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Manure management: Effects on the ammonia and methane emissions in a piggery

Manure management inside a piggery influences emissions of ammonia and methane. Knowledge on reduction potential and mitigation measures is insufficient. This project compared two treatments: weekly manure removal and manure surface cover with floating bodies against the reference system deep pit. Measurements covered a full fattening period. This paper describes the approach and gives preliminary results on the pros and cons of both emission mitigation strategies.

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Abstract
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Manure management inside a piggery influences emissions of ammonia and methane. So far, there is insufficient knowledge regarding reduction potential and mitigation measures. This project compared two treatments: weekly manure removal and manure surface cover with floating objects, both compared with a deep pit reference system. Measurements covered a full fattening period. This paper describes the approach and gives preliminary results on the pros and cons of both emission mitigation strategies.

Contrary to the management of dairy cattle whereby the majority of methane emissions come from the animal itself, methane emissions in feeding pig production come mainly from the animal excrement which, conventionally, is stored beneath the slatted flooring of the housing [1]. Concerning the influencing of methane and ammonia emissions by different manure management strategies within the housing, no concrete statement on an optimal approach has been possible so far. Amongst the potential management strategies may be included the regular emptying of the manure from the underfloor storage capacity, or the covering of the liquid manure surface [2, 3, 10].

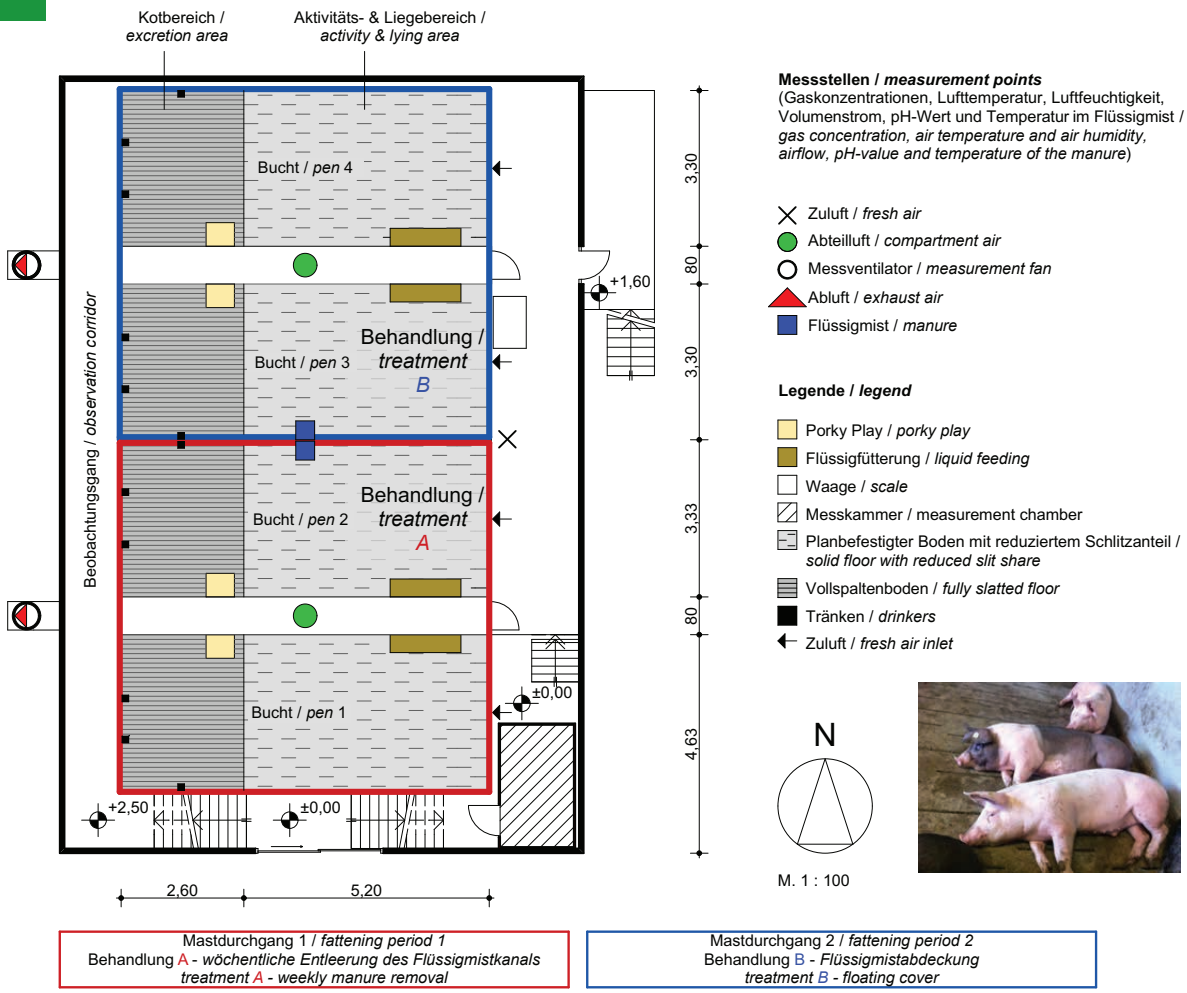
Primarily, the level of the manure in the holding area influences methane emissions whereby the ammonia emissions are not influenced by this factor [4, 5]. It has been shown that daily removal of manure [6], or twice daily flushing of the manure holding area [7], can reduce both methane and ammonia emissions. Such findings are confirmed by trial results from Meissner [3]. In this case, through daily or twice-daily flushing using flush channels with biologically treated flushing liquid, ammonia emissions could be significantly reduced (by 10–50 %), and methane emissions too (60–90 %). Ammonia emissions can be influenced to a great extent by reducing the exposed surface area of the manure [8], although only limited experience and results exist so far from covering the surface of stored manure in animal housing. In one experiment [9], for example, curtains were fitted under the slatted floor to reduce the area of manure surface in direct contact with the ventilation system air currents. Even this action led to a reduction of between 2–20 % in ammonia emissions.

The aim of this study was to investigate the potential of as easy as possible to apply management strategies for liquid manure handling in pig housing.

Housing and animals involved in the experiment

Trials took place in a feeding pig barn with two compartments on the Agricultural Sciences Experimental Station at the University of Hohenheim. One compartment with two pens served as an experimental compartment (treatment A – weekly liquid manure release; treatment B – covering of liquid manure surface). In the other compartment the two pens acted as reference areas R with liquid manure underfloor (stored liquid manure) retained there throughout the entire batch feeding cycle of approx. 105 days. The treatment A (weekly emptying of liquid manure channel) was selected to minimise labour requirement and to ensure a minimum amount of liquid manure in the channel for an acceptable degree of emptying. Naturally, daily emptying of the liquid manure channel offered a higher emission reduction potential. In this investigation the aim was to discov-

Fig. 1



Floor plan from the experimental stable and array of the measurement points (Photo: S. Gronow-Schubert)

er whether weekly emptying also offered effective emission reduction. The trial compartment and the reference compartment were changed-over following the first batch feeding cycle (trial). Both trials followed an all-in, all-out system with 50 pigs in each compartment (genetics: German Landrace x Pietrain) housed in two pens per compartment at 25 pigs per pen. Starting weight was approx. 28 kg. Each animal had around 1 m^2 floor space. One-third of the concrete flooring in both compartments comprised concrete flooring with slits with reduced interspaces representing around 6% of the area and two-thirds comprised conventional slats with spaces representing approx. 14% of the respective area (referred to as fully slatted flooring).

Every pen had its own manure tank (depth: 1.20 m, breadth: 3.30 m, length: 7.80 m) and maximum storage volume 20 m^3. Fresh ventilation air was introduced into the barn interior from porous ducts and was extracted underfloor in each compartment. The feeding was via sensor-controlled liquid feeding system with 12 feeding periods daily between 6 am and 10 pm. Drinking water for the animals was available ad lib with three drinkers per pen.

To a great extent, ceteris paribus was achieved in housing conditions and adjustments in ventilation and feeding. This also applied to feeding performances in both compartments (treatment and reference) (**Table 1**). Ration composition differed only slightly between the batch feeding cycles and the compartments. A nitrogen-adjusted 3-phase ration was fed following good management practice. The recorded daily weight gain hardly differed between both treatments and this also applied to the intake and exit weights of the pigs. The recorded state of dirtiness showed that, through both feeding cycles, the function areas (activity and lying; dunging) in both compartments were conventionally used in all four pens. The animals accepted the pen restructuring with different flooring surfaces and deposited their faeces and urine mainly in the predetermined dunging area. This was a fundamental requirement for the second trial (treatment B).

Experiment method

Weekly emptying of the liquid manure channel

For the period of the first feeding cycle (14 weeks) from beginning of August to mid-November 2013, weekly removal of

Table 1

Experimental conditions in both fattening periods resp. treatments

Parameter/*parameter*		Wöchentliche Entleerung des Flüssigmistkanals *Weekly manure removal* 05.08.2013–19.11.2013 Behandlung A/*Treatment A*			Abdeckung der Flüssigmistoberfläche *Floating cover* 16.01.2014–22.04.2014 Behandlung B/*Treatment B*		
		Tage/*Days* N	Mittelwert *Mean*	± SA ± *SD*	Tage/*Days* N	Mittelwert *Mean*	± SA ± *SD*
T_{Zuluft}/$T_{fresh\ air}$ [°C]		97	15,8	5,2	87	9,6	3,2
RH_{Zuluft}/$RH_{fresh\ air}$ [%]		97	72,3	9,7	87	63,0	9,2
T_{innen}/T_{indoor} [°C]	Behandlung/*treatment*	97	20,7	3,5	87	18,2	1,3
	Referenz/*reference*	97	20,5	3,6	87	18,5	1,3
RH_{innen}/RH_{indoor} [%]	Behandlung/*treatment*	97	63,8	6,07	87	60,8	4,7
	Referenz/*reference*	97	71,7	5,9	87	56,7	5,8
V_{strom} [$m^3\ h^{-1}$ Tier^{-1}] V_{flow} [$m^3\ h^{-1}$ *animal*$^{-1}$]	Behandlung/*treatment*	97	58,1	9,6	87	49,4	8,6
	Referenz/*reference*	97	60,0	7,1	87	47,2	9,0
Mastparameter *Fattening parameters*		SG/*SW* [kg]	EG/*EW* [kg]	TZ/*DWG* [g]	SG/*SW* [kg]	EG/*EW* [kg]	TZ/*DWG* [g]
	Behandlung/*treatment*	1398	5448	780	1508	5451	800
	Referenz/*reference*	1392	5402	770	1482	5449	810

T = Temperatur/*temperature*
RH = relative Luftfeuchtigkeit/*relative humidity*
V = Volumenstrom/*air flow*
N = Stichprobenumfang/*sample size*
SA = Standardabweichung/*SD = standard deviation*
SG = Startgewicht/*SW = start weight*
EG = Endgewicht/*EW = end weight*
TZ = tägliche Zunahmen/*DWG= daily weight gain*

the manure (treatment A) was compared over the entire feeding cycle with storage of the manure under the slats (reference – R). Weekly removal of manure took place via two drainage plugs in the floor of the manure channel. Following release of the manure, no additional flushing was carried out with water or by using manure with a higher liquidity. As a result, the channel floor remained covered with a small remaining amount of manure.

Covering the manure surface area

Investigated mid-January to end of April 2014 in the second feeding cycle was covering of the manure surface (treatment B) beneath pen areas with flooring of reduced slat interspacing. These served as activity and lying areas for the animals. Applied for covering the manure surfaces were hexagonal plastic floats (brand: Hexa-Cover®) diameter Ø = 18 cm (**Figure 2**).

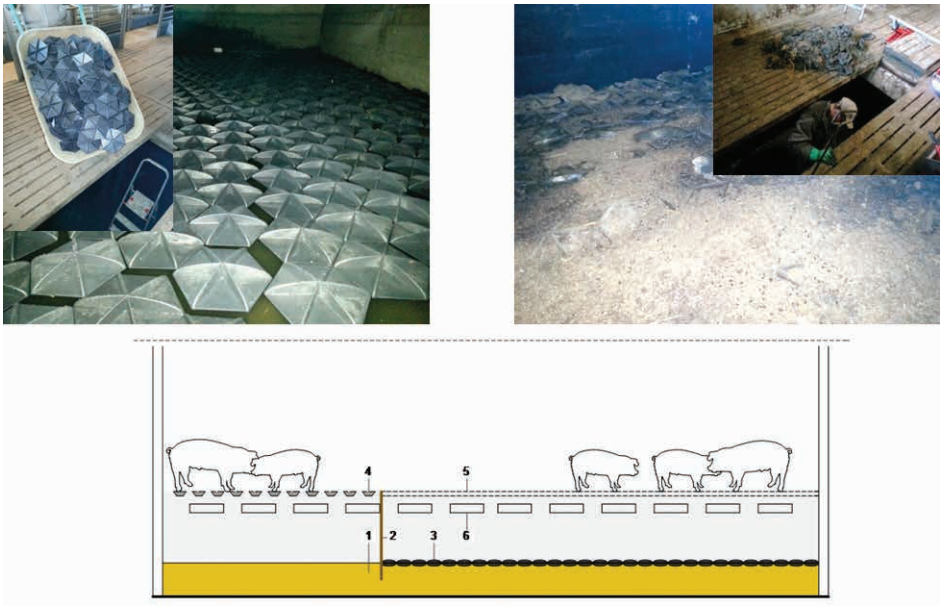
No Hexa-Cover® floats were placed on the manure surface beneath the $^1/_3$ fully slatted floor area (dunging area). A barrier of wooden planks was placed in the manure channel to stop free movement of the floats whereby a gap of 10 cm from the manure channel bottom and the plank barrier remained open so that the liquid manure level underneath the entire pen could rise uniformly. At the beginning of the feeding cycle water was poured into all four underfloor liquid manure channels within the trial housing to a depth of 10 cm (R).The establishment of this depth of water was necessary for the independent movement and positioning of the Hexa-Cover® floats in trial pens 3 and 4 (treatment B) (**Figure 1** and **2**).

Recording equipment

The concentrations of ammonia (NH_3), carbon dioxide (CO_2) and methane (CH_4) in the fresh air inlet, compartment air and exhaust air were quasi-continuously recorded with the Multigasmonitor 1412 from LumaSense™ Technologies (Denmark) applying photoaccoustic recording. The Multigasmonitor was linked with the appropriate Multiplexer 1309 from LumaSense™ Technologies. For a secure statistical evaluation it was important that the sampling of the five measurement points be randomised. For this, a measuring point sequence is inserted in the control software including a random generator. Following each feeding cycle, a zero point and humidity interference calibration via Multigasmonitor was carried out by the author and the gases ammonia, carbon dioxide and methane calibrated in moist condition.

Within the calibrations regular comparative measurements were conducted with an FTIR (Fourier transform infrared spectroscopy). Recording and assessment of potential nitrous oxide (N_20) emissions were not carried out in this study as there was no reliable method available for sufficiently precise recording of nitrous oxide levels. For the continuous recording of air temperature and relative air humidity, a digital sensor (Ahlborn, Germany) was used per measurement point. The determin-

Fig. 2



Coverage of the manure surface with Hexa-Cover® floating bodies. Status before (top left) and after (top right) the fattening period. Cross section of the compartment (below: 1 = manure, 2 = wodden post, 3 = Hexa Cover®; 4 = fully slatted floor, 5 = solid floor with reduced slit share, 6 = slits for underfloor extraction in the concrete wall (Photos: S. Gronow-Schubert)

ing of the separate airflows for treatment A and treatment B took place via measurement fans (Multifan, Netherlands) built into the two exhaust air shafts. For measurement of temperature and pH on the manure surface a digital combisensor (Endress+Hauser, Germany) was installed so that, with the help of a specially made wooden beam, it remained floating on the manure surface. In 14-day rhythm all 100 pigs were individually weighed and samples taken for manure analyses (Kjel-

Table 2

Manure parameter in both fattening periods resp. treatments

Parameter/*Parameter*		**Wöchentliche Entleerung des Flüssigmistkanals *Weekly manure removal* 05.08.2013–19.11.2013 Behandlung A/*Treatment A***			**Abdeckung der Flüssigmistoberfläche *Floating cover* 16.01.2014–22.04.2014 Behandlung B/*Treatment B***		
		N Tage/*Days*	**Mittelwert *Mean***	**± SA ± *SD***	**N Tage/*Days***	**Mittelwert *Mean***	**± SA ± *SD***
$T_{Flüssigmist}$/T_{slurry} [°C]	Behandlung/*treatment*	6	17,0	1,2	47	15,7	0,4
	Referenz/*reference*	43	17,5	1,7	63	14,9	0,7
$pH_{Flüssigmist}$/pH_{slurry}	Behandlung/*treatment*	6	7,6	0,3	47	7,2	0,5
	Referenz/*reference*	43	7,4	0,2	63	7,6	0,3
Trockenmasse/*Dry matter* [g kg^{-1}]	Behandlung/*treatment*	12	9,1	3,0	14	1,5	0,9
	Referenz/*reference*	12	5,5	2,2	14	3,8	2,8
Gesamt N in FS/*Total N in FM* [g kg^{-1}]	Behandlung/*treatment*	12	5,9	0,9	14	2,8	1,3
	Referenz/*reference*	12	5,1	1,1	14	3,9	2,0
NH_4-N in FS/*NH_4-N in FM* [g kg^{-1}]	Behandlung/*treatment*	12	2,7	0,5	14	2,4	1,1
	Referenz/*reference*	12	3,2	0,7	14	2,7	1,4
Anteil NH_4-N an Gesamt N *Percentage of NH_4-N in Total N* [%]	Behandlung/*treatment*	12	46,1	11,3	14	82,1	6,3
	Referenz/*reference*	12	64,9	15,5	14	68,6	11,7
Flüssigmistpegel/*Slurry level* [cm]	Behandlung/*treatment*	12	Start/*start*: 7	Ende/*end*: 5	14	Start/*start*: 10	Ende/*end*: 52
	Referenz/*reference*	12	Start/*start*: 10	Ende/*end*: 51	14	Start/*start*: 10	Ende/*end*: 60

T = Temperatur/*temperature*
FS = Frischmasse/*FM = fresh matter*
N = Stichprobenumfang/*sample size*
SA = Standardabweichung/*SD = standard deviation*

Table 3

Ammonia and methane concentrations and emissions in both fattening periods resp. treatments

Messstelle *Measurement point*	**Parameter** */parameter*	**Wöchentliche Entleerung des Flüssigmiskanals** *Weekly manure removal* 05.08.2013 - 19.11.2013 **Behandlung A** */Treatment A vs. reference R*			**Abdeckung der Flüssigmistoberfläche** *Floating cover* 16.01.2014 – 22.04.2014 **Behandlung B** */Treatment B vs. reference R*		
		N Tage */Days*	**Mittelwert** *Mean*	**± SA** *± SD*	**N Tage** */Days*	**Mittelwert** *Mean*	**± SA** *± SD*
Zuluft *Fresh air*	NH_3-Konzentration [ppm] *NH_3 concentration [ppm]*	A 105 R 105	A 1,3 R 1,3	A 0,3 R 0,3	B 89 R 89	B 2,2 R 2,2	B 0,6 R 0,6
	CH_4-Konzentration [ppm] *CH_4 concentration [ppm]*	A 105 R 105	A 1,8 R 1,8	A 2,2 R 2,2	B 89 R 89	B 2,8 R 2,8	B 0,8 R 0,8
Abteilluft *Compartment air*	NH_3-Konzentration [ppm] *NH_3 concentration [ppm]*	A 105 R 105	A 2,6 R 2,6 n.s.	A 1,4 R 0,8	B 89 R 89	B 3,7 R 4,7 s.	B 1,1 R 2,2
	CH_4-Konzentration [ppm] *CH_4 concentration [ppm]*	A 105 R 105	A 2,9 R 3,0 n.s.	A 2,9 R 2,8	B 89 R 89	B 5,3 R 4,8 s.	B 1,3 R 1,2
Abluft *Exhaust air*	NH_3-Konzentration [ppm] *NH_3 concentration [ppm]*	A 105 R 105	A 11,5 R 10,8 n.s.	A 3,6 R 3,0	B 89 R 89	B 12,2 R 12,8 n.s.	B 2,7 R 3,3
	CH_4-Konzentration [ppm] *CH_4 concentration [ppm]*	A 105 R 105	A 3,8 R 5,9 s.	A 3,4 R 2,4	B 89 R 89	B 11,3 R 6,8 s.	B 4,3 R 1,8
	NH_3-Emissionsrate [g Tag^{-1} GV^{-1}] *NH_3 emission rate [g d^{-1} LU^{-1}]*	A 87 R 87	A 60,2 R 60,8 n.s.	A 10,0 R 9,3	B 82 R 82	B 63,2 R 72,9 s.	B 11,5 R 31,3
	NH_3-Emissionsfaktor [kg $Tierplatz^{-1}$ $Jahr^{-1}$] *NH_3 emission factor [kg animal $place^{-1}$ $year^{-1}$]*	A 87 R 87	A 3,0 R 2,9 n.s.	A 0,8 R 0,6	B 82 R 82	B 2,9 R 2,8 n.s.	B 0,8 R 0,8
	CH_4-Emissionsrate[g Tag^{-1} GV^{-1}] *CH_4 emission rate [g d^{-1} LU^{1}]*	A 87 R 87	A 18,4 R 29,5 s.	A 15,9 R 13,8	B 82 R 82	B 48,9 R 24,1 s.	B 21,2 R 9,4
	CH_4-Emissionsfaktor [kg $Tierplatz^{-1}$ $Jahr^{-1}$] *CH_4 emission factor [kg animal $place^{-1}$ $year^{-1}$]*	A 87 R 87	A 0,7 R 1,3 s.	A 1,3 R 0,3	B 82 R 82	B 2,3 R 1,0 s.	B 1,2 R 0,4

N = Stichprobenumfang/*sample size*
n.s. = nicht signifikant/*not significant*
s. = signifikant***, Mittelwertunterschiede zwischen Behandlung und Referenz (U-Test nach Mann und Whitney, $p < 0,05$)/*significant***, mean deviation of the treatment and the reference (Mann-Whitney U test, $p < 0.05$)*
SA = Standardabweichung/*SD = standard deviation*
GV = Großvieheinheit/*LU = livestock unit*
Jahr = 330 Tage/*year = 330 days*
R = Referenzabteil/*reference compartment*

dahl nitrogen analysis, dry matter content, organic dry matter content and potassium and phosphate contents). Sampling the manure took place from each pen always at the same point. Despite this, the manure inhomogeneity means it is barely possible to achieve representative samples in the classical sense without upsetting the manure composition and structure as well as stabilization of the manure as emission source. Recording a profile of the dirtiness of the four pens took place on a weekly basis.

Results and discussion

Manure parameters

The manure parameters differ between the two variants particularly regarding dry matter, total nitrogen and proportion of

NH_4-N in total nitrogen in fresh material, but can only serve as reference points for the above reasons (**Table 2**). Additionally, it should be noted that with treatment A, with weekly removal of the liquid manure channel, the level of the stored manure never rose above 7 cm depth, which additionally made sample taking more dificult. The low level of manure is also the reason for the limited number of pH and temperature samples (N) on the manure surface in treatment A that could be recorded by the digital sensors.

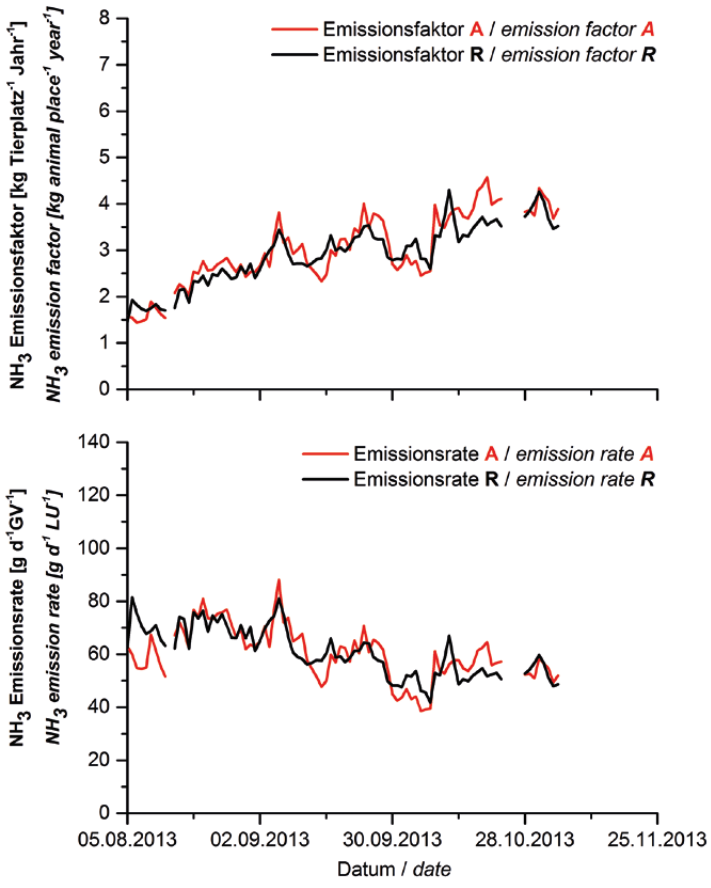
Influence of weekly emptying of the liquid manure channel on ammonia and methane

Compared in **Table 3** are NH_3 and CH_4 concentrations in the intake air, in the air of both compartments, and in the exhaust air as well as the emission rates and emission factors for both feeding cycles and variants.

The NH_3 concentrations did not differ significantly over the entire feeding period at all measurement points and are comparable with results of previous measurements in this experimental pig barn [10; 11]. The NH_3 concentrations in the interior (A and R: 2.6 ppm) are assessed as very low compared to another study [12]. In this experiment the ammonia emissions remain unaffected through emptying of the liquid manure channel at only weekly periods (A: 60.2 g per day and livestock unit; R: 60.8 g per day and livestock unit; **Figure 3**). This agrees with other trial results whereby it was established that the height of the liquid manure surface [4], as well as the interior space above the recorded surfaces [9], have no influence on ammonia emissions. An appreciable ammonia reduction was able to be shown in experiment [7], whereby the liquid manure was removed very often (1–2 times daily) and the channel was additionally flushed (ammonia emissions reduced by 13–29 %). This could also be observed in [3,] where ammonia emissions were reduced by 10-40 % through once or twice daily flushing.

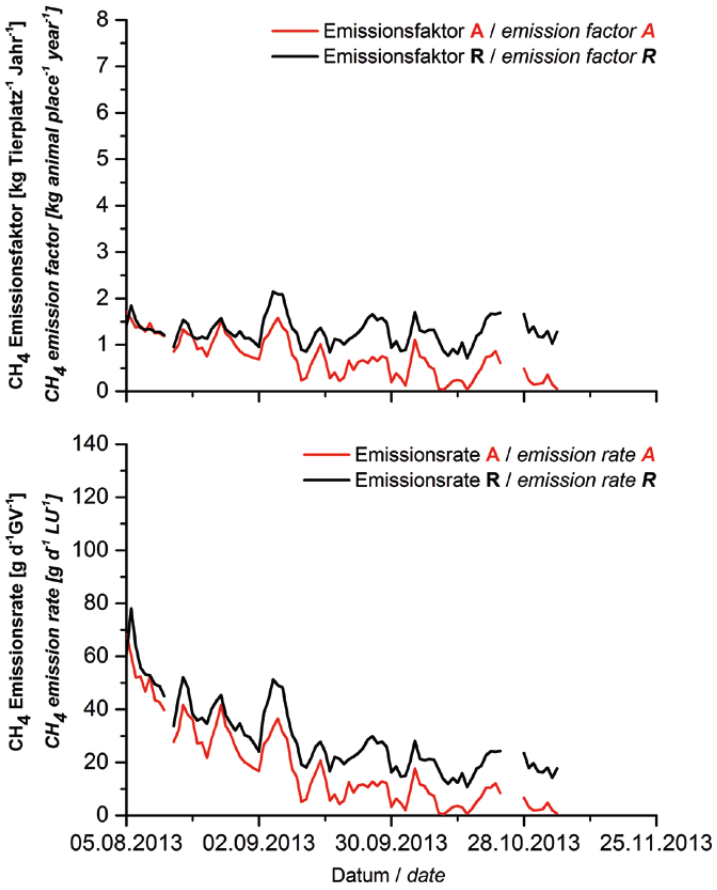
One explaination for the significant differences in CH_4 concentrations in the exhaust air (A: 3.8 ppm; R: 5.9 ppm; -36 %; **Table 3**) and the CH_4 emission rates (A: 18.4 g per day and livestock unit; R: 29.5 g per day and livestock unit; -38 %; **Figure 4**) is the weekly emptying of the liquid manure channel and the associated marked reduction of fermentable substances, which otherwise would have been available for methane production [13]. With [13], the entire manure storage area under the slats was washed out and disinfected after every feeding cycle. These measures alone slowed down the methane production during the feeding period compared with the investigations of [10], where no such measures were carried out. Through twice daily flushing with the more liquid proportion of the manure, an emission reduction of 26–46 % could be achieved [7]. There ex-

Fig. 3



NH_3 emission rates and NH_3 emission factors for the treatment A with weekly manure removal and reference R

Fig. 4



CH_4 emission rates and CH_4 emissions factors for the treatment A with weekly manure removal and reference R

ists a direct association between the amount of liquid manure present and the methane emissions occuring in the barn. In the trials from [3], methane emissions could be reduced by as much as 60–90 % through regular flushing.

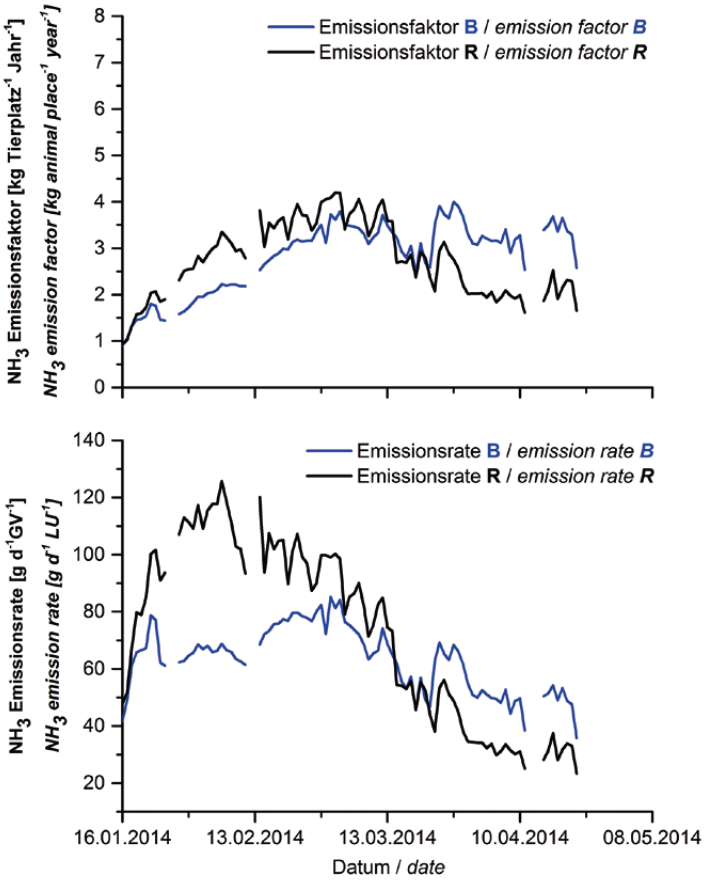
In the experiment reported here, (treatment A) the regular emptying of the liquid manure channel only influenced the methane emissions and not the ammonia emissions, as already stated above, which is a different result from Meissner [3] and Guingand [7]. In comparison with the results from Gallmann [10], where the range in the emission rates lay between 68-134 g per day and livestock unit in a fully slatted system and [11] (range: 33–73 g per day and livestock unit), the methane emission rates are low in total and fit with the results from [10] which, with a production system with separate climate areas and free shaft ventilation (range of emission rate: 17–36 g per day and livestock unit). In similar recording periods (autumn `99 and `00) almost the same emission rates as in this experiment were observed (24 and 36 g per day and livestock unit). The reduction of methane emission rates during progress of the feeding period can be explained by the animal liveweight (LU) reference values.

Influence of manure covering

Ammonia concentrations in the compartments differed significantly (B: 3.7 ppm; R: 4.7 ppm), whereby the exhaust air concentrations (B: 12.2 ppm; R: 12.8 ppm) remained uninfluenced (**Table 3**). Based on the NH_3 emission rates (B: 63.2 g per day and livestock unit; R: 72.9 g per day and livestock unit; **Figure 5**), covering the manure surface resulted in a 13 % reduction in emissions. The progress of NH_3 emission rates reduction is explained through the selected reference values, i.e. the increasing animal liveweight based on livestock units. The emission reductions can be attributed to the fact that, because of the covering of $^2/_3$ of the liquid manure surface with Hexa-Cover® floats under the solid flooring of the pen, only $^1/_3$ of the total surface of the liquid manure is open to the air volume flow (**Figure 2**) [8; 9; 14]. Ammonia emission rates from treatment B were also lower in comparison to Gallmann [10] and Häußermann [11] in the fully slatted system (emission rate range: 100–149 g per day and livestock unit and 94–130 g per day and livestock unit). Looking at the results from the production system with separate climate area and free shaft ventilation from [10] in the same recording period (spring: 92.7 g per day and livestock unit), the values recorded from that trial also lie below.

Methane concentration results show clearly that, as described in [1], manure represents the main emission source for methane. The compartment concentrations in B: 5.3 ppm compared with R: 4.8 ppm, while differing significantly from one another, do not differ as markedly as the exhaust air concentrations B: 11.3 ppm and R: 6.8 ppm (**Table 3**). Based on the

Fig. 5



NH_3 emission rates and NH_3 emission factors for the treatment B with floating cover and reference R

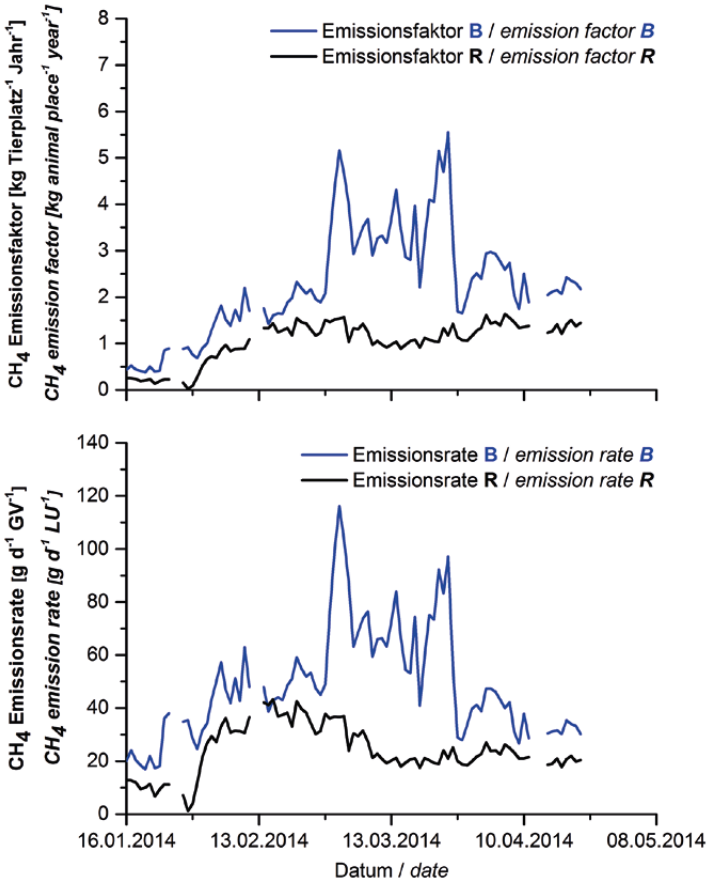
emission rates (B: 48.9 g per day and livestock unit; R: 24.1 g per day and livestock unit) the values differ by around + 50 % in the treatment (B), compared with the reference compartment (R) as presented in **Figure 6**. The cause of this marked increase in emissions could be that the anaerobic conditions engendered by coverage of the manure surface (**Figure 2**) were more advantageous for methanogenesis. During the feeding cycles a layer of straw, mainly dry but partially moist, from the straw falling through the slats from the environment enrichment dispenser in the pen, plus dust and food residues, became established on the Hexa-cover® floats. All these materials, in addition to the Hexa-Cover® floats, helped increase exclusion of air from the surface of the manure (**Figure 2**). The lying area over the Hexa-Cover® area floats mainly remained clean, a situation emphasised by the dirtiness profiles already noted in the preliminary trial. However, it was not possible to completely stop the fact that excrement was produced on the activity and lying areas. These results agree with the presentation in [15] whereby covering with only natural stone granulate Pergülit™, clay granulate Leca™ , or straw also led to an increase in methane emissions, although not under barn conditions. If one takes for comparison the trial results from [10] in the housing system with separate climate compartments during the same recording period (spring: 18 g per day and livestock unit), it can be established that the results from the reference compartment (R: 24 g per day and livestock unit) are similarly high. However, these results from the experiment compartment (B: 48 g per day and livestock unit) deviate markedly. The reduction of the emission rates over the entire feeding period was also here attributed to the animal liveweight (LU) reference values. Up until now, no sufficiently acceptable explanations could be found for the existence of the peaks. The reference system differences between treatment A and B are explained by the seasonal influences during test periods (A = summer/autumn; B = winter/spring).

Where the liquid manure surface in the pig housing is covered, the influence of added faeces and urine is to be considered. Hereby, natural covering materials – as opposed to the floats used – are susceptible to increased biological degradation [3] which in turn influences the emission process. Results from studies [15; 16; 17] concerning the covering of liquid manure containers outdoors are, therefore, not 1:1 transferrable onto trials within pig housing.

Conclusions

The tested reduction strategies were able to partially reduce ammonia and methane emissions (treatment A – weekly emptying of the liquid manure channel: emission reduction with

Fig. 6



CH_4 emission rates and CH_4 emission factors for the treatment B floating cover and reference R

methane by 38% based on the emission rates in grams per day and livestock unit; treatment B – manure covering: 13 % reduction for ammonia emission rates in g per day and livestock unit) but had, in part, no effect, or even a negative influence, on the emissions (treatment A – weekly emptying of the liquid manure channel; no effect on the ammonia emissions; treatment B – manure covering: 50% rise in methane emission rates in g per day and livestock unit). The selected weekly interval for the emptying of the liquid manure channel cannot be recommended as reduction strategy.

In the context of studies already conducted, these results show that in manure management it would appear to be practical in the future to combine several reduction strategies (simultaneous covering of the manure surface and regular emptying of the same). Regarding floor coverage over liquid manure surfaces, it is important that the animal function areas be clearly structured. Thus, floor covering must be presented in such a way that the animals dung only in the pen area predetermined for this.

Additionally, further studies are necessary regarding the covering of manure in the barn and the appropriate materials for this, so that reliable information regarding applicability in commercial farming can be gathered.

Observed as a whole, however, every emission reduction achieved at livestock housing level is only conducive to reaching a particular goal when emission reducing actions take place along the entire process chain (e. g. storage and field application too).

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