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Indirect Measurement of Building Ventilation Rate for Manure-belt Laying Hen House Using CO_2 Balance

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Summary and Implications

Direct measurement of building ventilation rate in livestock housing is a formidable task due to uncontrollable variations in fan and system performance. Estimating building ventilation rate based on a CO_2-balance offers a potentially viable alternative to direct measurement. Building ventilation rates obtained by direct measurement and by a CO_2 balance were compared in this study for a commercial laying hen house with manure belts. The results indicate that ventilation rates estimated by the CO_2 balance method were not significantly different (P>0.2) from those as determined by the direct measurement when the averaging or integration time interval was two hours or longer. Careful application of the CO_2 balance method will greatly improve the affordability and versatility of endeavors toward quantifying air emissions from confined animal housing.

Introduction

The need to quantify air emissions from animal feeding operations (AFOs) with relative ease and reasonable certainty continues to rise. Ventilation rate through an emission source is one of the two essential elements for quantifying emission rates, with the other element being concentration of the substance under consideration. By monitoring the incoming and exhaust air, metabolic carbon dioxide (CO_2) can be used to estimate the ventilation rate in livestock buildings. The validity of the CO_2 balance method largely depends on validity of the metabolic data for the animals. Accuracy of the indirect method remains to be evaluated under field production conditions.

The objective of this study was to evaluate the performance of CO_2-balance indirect method for determining the building ventilation rate (BVR) of a commercial laying hen house with manure belts and daily manure removal. The evaluation was conducted by comparing the BVR obtained through either direct measurement of the fan capacity and runtime or indirect (CO_2-balance) estimation.

Materials and Methods

A manure belt laying hen (W-36 breed) house located in north central Iowa was used for the study. The layer house had an east-west orientation and a dimension of 61 ft ×522 ft. It used a quasi-tunnel ventilation system with 13, 48-inch and two 36-inch exhaust fans in each endwall. A specialized device for in-sit calibration of fan performance, known as FANS (fan assessment numeration system), was used to determine the actual fan performance of the individual fans under different building static pressures. Operation time of each fan and the building static pressure were continuously monitored to directly determine the total BVR. Portable monitoring units (PMUs) were used to continuously collect CO_2 concentrations of the incoming and exhaust air at 30-min intervals. Metabolic rates and respiratory quotients (RQ) of modern W-36 hens had recently been quantified and were used in the CO_2-balance calculation. The BVR and CO2 production rates are related as follows:

$$BVR = \frac{CO_{2\,production} \times 10^6}{[CO_2]_e - [CO_2]_i}$$

where $[CO_2]_e$ and $[CO_2]_i$ = CO_2 concentration (ppm) of exhaust and incoming air, respectively; $CO_{2production}$ is the amount of metabolic CO_2 generation by the hens.

Data from March 2003 to December 2003 were used in the comparison of BVR between the direct and indirect or CO_2-balance methods.

Results and Discussion

Figure 1 shows paired comparisons of BVR between the direct measurement and CO_2 balance methods at semi-hourly, hourly, bi-hourly (2-hr) and daily average or integration time intervals. The number of observations associated with each of the time intervals were, respectively, 1318, 660, 330, and 28. The corresponding regression lines of indirect vs. direct BVR revealed good regression coefficient (R^2) of 0.904, 0.916, 0.926 and 0.956, respectively, with a p-value of 0.019, 0.1, 0.205 and 0.763, respectively, for the paired t-tests. Hence, the results indicate that the CO_2 balance method based on bi-hourly or longer averaging/integrating time interval would yield BVR not significantly different from BVR obtained by direct measurement (P>0.2). All regression equations had a slope of about 1.0. The result also indicated that for manure-belt layer house with daily manure removal, CO_2 generation by the manure was negligible as compared with the metabolic CO_2 production by the hens. Hence, for commercial laying hen (W-36 breed) houses using a manure belt with daily manure removal, a CO_2 balance can provide a viable alternative to reasonably estimate BVR when the integrating time interval is two hours or longer. It should be noted that the indirect BVR measurement technique relies on realistic metabolic rate of the birds.

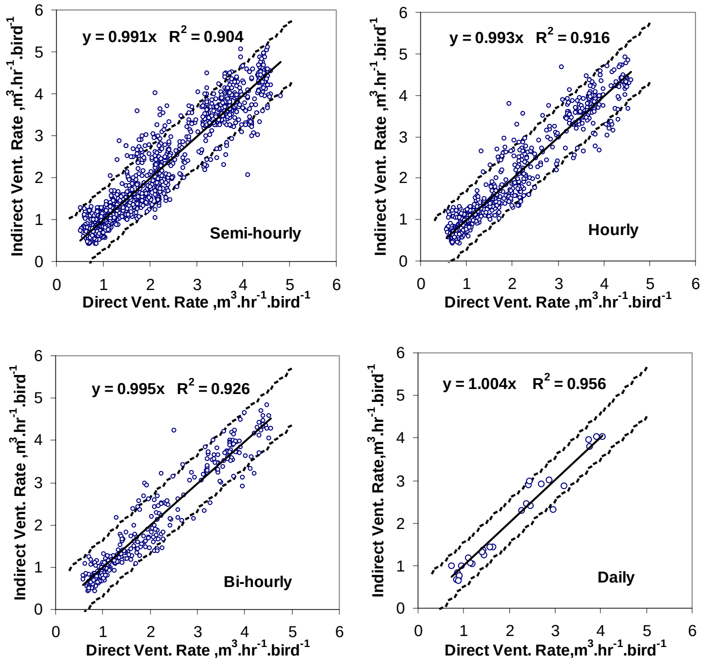

Figure 1. Relationship of building ventilation rates determined by direct measurement vs. by CO_2-balance derivation for a commercial layer house with manure belts and daily manure removal at different integration time intervals. The dash lines below and above the regression lines represent 95% confidence intervals of the observations (1 cfm =1.7 m^3.hr-1).