

MECHANICAL AND CHEMICAL TREATMENT OF SLURRY FROM PIG FINISHING UNITS TO REDUCE ODOR AND AMMONIA EMISSIONS

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ABSTRACT

Emissions of odor and ammonia from small-scale pig finishing units were reduced by 40 % as a result of mechanical and chemical treatment of the slurry. Once a week, the pits were drained, and the slurry was separated mechanically using polymers, then ozonated and finally acidified with sulfuric acid. After treatment, the slurry was reflushed into the pits to function as a carrier liquid for the finishers' continuous delivery of new material to the slurry. Between the weekly three-step treatments, the slurry was flushed out once, separated and acidified.

Experiments were carried out as a case-control study in four small experimental units, each containing 32 finishers. During the production period of two batches between March and August 2009, online monitoring of exhaust ventilation rates and ammonia concentrations was performed. Odor and hydrogen sulfide concentration were measured on 9 data acquisition days during the two production periods. There was a statistically significant reduction in odor emissions from 74 OUE/sec. per 1,000 kg of animal from the control sections to 44 OUE/sec. per 1,000 kg of animal from the sections with slurry treatment. Ammonia emissions were reduced from 0.20 to 0.12 g NH₃-N/hour per animal as a result of the slurry treatment.

KEYWORDS. Ammonia, Odor, Emission, Pig Slurry, Slurry pits, Ozone, Acid, Slurry separation

INTRODUCTION

Most of the odor and ammonia emissions from pig housing originate from the slurry (Lyngbye and Riis, 2005, in Danish). The Danish company Bio-Aqua has, in collaboration with the Pig Research Centre, Danish Agriculture and Food Council, shown that it is possible to reduce the odor emissions from pig housing by treating the slurry with ozone outside the housing facility and then reflushing the thin fraction of the treated slurry into the slurry pits (Lyngbye et al., 2008). During this process, odorous compounds are oxidized and degraded by ozone (Wu et al., 1999). Another effect of the ozone addition was that the slurry was separated. This side-effect might be one of the reasons for achieving the observed reductions, since many odorous compounds originate from the faeces. It seems reasonable that the removal of the solid fraction from the slurry before ozonation would have a dual beneficial effect. First, the ozonation process would be less ozone-consuming and faster, because the energy from the ozone was only used for degradation of odorous compounds in the thin fraction of the slurry, and not for separation. Secondly, the effect on odor reduction would be better.

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Another effect of the ozonation process was that the pH in the slurry increased to approximately 8, which probably resulted in increased ammonia emissions. Acidification of slurry is a known way to control ammonia emissions from livestock housing, with reductions in emissions reaching 70 % (Kai et al., 2008). The Danish supplier of slurry acidification systems, Infarm A/S, were involved in the development of the technology due to their knowledge of acidification of pig slurry with sulfuric acid and handling of large amounts of slurry on a daily basis.

Preliminary work showed that weekly treatment of the slurry, whereby the slurry is first separated mechanically and then treated with ozone and sulfuric acid, results in a 40 % reduction in odor emissions and a 30 % reduction in ammonia emissions from small experimental sections with finishers. The same study showed that the effect of slurry treatment on odor emissions was constant for at least a period of one week (Jonassen et al., 2009).

The aim of this study was to investigate whether the weekly three-step treatment of slurry, in combination with an additional weekly acidification of the slurry, would increase the reduction in ammonia emissions without having a negative effect on the odor reduction.

METHODS AND MATERIALS

The study was performed in four identical experimental sections at the experimental pig production facility of the Pig Research Centre, located near Grønhøj, Denmark.

Each experimental section contained two pens measuring 2.4 m x 4.8 m, each housing 16 finishers. The sections were equipped with mechanical ventilation with air intake via a diffuse ceiling and one exhaust per section. The two pens shared a simple dry feeder, and each pen was equipped with a nipple drinker. Feed was supplied *ad libitum*. The pens had fully slatted concrete flooring with 40 cm deep slurry pits below; the pens were drained through two separate pits. The ventilation rate was controlled by the room temperature, which was attempted to be maintained at 18°C. When the outdoor temperature exceeded 14°C, the pigs were cooled by water from a sprinkling system above the dunging area.

In two of the sections, the slurry was treated as described below, and in the other sections the slurry was drained once during the production period and after delivery of the finishers to the slaughterhouse. The first batch of finishers was placed in the sections on March 3 and was delivered to the slaughterhouse on May 14. The second batch of finishers was placed in the sections on May 25 and was delivered to the slaughterhouse on August 18. The weight of the pigs in the first batch increased from 27 to 101 kg during the production period, and the weight of the pigs in the second batch increased from 32 to 113 kg.

Odor, ammonia, hydrogen sulfide, ventilation rate, temperature and slurry depth were measured during the two production periods.

Slurry treatment

Once a week, the slurry in the pits was flushed into a concrete tank located outside the building before treatment. In the first step of the treatment, the slurry was separated in a Volute separator (Amcon Inc., Japan) using a polymer to obtain a gentle and efficient separation. The solid fraction was removed mechanically, and the thin liquid fraction was pumped into a plastic container for further treatment. The thin fraction was subsequently treated with ozone at a rate of approximately 2 m³/hour. Finally, the thin fraction was acidified with 96% sulfuric acid until the pH level decreased to 5.5. After treatment, the thin fraction was reflushed into the slurry pits to function as a carrier liquid for the finishers' continuous delivery of new material to the slurry. Between the weekly three-step mechanical and chemical treatments, the slurry was flushed out once, separated and acidified to pH 5.5. The amount of liquid reflushed into the pits was between 4.5 and 5 m³ per section, resulting in a depth in the slurry pit of approximately 20 cm. Surplus material was transferred to storage.

During the process, approximately 75 g ozone was added to the slurry per hour, resulting in 40 g ozone per m³ of treated slurry. The consumption of acid was between 750 and 1200 ml per m³ of treated slurry, and approximately 40 g polymer was used per m³ of treated slurry.

For the first batch of finishers, the slurry treatment began 5 weeks after placing the pigs in the sections, and for the second batch treatment began when the pigs were placed in the sections. For both batches, the slurry treatment continued until delivery of the pigs to the slaughterhouse.

Odor

Samples for olfactometric measurements were taken inside the ventilation duct in each section six days after the treatment of the slurry. In total, 9 days with olfactometric measurements were performed in the two batches. On each measurement day, two odor samples were taken in each section; one sample was taken between 11 a.m. and 12 p.m., and the other sample was taken between 1 p.m. and 2 p.m. The odor samples were collected in 30-liter Nalophane bags through a Teflon tube. The bags were flushed once before the sampling started in order to condition the surface in the bags with odorants. The sampling time was 30 minutes, and the sampling equipment was located outside the sections to ensure that the technicians did not disturb the behavior of the pigs. The following day, the samples were analyzed at the Danish Meat Research Institute using an Ecoma T08 olfactometer to determine the odor concentration using dynamic olfactometry in accordance with the European CEN-standard (CEN, 2003).

Ammonia and carbon dioxide

The ammonia and carbon dioxide concentrations in each section were measured online once every other hour using the Danish VengSystem. This equipment consisted of pumps that delivered approximately two liters of air per minute from the air inlet and from the air exhausts through Teflon tubes to instruments that analyzed the ammonia and carbon dioxide content in the air. A Polytron 1 from Dräger was used to measure the ammonia concentration, and a Vaisala instrument was used to measure the carbon dioxide concentration. A manifold placed immediately before the two instruments ensured that the air from each source was sent separately to the instruments. The air was analyzed for a period of ten minutes, and only the last recorded value was stored, so the system recorded a new value in each section every other hour.

Before being pumped into the instruments, all the air was preheated to 34°C to avoid condensation of water droplets, and the inlet air was analyzed during every second measurement period. This was done in order to stabilize the ammonia instrument. Otherwise, it would not have been possible to use the Polytron 1 from Dräger.

Immediately after the olfactometric sampling had been completed, the ammonia and carbon dioxide concentrations were measured using detector tubes from Kitagawa (No.105SD for ammonia and No.126SF for carbon dioxide). This made it possible to check and calibrate the data from the VengSystem.

Hydrogen sulfide

The hydrogen sulfide concentrations in the exhaust air in each section were measured immediately after the olfactometric sampling had been completed. The hydrogen sulfide concentrations were measured using a Jerome 631-XE Analyzer from Arizona Instrument LLC.

Ventilation rate and temperature

The ventilation rate was measured using measurement fans (Fancom, the Netherlands), and the room temperature was measured using VE10 temperature sensors (VengSystem, Denmark) placed immediately below the ventilation duct. Both were measured and stored electronically at 5 minute intervals using software from VengSystem, Denmark.

Calculations and statistical analyses

Emissions of ammonia and hydrogen sulfide were determined by multiplying the concentrations by the ventilation rate. The experimental set-up was a case-control study, and the log-transformed odor emissions were analyzed statistically using a variance analysis in SAS (SAS, 2009). The

group and batch were included as systematic effects. For each batch, means and standard deviations were determined for temperature in the ventilation duct, the ventilation rate, and concentrations of ammonia and carbon dioxide.

RESULTS AND DISCUSSION

The slurry treatment system was installed and implemented in the period February - April 2009, and the treatment of slurry began on April 17, 6 weeks after the finishers had been placed in the sections. The slurry pits in the control sections were drained on April 15. Measurements began on April 17 and ended when the finishers were delivered to the slaughterhouse. In the second batch, the slurry treatment and online measurements began when the finishers were placed in the sections on May 25 and continued until delivery to the slaughterhouse on August 18. The pits in the one of the control sections were drained on July 6 and in the other control section on July 13.

Odor

All individual measurements are shown in Fig. 1. On every measurement day, there was a lower odor concentration in the sections with treated slurry in the pits compared with the control sections. The only exceptions were April 23 and July 16 when the pits in the control sections were newly drained. In those two cases, there was no difference between the four sections. The odor concentrations and emissions on each measurement day are shown in Table 1.

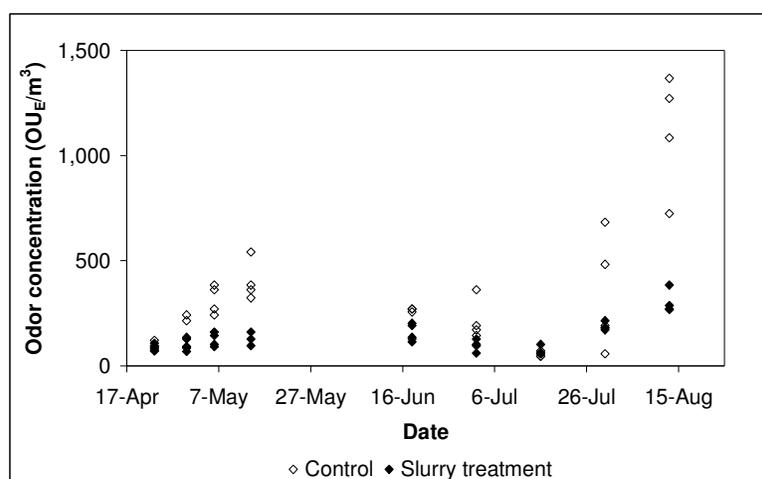


Figure 1. Odor concentration in the exhaust air from the four experimental sections with and without treatment of the slurry

A statistically significant lower odor emission was measured in the finisher sections with slurry treatment. The odor emission was 74 OU_E/sec. per 1,000 kg of animal from the control sections and was 44 OU_E/sec. per 1,000 kg of animal from the sections with weekly draining of the pits, corresponding to a reduction of 40 %.

Table 1. Odor concentrations and emissions from four experimental sections in a finisher unit with and without treatment of the slurry. The measured values must be compared within the individual batches. The confidence interval (95 %) is shown in brackets.

Batch Group	1		2		1+2	
	Control	Slurry treatment	Control	Slurry treatment	Control	Slurry treatment
Number of measurements	16	16	20	20	36	36
Odor concentration (OU _E /m ³)	190 (120-300)	110 (72-170)	240 (160-360)	140 (91-210)	210 (150-300)	120 (87-170)
Odor emission (OU _E /sec. per 1,000 kg of animal)	59 (40-87)	36 (24-52)	93 (65-130)	56 (39-80)	74 (55-100)	44 (33-60)

Ammonia

Table 2 shows the ammonia concentrations and emissions from the four sections together with the other data recorded electronically. Online recordings of ammonia and carbon dioxide concentrations from one of the control sections for the period July 30 - August 13 are not included in the study since the pump was not running at that time.

The ventilation rates were slightly higher in the sections with slurry treatment compared with the control sections. However, there was no difference in the carbon dioxide concentrations in these sections, and, therefore, when comparing the ammonia emissions between the two groups, the slight difference in the ventilation rates is of no importance. There was no difference in temperature inside the sections between the groups in each batch.

Table 2. Temperatures, ventilation rates, carbon dioxide and ammonia concentrations, and ammonia emissions in four experimental sections in a finisher unit with and without treatment of the slurry. The measured values must be compared within the individual batches. The confidence interval (95 %) is shown in brackets.

Batch	1		2		1+2	
Days of measurements	30		86		116	
Outdoor temperature (°C)	10.3 (7.6-13.6)		15.1 (10.6-20.3)		-	
Group	Control	Slurry treatment	Control	Slurry treatment	Control	Slurry treatment
Temperature in exhaust air (°C)	16.8 (14.7-18.9)	16.5 (14.7-18.5)	20.2 (17.4-24.0)	20.5 (17.7-24.0)	-	-
Ventilation rate per animal (m ³ /hour)	83 (67-99)	86 (69-103)	83 (21-112)	89 (31-128)	-	-
Carbon dioxide concentration (ppm)	830 (730-940)	820 (720-910)	760 (650-990)	740 (620-950)	-	-
Ammonia concentration (ppm)	4.3 (4.1-4.6)	2.6 (2.4-2.9)	3.9 (3.7-4.1)	2.3 (2.1-2.5)	4.1 (4.0-4.3)	2.5 (2.3-2.6)
Ammonia emission (g NH ₃ -N/hour per animal)	0.21 (0.19-0.23)	0.13 (0.11-0.15)	0.19 (0.18-0.20)	0.12 (0.11-0.13)	0.20 (0.19-0.21)	0.12 (0.11-0.14)

Figure 2 shows the daily average ammonia concentration in the two groups for both batches of finishers. There was a statistically significant lower ammonia concentration in the sections with slurry treatment compared with the control sections (Table 2). The ammonia concentration was 4.1 ppm in the control sections and 2.5 ppm in the sections with treated slurry, corresponding to approximately 40 % lower concentration in the sections with slurry treatment.

Since the ventilation rates were at the same level both within the groups and within the batches, and the ammonia concentrations were not different within the groups between the batches, the ammonia emissions can be compared both within the individual batches and in total. As for the ammonia concentration, there is a statistically significant difference between the ammonia emissions from the two groups. The reduction in ammonia emissions achieved by the slurry treatment was 40 %.

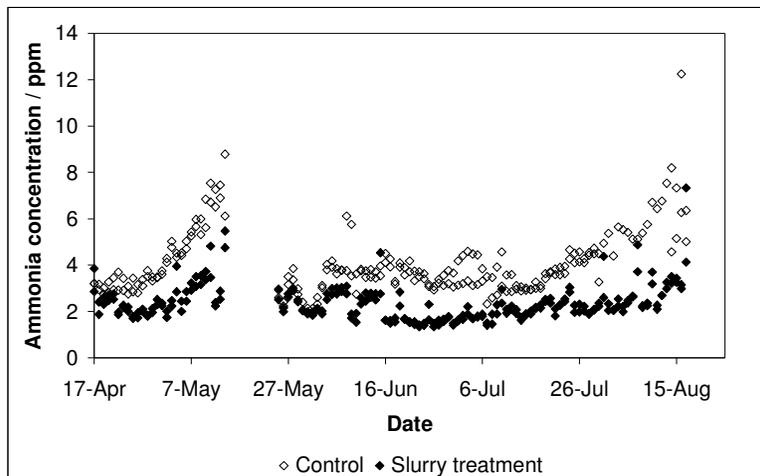


Figure 2. The daily average ammonia concentrations in the exhaust air from the four experimental sections with and without treatment of the slurry

Based on this study and an earlier study (Jonassen et al., 2009), it is evident that the reduction in ammonia emissions increases with the frequency of acidification of the slurry. In ongoing studies, the slurry is acidified every day and then separated and ozonated once a week. These studies are currently being carried out both at the experimental pig production facility of the Pig Research Centre, Grønholm, and at a full-scale production site with an annual production of approximately 8,000 finishers.

Hydrogen sulfide

Figure 3 shows the individually measured concentrations of hydrogen sulfide in the four experimental sections with finishers. The average concentrations and emissions are shown in Table 3.

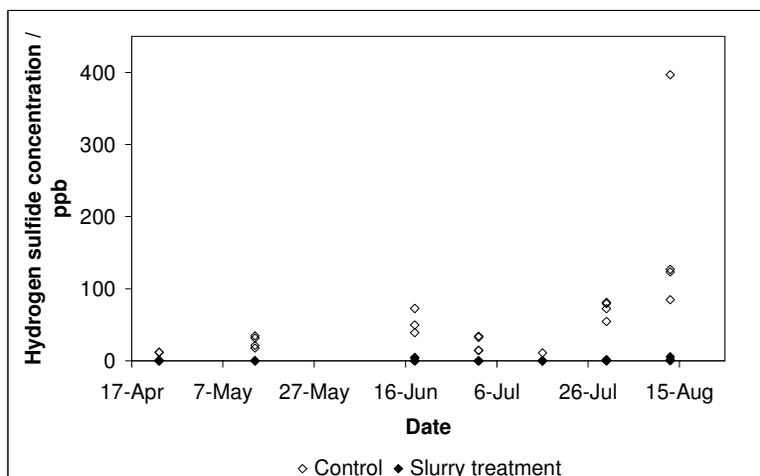


Figure 3. Hydrogen sulfide concentrations in the exhaust air from the four experimental sections with and without treatment of the slurry

Both the concentrations in the exhaust air and the emissions were statistically significantly lower from the sections with slurry treatment. On most measurement days, there were no measurable concentrations of hydrogen sulfide in the sections with slurry treatment. The daily average concentration in the control sections was between 25 and 180 ppb except on the measurement days immediately after draining of the pits. Since hydrogen sulfide is produced in the slurry under anaerobic conditions, this pattern was expected and is similar to what has been seen in other studies, e.g. Lyngbye et al. (2008) and Jonassen & Lyngbye (2010).

Table 3. Hydrogen sulfide concentrations and emissions in four experimental sections in a finisher unit with and without treatment of the slurry. The measured values must be compared within the individual batches. The confidence interval (95 %) is shown in brackets.

Batch Group	1		2		1+2	
	Control	Slurry treatment	Control	Slurry treatment	Control	Slurry treatment
Number of measurements	8	8	20	20	28	28
Hydrogen sulfide concentration (ppb)	33 (0-72)	0 (0-22)	58 (30-86)	8 (0-36)	45 (18-73)	0 (0-23)
Hydrogen sulfide emission (mg H ₂ S/hour per animal)	4,6 (0-9.7)	0 (0-2.8)	8.0 (4.3-12)	1.1 (0-4.8)	6.3 (2.7-9.9)	0 (0-3.0)

Operating costs

The cost of treating the slurry in the second batch of finishers was approximately US\$ 1.8 (DKK 10) per produced finisher. Half of this is related to the electricity required to pump and separate the slurry and to generate the ozone. The other half is related to the use of sulfuric acid and polymers. Besides the daily expenses, investments and maintenance costs must also be considered.

CONCLUSION

Measurements in connection with the slurry treatment have shown that it is possible to use mechanical separation of pig slurry followed by treatment with ozone in combination with acid to achieve statistically significant reductions in odor and ammonia emissions from pig housing.

In this study, the odor emissions from experimental sections with 32 finishers were reduced by 40 % from 74 OU_E/sec. per 1,000 kg of animal from the control sections to 44 OU_E/sec. per 1,000 kg of animal from the experimental sections. A larger effect was observed on the hydrogen sulfide emissions. The ammonia emissions were reduced by 40 % as a result of acidifying the treated slurry twice a week.

Studies of daily acidification of the weekly separated and ozone-treated slurry are currently being carried out both at the experimental pig production facility of the Pig Research Centre, Grønholm, and at a full-scale production facility.

Acknowledgements

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