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Emission Potential of Animal Husbandry: Dairy Cattle

A tracer gas technique for continuously recording the air exchange rate in naturally ventilated stables has been enhanced and was successfully used in two dairy cattle farms. The method using carbon monoxide as tracer gas and a variable distribution technique is suitable for continuously recording emission rates for naturally ventilated stables with different designs and sizes.

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Keywords

Emissions, emission rates, air volume flow, natural ventilation, ammonia, nitrous oxide, methane

Measuring the air exchange rate particularly for naturally ventilated stables is difficult concerning experimental setup, measurement technique and data acquisition. This is shown in recent works, where flow patterns in naturally ventilated stables are determined [1, 2]. Basic principles for measuring ventilation rate are published in literature [3]. For naturally ventilated stables some difficulties have to be taken into account. The high variability of the ventilation rate and the fact that openings at the wall and roof - depending on the weather conditions - act as air inlet and air outlet simultaneously. The method of continuously tracer gas injection is, in comparison to the heat balance or CO_2 balance method, able to record the temporal and spatial variations of the air exchange within the stable [4]. This work describes a method of continuously tracer gas injection and detection, working with carbon monoxide and not with common tracers as SF_6 or ^{85}Krypton.

Material and method

The investigation took place during late summer 2005 at two dairy farms. Some basic characteristics of the stables are listed in *table 1*.

The tracer gas measurements took place during warm weather situations (minimum and maximum air temperatures 4 to 17 °C) over a period of five days. The continuous gas measurements and the determination of the local weather situation lasted for several weeks.

Carbon monoxide (purity 2.0) was used as tracer gas. The advantages and disadvantages of carbon monoxide as a tracer gas for air exchange measurements are described by [5]. Especially for transportation and storage of the gas cylinders, safety standards have to be met. In this work the tracer gas was dosed up to 400 l/min using a flow meter, which was calibrated for carbon monoxide from the manufacture. To achieve a homogeneous distribution in the whole stable, a special ventilation-system[a] consisting of an inlet, a main-distributor, 8 by-distributors and 24 well defined vertical outlets, was used. The inlet air from the centre of the stable is sucked continuously through a dust filter into the ventilation system. The tracer gas injection is placed directly after the inlet ventilator into the turbulent air stream. The volume flow of the inlet ventilator (100 m^3 stable air/h) is controlled by a calibrated measurement fan. The gas-tight distributor tubes are fixed together by gas-tight zippers, easily adjustable to a stable's layout. The 24 outlets are designed for 250 l/h each. The defined outlet design is achieved by a special lacer perforation technique. For tracer gas detection nine carbon monoxide detectors[b] (0 to 100 ppm) and transmitters (4 to 20 mA outlet) have been used. The sensors are directly mounted in the stable. The data acquisition was simultaneously carried out at all nine sampling points. The signals were sent via cable to a computer mounted in a service container next to the stable.

Control and processing of the whole system was designed under some safety a-

[a] CO-sensor: MK 174-2, transmitter: EC24, Inc. GfG, Dortmund, Germany
[b] NLI Polyester, Inc. Airquell, Herzogenaurach, Germany

Table 1: Key data of the dairy cow stables

	Dairy 1	Dairy 2
number of animals	103, German Black Pied	85, German Simmental
housing type	cubicle loose housing, with solid floor integrated milking parlour	paddock and corral, with perforated floor separate milking parlour
l • w • h	54,4 • 26,4 • 10,2 [m]	45,6 • 29,0 • 10,6 [m]
manure system	manure scrubber	slatted concrete floor
ventilation	ridge ventilation with large area curtains (climate controlled)	ridge ventilation with large area curtains (manually controlled)
feeding	partly-TMR with feed mixer and tractor, 2 concentrate feeders	TMR with feed mixer and tractor, group feeding

Fig. 1: Total view of the system for continuous homogenous tracer gas injection in a fattening bull stable

Fig. 2: Sectional view of the system for tracer gas injection with main-distributor, by-distributor and two vertical outlets

spects. The tracer gas injection was interrupted automatically by the following errors: broken sensor, broken cable, circuit break down, CO concentration over 25 ppm (MAK-Value). A reconnection only was possible manually.

The simultaneous gas detection was done with a photo acoustic multi gas analyzer[c] and an own multi point sampling system. The sampling of the stable air run continously at the nine sampling points and from there through heatable tubes to the service container. For each sampling point the concentrations of ammonia, nitrous oxide, carbon monoxide, carbon dioxide, methane and water vapour were determined. One sampling interval to measure all those six compounds at one sampling point lasted three minutes [6].

Results and discussion

Mean air exchange rates and mean emission rates for the two dairy cow stables are listed in *table 2*. The results stress the high variability of the data.

As the results show, the traces gas method records the air exchange rate in a wide range and is suitable for different housing types and stables of different size. Combined with the simultaneous gas detection at nine sampling points the emission rates of different gases can be calculated. Despite the relative long measurement time of five days, in comparison to other published emission rate measurements, some seasonal works or special weather situations affect the results quite strongly. These effects result in the high standard deviations listed above. Examples are long and strong winds from the eastern direction (dairy 1) and pumping of manure into the under-floor manure storage (dairy 2).

Investigations from [7] about the emission from several naturally ventilated dairy stables show for three comparable housing systems during warm temperatures tendentiously higher emissions rates for ammonia (1629, 2000 und 5066 mg•LU^{-1} h^{-1}) and methane (16291, 24750 and 26600 mg•LU^{-1} h^{-1}). The emission rates of nitrous oxide are smaller (13,3 <14,1 und 230 mg•LU^{-1} h^{-1}). [5] calculate mean ammonia emission rates for a comparable dairy farm with manure scrubber in the range of 1.316 mg•LU^{-1} h^{-1}. Emission rates also cited in this paper for other dairy cow housing systems are 1820 and 1930 mg•LU^{-1} h^{-1}.

By now, the absolute values of the emission rates in *table 2* are not suitable as a mean annual emission rate. Firstly the measurements have not been carried out during different seasons. Secondly the weather effects and seasonal works inside the stable and at the manure storage mentioned above have strong effects on the emission potential of the stables. To minimize these effects the measurements should be realized even longer, but this will cause higher costs. Therefore a method for estimating the air exchange rate is tested, combining the local meteorological time series and measurement data.

Nevertheless the method is suitable to determine emission rates from stables with natural ventilation. Developing a radio based data transmission [2, 8] would improve the flexibility of the system and reduce time for installation.

Table 2: Mean air exchange rates with minimum and maximum values and mean emission rates (mg•$LU^{-1}h^{-1}$) for ammonia, nitrous oxide and methane for two dairy cow stables

	dairy 1	dairy 2
mean air exchange rate (min – max) [h^{-1}]	14,1 (2,7 – 53,7)	9,8 (2,5 – 24,5)
mean emission rate NH_3 [mg • LU^{-1} h^{-1}]	1551 ± 657	1656 ± 805
mean emission rate N_2O [mg • LU^{-1} h^{-1}]	581 ± 327	628 ± 246
mean emission rate CH_4 [mg • LU^{-1} h^{-1}]	18926 ± 9253	16998 ± 5662

[c] Multi gas monitor, model 1312 A-5, Inc. Innova, Ballerup DK

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