure removal which, in turn, could be achieved only through the redesign of the conventional methods of droppings storage in broiler breeder barns.

Hydrogen Sulphide

The maximum detected H_2S concentration recorded in this study was 40 ppb during the first monitoring cycle in Barn B. Only traces of H_2S (less than 20 ppb) were detected in subsequent monitoring cycles, with similar levels being detected in Barns A and C. Such concentrations were not considered hazardous, being far below the TLV of 10 ppm proposed by ACGIH (1985) and the maximum concentration of 5 ppm recommended by the SFBIU (1984) for animal housing. However, the very presence of H_2S in all three barns would suggest that, until data are available to the contrary, caution should be exercised in working in or around the droppings storage areas in barns of these types, particularly during cleanout of the areas.

Dust

Dust particle counts were grouped into two overall size ranges to describe the potential of the poultry environment as a health hazard to both operators and birds. Particles were classified as being either respirable (diameters less than 5 μm) or nonrespirable (diameters greater than 5 μm) according to their ability to penetrate the lung tissue (Cermak and Ross 1978). The mean concentrations of respirable and nonrespirable dust particles for the light and dark hours of each monitoring cycle are given in Table III.

Because of the high dust concentrations encountered and the adhesive nature of poultry house dust, some instrument calibration failure occurred which resulted in no dust data being available for 4 of the 20 d of experimental data. As expected, the nighttime dust concentrations were found in all cases to be lower for both size ranges than the corresponding day-time values. Maximum dust concentrations corresponded to times of peak bird activity, such as feeding, egg collection or activation of the lights.

Barn A had the highest overall mean concentrations of respirable and nonrespirable particles of 27.2 and 9.4 particles/mL, respectively. Low ambient relative humidities and dry litter conditions, together with the observed aggressive bird behavior, explain the high dust production in this barn.

Leonard et al. (1984) and McQuitty et al. (1985) reported maximum values of daily mean dust concentrations of 7.5 and 39.7 particles/mL in broiler and layer facilities, respectively. These studies were carried out in Alberta using the same equipment and methodology and under similar climatic conditions. The highest recorded mean daily dust concentration in this study was 67.8 particles/mL. The combination of the high ammonia and dust concentrations could be challenging bird health.

The dust concentrations found in the breeder environment did not exceed the TLV of 1060 respirable particles/mL recommended by the ACGIH (1985). Donham et al. (1986) suggested that the dust TLV for animal housing be lowered substantially because of dust particles of animal origin (scurf and fecal) while O'Blenis et al. (1984) recommended 4 mg/m^3 or 850 particles/mL as an acceptable upper limit.

Because standards are lacking for dust concentrations in poultry housing, no conclusions can be drawn on the effects of the dust concentrations encountered in this study on broiler breeder health and performance. Barn A, with the highest mean respirable dust concentrations, also had the highest bird mortality over the production cycle (Table I). The effects of the various combinations of particulate and nonparticulate contaminants encountered cannot be assessed because of the lack of information pertaining to the consequences of such contaminant loads on the health and performance of both operators and poultry. The high NH_3 concentrations and substantial dust concentrations, however, in these three barns were, in the opinion of the authors, an unpleasant and unacceptable combination.

Summary and Conclusions

The measurements of air quality contaminants can be summarized as follows:

(1)Carbon dioxide concentrations, ranging from 1294 to 2727 ppm were low in terms of health hazards.

(2) Overall mean carbon dioxide production rates ranged from 3.6 to 3.8 L/(h.bird).

(3) Overall mean ammonia production rates ranged from 73.5 to 128.5 mL/(h.bird), with the highest values occurring in a barn utilizing shallow-pit droppings storage.

(4) Ammonia concentrations in all three barns, ranging from 17 to 123 ppm, were considered to pose a potential health hazard to both operator and bird health.

(5) The high ammonia concentrations measured in all three barns together with low measured relative humidities suggests that ammonia control rather than moisture control should be the criterion on which minimum ventilation rates were based.

(6) Hydrogen sulphide did not pose a problem in any of the barns monitored, the maximum concentration measured being 40 ppb.

(7) Dust concentrations showed appreciable diurnal variations in all three barns, with the maximum daily total dust concentration being 68 particles/mL.

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