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Decrease of methane emissions by slurry aeration in a pilot plant

In barns for fattening pigs the main origin of methane is the slurry store under the slatted floor. Furthermore it is one of only a few selective sources of greenhouse gases in the agriculture and so on best suitable for decreasing the emissions of these gases. With a developed pilot plant the conditions in the animal barn were simulated. About 70 % of the methane emissions were decreased by slurry aeration in the pilot plant. The air flow for the lowest emissions was given with 7,2 m^3 air per m^3 slurry and day.

Keywords
Emission, methane, slurry aeration, ammonia

Abstract
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AMON et al. [2] have achieved a reduction of the methane emissions by 40 % aerating the slurry. The aeration took place intermittently with 1-3 m^3 air per m^3 slurry and day. STEINFELD et al. [8], too, observed decreasing methane emissions under aerobic conditions. Data about the decreasing potential under aerobic conditions or about the optimal air flow are missing. Furthermore the used plants couldn't be copied in the run experiments due to missing details and due to other issues of the reported work. Therefore, a pilot plant has to be develop for the planned trials in order to check the dependence of the emissions on different parameters. By this means a basic knowledge for the plant trials has been worked out.

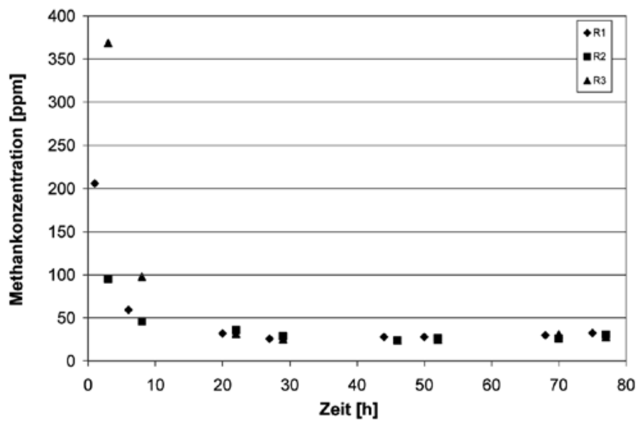
Material and methods

Pilot plant. For the trials in small scale a pilot plant has been developed consisting of three reaction vessels and a analytical equipment **(fig. 1)**. Each vessel was a 1,5 m long vertical PVC-pipe with a diameter of 16 cm closed on both sides with a plug. The air was pressed through 19,0 l slurry via two porous stones 12 cm above the bottom. Four cocks on the pipe make a fast and easy discharge of the slurry after the trials possible. Above the slurry were four valves in the plug and four valves in the pipe

Fig. 1

Pilot plant

Fig. 2



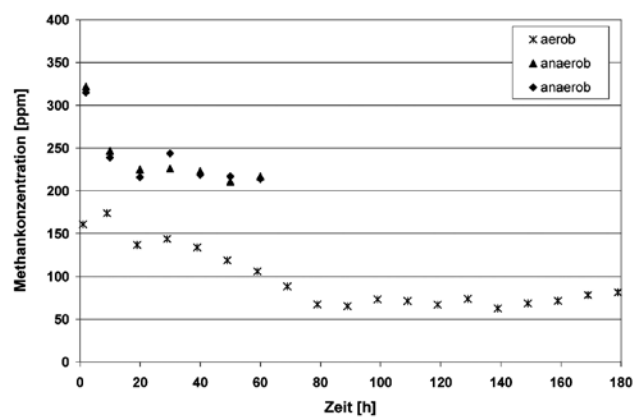
Test for reproducability in the pilot plant under aerobic conditions

40 cm below the plug. They were used for pressure adjustment and for analytical purposes.

The gas flow was controlled by an arrangement or a filter, a pressure reducing unit and a regulating device. So particals and water drops have been eliminated from the air. The fine pores in the porous stones were not closed. The air pressure could be varied from 10,0 to 1,0 bar and the flow from 2,5 to 5000 ml min^{-1}. The measurement has been controlled by hand or by magnetic devices via a software depending on the trial. The gas detector 1312 of the company LumaSense Technologies has been used for the analysis. It is run on the basis of ir-spectroscopy which has been proven in former works [5].

Reproduceability. Firstly the plant has been checked for reproduceability in two from each other independent runs. The methane concentrations versus time with a air flow of 800 ml min^{-1} at room temperature is plotted in **fig. 2**. The figures of all three reaction vessels (R1, R2, R3) are very close together and can be represented by one curve. Furthermore the variation coefficient amounts 10,7 % and the measuring error of the figures is 2,9 %. Therefore the plant delivers reproducible results and can be used to clarify the issues above mentioned.

Fig. 3



Concentration of methane depending on time, air or nitrogen flow of 800 ml min^{-1}, room temperature

Table 1

Characteristic of the aerobic and anaerobic slurry reactions in the pilot plant producing methane

carrier gas	characteristic figures	
	C_{konst} [ppm]	m_{1d} [mg]
air	70	52
nitrogen	212	159
nitrogen	215	161

Aerobic and anaerobic conditions. The three reaction vessels has been filled with 19,0 l slurry, the gas detector has been connected, one of the reaction vessels has been aerated with air and the other two has been run with nitrogen with a flow of 800 ml min^{-1}at room temperature. The gas detector recorded the methane concentration in both gases online in fixed times. The constant methane concentrations of the curve $c_{konstant}$ and the developed mass of this gas m_{1d} are defined as characteristic figures. They are given in **table 1**.

Variation of the air flow. Each of the three reaction vessels has been filled with 19,0 l slurry. The air flow was varied from 10 to 4000 ml min^{-1} in seven steps at room temperature. At the low air flow of 10 and 50 ml min^{-1} the gas to be analyzed has been collected with a bag that has been connected with a valve directly above the slurry surface and was filled up with the air stream. At the higher air flow the gas to be analyzed has been taken from a valve on the top plug. Details of the trial condition and the results are given in **fig. 4 and 5**.

Results and discussion

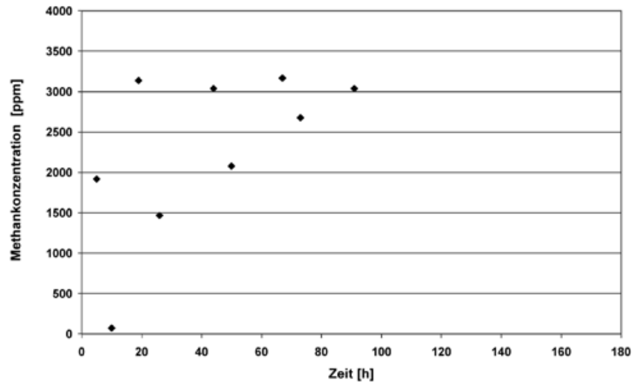
Aerobic and anaerobic conditions. In **fig. 3** the methane concentrations under aerobic and anaerobic conditions are plotted versus the time. Under aerobic conditions the concentrations run into a constant curve section at about 70 ppm. In opposite they figure much higher around 210 ppm at the same gas flow under anaerobic conditions. This difference is in agreement with reports published [1], [2], [3] and [6]. In addition the positive effect of the aeration is demonstrated by the characteristic figures in **table 1**. Changing the anaerobic to aerobic conditions the emission is cut down from about 160 to about 50 mg d^{-1} corresponding with a decrease of 70 %.

Variation of the air flow. Varying the air flow an optimal flow has been found for minimizing the methane emissions. In **fig. 4** the daily emissions are plotted versus the air flow. As expected the methane emissions are increasing with an increasing air flow. This increase amounts almost to 100 %, if the air flow increases from 1200 to 4000 ml min^{-1}. In addition **fig. 5** demonstrates strongly spreading figures by a low stream of 10 ml min^{-1}. A continuously curve cannot be plotted. This effect can be explained by mixed conditions of aerobic and anaerobic areas. THAER (1978) [5], too, reported not controllable emissions under such mixed areas. The optimal air flow has to be picked at the lowest producing homogenous aerobic conditions, in order to make sure minimal emissions. Using a flow of 100 ml min^{-1} this demand could be met. It is the basis for the calculation of 300 l air per m^3 slurry and hour later in the plant trial.

Conclusion and outlook

Using the developed pilot plant reproducible figures could be achieved and conditions in the plant could be well simulated. Aerobic and anaerobic conditions have been adjusted by using different carrier gases. With a methane decrease of 70 % at aerobic conditions a positive effect of the slurry aeration could be demonstrated. By varying the air flow mixed areas have been found at low flows that was not controllable. Very high flow rates increased the methane emissions. Therefore the design of the air flow in the stable has to be constructed in this way that a homogenous aeration of the total volume and aerobic conditions is made sure. Basis for the calculation should be the flow of 100 ml min^{-1} found in the pilot plant empirically.

Fig. 5



Concentration of methane depending on time with 10 ml min^{-1} air flow

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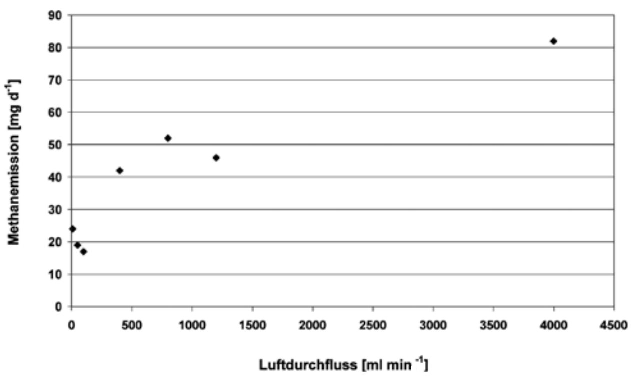
Fig. 4



Emissions of methane depending on different air flows

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