COMPARING NATURAL TRACER GAS METHODS WITH A SIMPLIFIED CONSTANT RELEASE TRACER GAS METHOD INSIDE A NATURALLY VENTILATED BROILER LIVESTOCK HOUSE

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Introduction

The need to accurately quantify livestock house emissions is increasingly becoming important as the effects of bioaerosols on local environments are recognised and pressure on industry and governments to reduce greenhouse gas emissions increases. The most important aerial pollutants originating from livestock houses are odours, gases, dust, micro-organisms and endotoxins, collectively known as bioaerosols, which are emitted via building exhaust systems into the environment. To quantify bioaerosol emissions, it is necessary to calculate the ventilation rate. The complexity of this task depending on the type of ventilation system installed.

Livestock housing ventilation systems are generally of 2 types, the more common natural ventilation (Louisiana) and the internally regulated mechanical ventilation systems. Continuously quantifying ventilation rates from mechanically ventilated livestock houses with fixed inlets and outlets, is relatively simple, however, to achieve the same level of accuracy in Louisiana type livestock houses with continuously interchanging air exchange surfaces (inlets and outlets) totally dependant on the weather and thermal conditions requires state of the art technology and is much more complex. This paper compares the application of the less complicated and cheaper CO_2, heat mass balance methods (natural tracer gas methods) with a simplified and sophisticated tracer gas constant injection method (artificial tracer gas) in a Louisiana type broiler house.

Because of the high costs of tracer gas, limitations of technical equipment and difficulties in fulfilling the requirements of the tracer gas method in large Louisiana type livestock houses, being (1) constant inter-exchange surfaces i.e dosing at inlets and sampling at outlets and (2) good mixing of air in selected envelope, a simplified method was devised. This involved the construction of a section within the livestock stall and measuring exchange rates under constant transverse wind conditions, hence reasonably constant inter-exchange surfaces can be achieved and with sufficient wind speeds good mixing of the section air with the tracer gas. The aim is that the exchange rate conditions of the section are representative of the whole livestock stall, during the measurement period, hence the ventilation rate calculated for the section is representative for the whole house.

Material and Methods

The Louisiana livestock house is situated in northern Germany. The livestock house runs from north to south and is relatively large 120m length by 16m width and 6.2m height. The livestock house produces around 40 000 broilers per grow out cycle and its internal climate is regulated by side wall curtains and chimney baffles automated by an internal computer based on temperature and humidity parameters. Ventilation rate measurements with tracer gas were conducted over a period of 2 weeks in the winter.

Three methods were used for calculating the ventilation rates. The carbon dioxide mass balance and temperature/humidity mass balance models (CIGR. 1984), with ventilation rates calculated according to 24hr averages. These natural tracer gas methods were compared with the constant injection tracer gas method (VDI. 2001). A section was created within the livestock house (Fig.1) and was partially separated from the livestock house with curtains (internal volume ≈ 1/10th total livestock house volume), here the temperature and humidity sensors, gas sampling and dosing equipment were installed. The curtains only very basic covered ≈ 47% of the livestock house width profile, were quickly installed and did not hamper farm management operations.

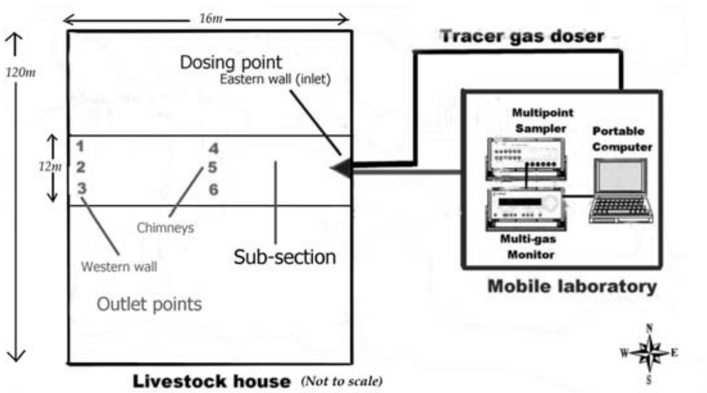

Figure 1: Livestock house experimental section set up schematic

The tracer gas was injected from the prevailing wind side at a height of ≈1,7m (dosing rate ≈ 3-15 ml/sec) and air samples were obtained from the chimney openings (5.7m high) and lee side windows (1.7m), all contained within the sub-section (Fig.1). The majority of measurements were conducted when transverse easterly winds were blowing, therefore, inter-exchange surfaces generally remained fixed.

The Innova 1309 sampling and dosing unit was used in conjunction with the Innova 1312 multi-gas monitor and 7620 Tracer gas monitoring system program. The tracer gas Sulfur Hexafluoride (SF_6) was used and all measurements were stored and calculated in Excel. The multi-gas monitor was set up to measure CO_2 and SF_6 from each of the 6 sample locations, with a whole sampling cycle including sample analysis and cell flushing lasting ≈10 minutes.

The external weather parameters were measured from a UK TOSS weather station, where temperature, humidity, wind speed and wind direction values were recorded hourly. Rotronics sensors measuring temperature and humidity were also installed at some locations within the experimental sub-section.

Results and Discussion

The basic principle behind the mass balance models used in these calculations are based on the following relationship.

Ventilation rate = Production or volume release of tracer / Tracer concentration inside envelope – Tracer concentration outside envelope

The hourly air exchange rate results with the three methods were found to be very inconsistent (Tab.1). The temperature/humidity method was shown to perform better than the CO_2 method. The very high exchange rates calculated with the CO_2 method (in excess of 50/hour) are unrealistic under such winter conditions. The average hourly CO_2 values (concentration difference between inside stall and ambient levels) failed to exceed the recommended difference of 200ppm for accurate exchange rate calculations (Pedersen *et al*., 1998), causing these high air exchange rate results. The instruments were checked before the experiment and were performing correctly. These low concentrations could be due to the well ventilated atmosphere and/or perhaps the animal density was not large enough.

On the other hand, inside and outside stall temperature and humidity values were above the recommended inside and outside stall level differences (> 2°C for temperature and > 0.5kg $x10^{-3}$ for humidity) for accurate exchange rate calculations (Pedersen *et al*., 1998). Although, the exchange rate values were lower than the tracer gas method they do seem reasonable and were similar to the recommended exchange rate (Büscher. 1998), which is based on winter install conditions and bird weight.

Table 1: Calculated exchange rates

24 hour Air Exchange rate calculations for CO_2, Temperature/Humidity and Tracer gas methods				
Date	Air exchanges/hr CO_2 method	Air exchanges/hr Heat method	Air exchanges/hr Tracer gas method	Recommended Air exchange rate/hr (Büscher. 1998)
07-08.11.03 (17-17hr)	63,5	3,2	14,7	2,4
08.11.2003 (00-00hr)	66,8	3,3	17,7	2,4
08-09.11.03 (12-12hr)	66,1	3,1	15,1	2,4
08-09.11.03 (17-17hr)	61,3	3	13,1	2,4
11-12.11.03 (15-15hr)	67,5	3	11,3	2,4
12.11.2003 (00-00hr)	70,2	2,9	10,4	2,4
13-14.11.03 (12-10hr)	51,8	2,3	1	2,4

The tracer gas method recorded higher exchange rates than the heat balance method and much lower than the CO_2 method. It can be assumed that the actual exchange rate would have been lower than the calculated tracer gas values because of tracer gas escape from section. Also, instrumental drift and gas sampling/analysis time (≈ 10 mins for complete cycle) would be additional sources of error. However, the higher ventilation rates seem realistic because of the wind direction and velocity. An overall average hourly wind speed of $3.2ms^{-1}$ was recorded with a median wind direction of 89.9° (where, 90° is a direct easterly transverse wind) and an average wind direction standard deviation of only 5.6°. It is recognised that wind speeds above $2ms^{-1}$ are required for sufficient transverse wind ventilation, but not too high resulting in short circuiting air flow and insufficient mixing of livestock house air with the tracer gas (Demmers *et al.,* 2001). Therefore, under these conditions the inter-exchange surfaces were reasonably fixed, clearly tracer gas escape from the section would have occurred, however, under such conditions the magnitude would have been reduced. The tracer gas exchange rates from the 7^{th}-12^{th} were correlated with the wind speed, with a $r^2 = 0.67$ $p<0.000$, suggesting a direct relationship between exchange rate and wind speed, as expected. This confirms the functioning of the method. The average hourly wind speed recorded in the last measurement period 13^{th}-14^{th} was only 0.3 ms^{-1}, thus well below $2ms^{-1}$, and the wind direction over the period was irregular recording a standard deviation of 116.5 degrees, therefore the air inter-exchange surfaces were variable, thus the effectiveness of the method under these conditions was reduced, however an air exchange rate of 1 per hour although low, is not entirely out of range.

Because of the nature of ventilation in Louisiana stalls, validating the calculated exchange rates for all methods is not possible. All techniques are subjected to errors depending on season, building design, materials etc. However, the correlation between air exchange rates and wind conditions with the tracer gas method is an important tool for confirming air exchange rate values with wind conditions yielding additional valuable information the other methods can not provide. On the otherhand, the mass balance methods are very cheap and easy and in this case the heat balance method provided relatively good results, the problem is there is even less certainty with mass balance results than well performed tracer gas techniques.

Conclusion

The carbon dioxide method performed poorly, however the heat balance recorded results within range of the recommended values and the tracer gas method. It could be assumed that the real exchange rate would be closer to tracer gas method results in comparison with the heat balance technique.

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