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AMMONIA EMISSIONS IN COMMERCIAL BROILER DARK HOUSE IN SOUTH OF BRAZIL

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ABSTRACT: Three dark houses (broiler breeding systems) were studied with multiple reuse litter. Four batches of broilers have been studied during spring, summer and autumn in southern Brazil. The litter had been reused during batches 11 through 16. Indoor and outdoor NH_3 air concentrations were measured using a photoacoustic infrared analyzer (INNOVA 1412). At the end of each batch, the amount and of manure and litter was determined to calculate N, c and p mass balances .The simplified methodology proposed by Ponchant et al. (2008) was used to assess emissions based on the method of concentration ratios. Results showed that the emissions varied between batches and broiler houses. For one batch, emissions increased from day 1 to day 42. The average NH_3-N emissions is 0.51±0.13 g bird^{-1}.d^{-1}. Even if this rearing system is based on intensive litter reuse, the emissions estimates is in agreement with recently published data that correspond to systems with reused litter over one year or fewer time (Moore et al. 2011) and confirm the values found by Miles et al. (2014) in litter reused for 9 to 13 batches (0.54 g NH_3-N bird^{-1}.d^{-1}).

Keywords: NH_3, poultry, litter reuse, emissions factors

INTRODUCTION: Importance of air quality from animal feeding operations has been well recognized in Brazil, especially, which is among the largest suppliers of animal products. Emissions estimates are needed, particularly in countries that cosigned the Kyoto protocol, for the broiler industry’s impact to be assessed on local and regional air quality. One of the major environmental concerns in the poultry industry is NH_3 volatilization (Moore, 1998) and litter reuse is considered a factor that can be increases ammonia emissions. This study aimed to evaluate NH_3 emissions by simplified methodology proposed by Ponchant et al. (2008).

1. MATERIAL AND METHODS: The experiment was conducted in three commercial broiler farms located in southern Brazil (State of Santa Catarina) between October 2014 and May 2015. Three dark house (DH) systems had forced ventilation, exhaust nine fans (flow of 44.000 m^3/h each), evaporative cooling, and the lateral areas were closed off with double black polypropylene curtains. In both houses, broilers were reared with reused litter. Pine wood shavings were the original bedding material set on the house floor. Concentrations of NH_3 were measured weekly after sampling in bags (6-day sampling in each batch). Outdoor air sampling was also carried out simultaneously. Air samples were collected with sampling bags made of polymeric materials connected to a pump. The duration of sampling in each house was 30 minutes. The simplified method was based on the concentration ratios method. The following equation (1) has been used:

$$\text{Emission } ENH_3\text{-N} = \text{Emission } CO_2\text{-C} * (GNH_3\text{-N} / GCO_2\text{-C}) \qquad (1)$$

Where E_{NH3_N} is N emissions in NH_3 form, and G_{NH3_N} and G_{CO2_C} are gradients of N concentrations in NH_3 form and C concentrations in CO_2 form, respectively.

2. RESULTS AND DISCUSSION: The average ammonia (nh$_3$) emission rate in this study was **0.51±0.13** g of NH$_3$-N bird^{-1} d^{-1}, to facilitate comparison with previous studies where the factor was also calculated for g of NH$_3$ kg^{-1} LW $^{-1}$ (broiler kilogram marketed). The emission rate was 0.22 g of NH$_3$ kg LW $^{-1}$ d^{-1}. Although Brazilian broiler emission rates may not be ideally comparable to us emission rates due to different management, housing type, and climate, the results found in this work agree well with the value (0.24 g of nh$_3$ kg^{-1} LW d^{-1}) reported by Miles et al. (2014) for birds of roughly the same age growing in reused litter in Mississippi. In Brazil, some studies observed the emissions rates in broiler houses. Lima et al. (2015) in the State of Mato Grosso evaluated emissions using the capsule method suggested by Jeppsson (1999) and litter of wood shavings reused third time. The value reported was approximately half of the current study, being 0.28 g of nh$_3$ bird^{-1} d^{-1} or 0.14 g of NH$_3$ kg^{-1} LW d^{-1}. Lima et al. (2011) in São Paulo observed 0.19 g bird^{-1} d^{-1} for new litter in broiler house with negative pressure (tunnel system) and density of 14 birds m^{-2}. The values of emission rates obtained in the Brazilian production systems were lower than those obtained in this study.

3. CONCLUSION: Average emission rate for "dark house" type broiler houses with intensive litter reuse was 0.22 ±0.13 g kg LW $^{-1}$ d^{-1}. Average emission obtained was higher than those observed in other Brazilian studies developed in new litter.

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AMMONIA EMISSION FACTORS IN FRENCH POULTRY HOUSES (BROILERS AND TURKEYS)

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ABSTRACT: The regulatory framework around ammonia has been strong for the last ten years. Thus, the European NEC Directive (2001/81 / EC) sets ammonia emission ceilings for France, for several gases, including ammonia. The BREF 2017 for livestock, reference document of the IED Directive (2010/75/EU), enforce for broiler breeders in 2020 the performance levels for ammonia emissions in their buildings (Value Limits Emission). The purpose of this study is to develop a methodology in order to accurately measure the gaseous emissions in poultry houses and to produce reliable and representative emission factors. The simplified method - developed in previous projects [3] and enhanced in this one – was used to estimate ammonia emission. The simplified method so-called "concentration ratio method" validated by carrying out mass balance was used for calculation of gaseous emissions in buildings for light, standard, and heavy weight chicken, as well as for turkeys. The measurements were made in 40 poultry farms located in the West of France in two contrasted seasons (n=80 batches). 10 poultry housing were equipped with heat exchangers (n=19 batches). For lightweight chicken, the emission factors (mgNH_3/animal/day) is estimated to 47.8 (n= 20; σ= 15.2). In production of standard broiler, the annual average emission factor amounts to 95.0 (n= 16; σ = 52.0). In heavy weight broiler production, the annual average emission factor is 136.3mgNH_3/animal/day (n=15; σ =28.47). For the production of lightweight chicken and turkey, heat exchangers tend to reduce ammonia emission. Although subject to significant variability related to measurements in field conditions, the measured values indicate a lower level than European references (EEA) but are nevertheless coherent with measures realized in some countries in Northern Europe. The global emissions level is lower in our sample because of low nitrogen excretion and TAN rate (part of ammonium in excrement) than the references values. These results underline the efforts realized by the breeders and the poultry sector as well as the improvements of breeding practices (litter, ventilation management, feed strategies, genetic and zootechnical performances).

Keywords: NH_3, Poultry, House, Emission Factor

INTRODUCTION: Nitrogen management is becoming a significant concern for public authorities. The regulatory framework around ammonia and air quality has been strong. European member states have taken mitigation strategy to improve air quality and fixed ambitious objectives to reduce particles emission (of which ammonia is a precursor) to protect human health and the environment. The National Emission Ceiling Directive (2001/81/CE) determine emissions upper limit for several gaseous including NH_3. The revised of BREF for livestock, reference document of the Industrial Emission Directive (2010/75/EU) enforce for breeders performance level for ammonia emission in their buildings. It seems essential to provide breeders, professional organizations and authorities with reliable and representative emission factors to the breeding practices and underline the efforts made by breeders. The aim of this study is to provide references on ammonia emissions factors, measured in commercial poultry buildings. The results from these measurements are representative of the farming practices in Brittany, the main poultry production area in French.

1. MATERIAL AND METHODS:

1.1. Farms studied: The measurement campaign have been made in forty broiler and turkey breeding in confinement production and located in West of France. We are based on the results of poultry survey carried out by the "Chambre d'Agriculture de Bretagne" to select poultry farms representative of practices and poultry houses in Brittany. 80 batches were followed. The poultry production is classified in light weight chicken (LW) - 35 days of rearing - standard weight chicken (ST) - 42 days of rearing - and heavy weight chicken (HW) - 50 days of rearing, as well as for turkeys.

1.2. Evaluation of Ammonia Emission Factors: Gaseous emission were estimated from the method of concentration ratio defined in simplified method of measurement developed by INRA and ITAVI (Ponchant and al., 2009; Hassouna and al., 2015). This method consist of measure concentration gradient and make mass balance to estimate the nitrogen loss. Gaseous concentrations of air samples have been taken inside and outside broiler and turkey houses and were quantified with photoacoustic infrared spectrometry (INNOVA 1412). Air samples were taken with Flexfoil® bag. The Flexfoil® bag samples appear as a suitable solution to maintain the needed air samples and obtain reliable concentration values bags. The number of air samples varies according to the species monitored. It ranges from 3 in LW production to 4 in turkey's production. The achievement of mass balance was permitted in answer to zootchenical survey. The main advantage is the ability to multiply, low cost and include the variability of breeding practices.

2. RESULTS AND discussioN:

2.1. Emission Factors (EF) in broiler production: The annual average of ammonia emission for HW broiler (0.136 gNH_3/animal/day) and ST broiler (0.095 gNH_3/animal/day) are higher than LW broiler production (0.048 gNH_3/animal/day) related to the duration of rearing and a final weight (Table 1). Great variability exist between different productions and also between the farms (standard deviation from 0.015 to 0.052). In the summer period for ST broiler, the EF is lower (-15.8% compared to the annual average). During the winter period, the ammonia emission factor also increased by 15.8% unlike for LW and HW broiler production where there are not impact of climatic period.

2.2. Emission Factors in turkey's production: An annual average reaching 0.43 g NH_3/animal/day was measured in turkey production (Table 1). This emission factor is subject to significant variability (standard deviation: 0.23). In the summer period, the EF is lower (- 4.7% compared to the annual value of EF) and in winter, the emission increases by 5.5%. This difference is due to winter breeding practices, during which period the breeders limit their air replacement (and thus the water and gaseous evacuation) as much as possible for reduce their energy consummation. These conditions in winter are more favorable to the formation of ammonia in buildings. Finally, buildings with heat exchanger have an emission of 26.4% less than the annual average of EF.

2.3. Emission Factors calculated with the TAN: The values of total ammonia nitrogen that we have measured are lower than the reference values provided by the EEA 2013 (Table 2). These differences can be explained by the wrong adaptation of the EEA references to poultry droppings. Indeed, urinary excretion in poultry droppings is mainly in the uric acid form. This uric acid is hydrolyzed to ammoniac nitrogen more slowly and variable than for urea (Nicholson et al., 1993, Groot Koerkamp, 1996). This poultry specificity could account for the differences in the TAN between the measurements made in our study and the default values existing in the EMEP / CORINAIR method of the EEA (2013). For EFs per unit of TAN (Table 2), the values proposed by

EEA (2013) are identical to those measured in light weight chicken and turkey and slightly lower than the results of measurements in standard chicken and heavy weight chicken.

Table 1. Ammonia emission factors EF (gNH3/an/day) in different poultry production and effect of contrasted climatic periods and heat exchangers.

		Emission Factors (gr NH_3/animal/day)				
		Annual	**Summer period**	**Winter period**	**Heat exchangers**	**Without Heat exchangers**
Turkey 124.2 days of rearing 11.7 kg	Mean	0,43	0,41	0,46	0,32	0,51
	Median	0,36	0,35	0,45	0,27	0,45
	Standard Deviation	0,23	0,23	0,23	0,11	0,26
Light Weight Chicken 31.2 days of rearing 1.38 kg	Mean	0,048	0,047	0,048	0,04	0,051
	Median	0,048	0,043	0,05	0,036	0,05
	Standard deviation	0,015	0,01	0,018	0,019	0,013
Standard Weight Chicken 39.1 days of rearing 1.93 kg	Mean	0,095	0,080	0,110	0,066	0,102
	Median	0,09	0,088	0,117	0,068	0,095
	Standard deviation	0,052	0,033	0,066	0,038	0,054
Heavy Weight Chicken 49 days of rearing 2.65 kg	Mean	0,136	0,132	0,142	-	-
	Median	0,14	0,14	0,144	-	-
	Standard deviation	0,028	0,031	0,026	-	-

Table 1: Comparison of ammonia emission factors with the reference method (EEA) in kg of total ammonia nitrogen (TAN) and in kgNH_3/place/year

	TAN		**Emission Factors (kg NH_3/kg TAN)**		**Emission Factors (kg NH_3/place/year)**	
	Our results	**Reference (EEA)**	**Our results**	**Reference (EEA)**	**Our results**	**Reference (EEA)**
Turkey	0,37	0,7	0,35	0,35	-	-
Light Weight Poultry	0,2	0,7	0,28	0,28	0,014	0.07
Standard Weight Poultry	0,3	0,7	0,35	0,28	0,032	0,07
Heavy Weight Poultry	0,3	0,7	0,4	0,28	0,044	0,07

3. CONCLUSION: Our results indicate emission factors below the European references (EEA) for poultry production but the results are consistent with the measures carried out in some Northern European countries. The emission factors in buildings in kg N-NH_3 /kg TAN are close to these of the EEA. The lower overall emission level of the farms in our sample is mainly due to a lower nitrogen excretion (optimized nutritional strategies) and a lower ammonia nitrogen (TAN) level than the reference values. Our results underline the efforts made by breeders and the poultry industry in genetics, feed management and zootechnical performances.

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DUST CONCENTRATIONS, AND DUST EXPOSURE OF WORKERS IN THE AIR OF POULTRY HOUSES DURING SPECIFIC "WORKING TASK".

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ABSTRACT: Dust and ammonia exposure of poultry workers is an important consideration in relation to the protection of their health. A study was conducted to characterize the quality of ambient air and respirable dust (< 5µm), ammonia and carbon dioxide exposure of poultry workers, during specific tasks: inspection of animals (INSP), catching birds (CATCH), the manure disposal (MAN), and litter distribution in the building (LIT). Twenty-one farmers rearing standard broiler were recruited. 168 measurement campaigns were conducted (between May 2015 and September 2017), enabling the monitoring of 31 INSP, 34 CATCH, 27 MAN and 31 LIT. The exposure to respirable dust (DEXPO) was measured using a captor CIP10 (TECORA®) carried by the worker at level of the respiratory tract. The ambient dust concentration (DAMB) was measured by a CIP10 fixed in poultry building. The captor was located in the middle of the poultry building at approximately 1.7 m above floor level. During INSP, LIT, CATCH and MAN, the means DAMB were 2.6 mg/m^3, 1.9 mg/m^3, 0.3 mg/m^3 and 0.3 mg/m^3 respectively. The average of DEXPO were 2.5 mg/m^3, 1.5 mg/m^3, 0.6 mg/m^3 and 0.5 mg/m^3 respectively. Although DAMB and DEXPO rarely exceeded the French threshold limit for occupational exposure over 8 hours (5 mg/m^3) established for dust so-called "deemed no specific effect", wearing an appropriate respiratory mask (FFP2) is recommended during LIT, INSP and CATCH.

Keywords: Dust, Ammonia, Broiler, Exposure

INTRODUCTION: The air in poultry houses inspired by workers is composed of a mixture of many types of organic and inorganic components including chemicals components and gases. Numerous studies have demonstrated the links between airborne particles concentrations and human health [Donham KJ et al, 2002; Gérault P et al, 2003; Guillam MT et al, 2013]. The differentiation of particles size fractions is important in health studies. In fact, respirable dust (diameter < 10µm) can be penetrate deeply in respiratory system and be deposited in pulmonary alveoli. Protective masks exist but their unsuitable induces a low use in breeding. In order to preserve the attractiveness of the poultry sector, it is important to raise breeders' awareness of the risks associated with exposure to respirable dust. The study AIRELEVEUR was carried out to characterize the ambient air quality and exposure of broiler breeders, to respirable dust during specific tasks particularly exposing tasks.

1. MATERIAL AND METHODS

1.1. Farms and breeders studied: The field study was carried out in twenty one farms specialized in broilers breeding. Breeding is in confinement production. The study involved in forty-nine poultry houses with an area of 1227 m² on average (980 to 1800 m²). All the poultry houses are equipped with forced ventilation system, only 4 floors are cover with concrete (4/49) and 9 buildings are equipped with heat exchangers (9/49).

1.2. Dust measurements (< 5 µm, en mg/m^3): The exposure to respirable dust (DEXPO) was measured using captor CIP10 (TECORA®, méthode INRS MetroPol, 2009) carried by the workers during the task. The sensor was carried by workers at the level of the respiratory tract. The ambient dust concentration (DAMB) was measuring using a captor CIP10 fixed in poultry buildings. The captor was located in the middle of buildings at 1.7 m to 2 m above the floor.

1.3. Ammonia concentrations: During the tasks, ammonia concentration (NH_3) was measured four times with colorimetric detector tubes **(**Dräger®: NH3 5/a: 5-600 ppm and NH3 2/a : 2-30 ppm) inside the houses buldings after and before each tasks.

1.4. Analysis: The impacts of building characterics, breeding practices, measure conditions and farmer's activities was assessed by calculation of Pearson coefficient of correlation and with Kruskal-Wallis test on ranks for qualitative parameters. For each exposing tasks, the average dust concentration (DEXPO and DAMB) was calculated over the duration of tasks and compared with each other using a test of multiple comparisons of means Tukey Test when the conditions of use are right.

2. RESULTS AND DISCUSSION:

2.1. Variations of respirable dust concentration in the ambient and exposure of workers: The average of DAMB for INSP (2.6 mg/m^3) and LIT (1.9 mg/m^3) are higher than CATCH (0.3 mg/m^3) and MAN (0.3 mg/m^3). The same trend is observed for respirable dust exposure measurements (DEXPO). The dust concentration reaches 2.49 mg/m^3 during the inspection of animals, and 1.9 mg/m^3 during litter distribution (table 1). The average of DEXPO and DAMB are correlated for the INSP (rho= 0.92, p<0.01), MAN (rho= 0.71, p<0.01), and LIT (rho= 0.57, p<0.01). According to the review by Cambra-Lopez et al. (2010), the respirable dust levels measured in the broiler building can vary from 0.10 to 9.71 mg/m^3. The INSP measurements in this study ranged from 0.1 to 16.3 mg/m^3. The measures appear to be consistent with the review. However, the average of DAMB during the inspection of animals is more than three times higher than that obtained by Le Bouquin (2013) in systems of rearing laying hens (ground or aviary) (2.5 mg/m^3 vs 0.5 ± 0.4 mg/m^3). There are four data of concentration (DEXPO) upper than occupational exposure limit over 8 hours (5 mg/m^3) and two data during litter distribution. We measure really high level of concentration dust in poultry bulding.The Doham et al (2002) study show that respiratory damage could be appear for exposure higher than 1.6 mg/m^3. In our study, twenty-six exposition measures are higher than this limit (11 measures during INSP, 3 measures during MAN, 3 measures during CATCH and 9 measures during LIT). Significant differences are observed for DAMB between the different tasks (p <0.01), and also for DEXPO (p <0.01).

2.2. Factors increasing respirable dust concentration: Many livestock management are observed in the study what induces many variability factors in statistical analysis. During the INSP, DEXP measurements are inversely correlated with the duration of task (rho= - 0.55; p<0.01). Although the task is relatively short (34 min mean), the high level of exposure to dust may related to the movement and excitability of the animals. Working of ventilation system during LIT induces a higher DAMB average (2.6 mg/m3 (n=27) vs 0.9 mg/m3 (n=17), p<0.01), but not significant effect is demonstrated on DEXPO. Banhazi et al (2008) underline that ventilation effects are complex but can increase particles in suspending. During CATCH, DAMB measurements are inversely correlated with the ammonia concentration average at the beginning of the task (rho=-0.38; p=0, 02). Several studies demonstrated that ambient dust concentration decrease when the humidity of air increasing (sedimentation effect) but a higher humidity rate participate in ammonia volatilization what could be explain the relation between DAMB and ammonia concentration.

Table 1. Number of observations (n), Respirable dust concentration (in mg/m3) and range in the data for different exposing tasks.

	n	Respirable Dust Concentration (mg/m^3)	Range (max- min)
In the ambient air (DAMB)			
INSP	33	2.6	0.1-16.3
CATCH	38	0.3	0.1-1.2
MAN	27	0.3	0-1.9
LIT	44	1.9	0.2-13.9
Exposure (DEXPO)			
INSP	33	2.5	0.1-34.3
CATCH	38	0.6	0.1-2.6
MAN	27	0.5	0.0-1.6
LIT	41	1.5	0.1-8.5

3. CONCLUSION: Although DAMB and DEXPO are rarely exceeded occupational exposure limit, the regulation targets only the dust "deemed no specific effect" on period of 8 hours exposure. Compared with previous publications, the study shows high levels of respirable dust exposure in poultry houses especially during daily tasks like inspection of animals and litter distribution. Rearing practices affect dust concentration like bird excitability during inspections of animal, working ventilation system during litter distribution. Wearing an appropriate respiratory mask (FFP2) should be recommended especially for the most exposing tasks.

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LOW FREQUENCY AERATION OF PIG SLURRY AFFECTS SLURRY CHARACTERISTICS AND EMISSIONS OF GREENHOUSE GASES AND AMMONIA

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ABSTRACT: The aim of this study was to quantify the effect of low frequency aeration of pig slurry on gas emissions and to establish the underlying mechanisms. A batch experiment was designed with 6 tanks with 1m^3 of pig slurry each. Three of these tanks were subjected to aeration (2 minutes every 6 hours, airflow 10 m^3 h^{-1}), whereas the other three tanks remained as a control. Emissions of NH_3, CH_4, CO_2 and N_2O were measured. Aeration increased NH_3 emissions by 20% with respect to the controls (8.48 vs. 7.07 g day^{-1} per m^3 of slurry, $P<0.05$). A higher pH was found in the aerated tanks at the end of this phase (7.7 vs. 7.0 in the aerated and control tanks, respectively, $P<0.05$). CH_4 emissions were 40% lower in the aerated tanks (2.04 vs. 3.39 g day^{-1} per m^3 of slurry, $P<0.05$). These differences in NH_3 and CH_4 emissions remained after the aeration phase had finished. No effect was detected for CO_2, and no relevant N_2O emissions were detected during the experiment. Our results demonstrate that low frequency aeration of stored pig slurry increases slurry pH and NH_3 emissions.

Keywords: Slurry, Swine, Storage, Aeration, Mixing, pH, GHG, NH_3

INTRODUCTION: Pig slurries emit considerable amounts of ammonia (NH_3) and greenhouse gases (GHG) to the atmosphere, mainly as methane (CH_4). Slurry treatment techniques may contribute to reduce these emissions (Amon et al., 2006), in accordance with the environmental regulations. Aeration of slurries has been widely studied in the literature as a technique to reduce nitrogen and organic matter loads, with potential benefits associated to reductions of odour and CH_4 emissions. However, increased nitrous oxide (N_2O) emissions arise as a relevant side effect. Recent research suggests that low frequency aeration of slurries may reduce NH_3 emissions because mixing induces changes in the physical-chemical characteristics of the slurry surface, without increasing N_2O emissions (Dai and Blanes-Vidal, 2013; Van Dooren et al., 2016). A pH gradient is described at the surface of pig slurries, with higher pH at the layer in contact with the air. Mixing slurries breaks this gradient. Aeration contributes to the aerobic degradation of organic matter and could reduce CH_4 emissions. However, aeration increases pH as a consequence of the degradation of volatile fatty acids (Burton, 1992), and therefore a driving force towards increasing NH_3 emissions might also be expected. Therefore, specific research is required to evaluate the combination of these two effects.

This study aims to determine the effect of low frequency aeration (2 minutes each 6 hours) on pig slurry composition and related gas emissions.

1. MATERIAL AND METHODS: A study was conducted to evaluate the effect of low frequency aeration on the gaseous emissions from pig slurry. The experiment was conducted at Rothamsted Research North Wyke site from June to July 2016. A similar methodology to Misselbrook et al. (2016) was followed to measure emissions. A batch experiment was designed with 6 tanks with 1 m^3 of pig slurry each, which was obtained from a fattening unit of commercial farm (total solids 25.4 g/kg, total nitrogen 4.0 g/kg).

After an initial phase of 7 days when none of the tanks were aerated (phase 1), an experimental phase of 4 weeks (phase 2) subjected three of the tanks to aeration (2 minutes every 6 hours, airflow 10 m^3 h^{-1} per m^3 of slurry), whereas the other three tanks remained as a control. A final phase of 9 days was established (phase 3) with no aeration at any tank, to compare permanent effects of aeration. Slurry samples were taken at the start of each experiment phase and were analysed for total solids, volatile solids, total nitrogen and ammonium nitrogen. pH was measured three times per week using a portable meter with pH probe HI 9025, Hanna Instruments, Leighton Buzzard, UK). Measurements were conducted throughout the experimental period at 1 cm and 10 cm depth. Temperature of ambient air and of each slurry tank was continuously monitored using a data logger (Grant Data Acquisition Series 2040, UK).

Gas concentrations were measured using Los Gatos analysers (Model 911-0016 for NH_3 and 915-0011 for CH_4 and CO_2, Los Gatos Research, California). A sampling protocol was devised to measure emissions in the moments of aeration. As a validation of NH_3 concentration measurements, these were also measured by means of acid absorption flasks twice per week. Finally, spot measurements of N_2O and H_2S concentrations were also conducted by means of gas chromatography (Clarus 500, Perkin Elmer, Buckinghamshire, UK) and colorimetric detection tubes (Draeger Safety), respectively.

Emissions were integrated on a daily basis and a two-way analysis of variance was conducted to determine the effects of treatment, phase and their interaction. During the moments of aeration, the immediate effect of aeration on slurry emissions was analysed in qualitative terms.

2. RESULTS AND DISCUSSION: The evolution of temperature of ambient air and tanks is shown in Figure 1. Temperatures ranged mostly between 14ºC and 18ºC. The effect of aeration on slurry temperature was of minor importance (less than 0.5ºC variation).

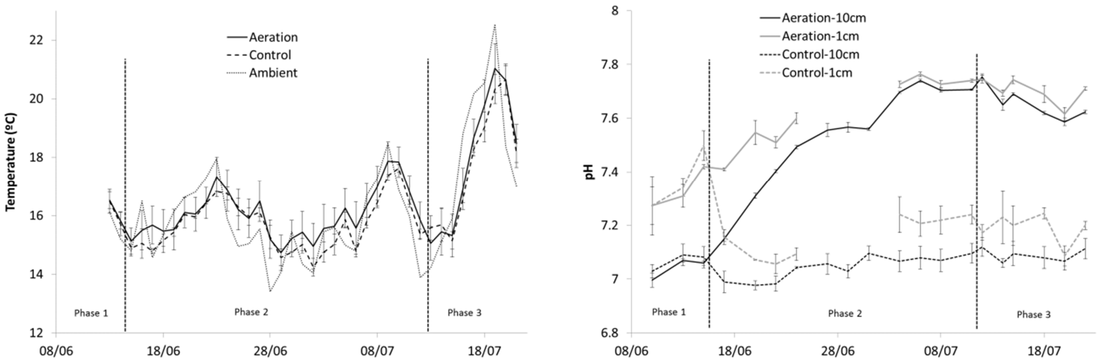

Figure 1. Evolution of ambient and tank temperature (left) and pH (right) during the experiment. Aeration and control tanks are shown separately.

No statistical differences were found in pH during phase 1, where no aeration was conducted in any tank. During phase 2 pH measured at 10 cm depth raised steadily for the first days of aeration and reached a constant level of about 0.7 pH units above the pH of slurries in control tanks (Figure 1). These differences were statistically significant and continued in phase 3, where no aeration was conducted. Slurry surface pH was also measured, but the divergence between surface and bulk measures was lower than the difference between aeration and control tanks.

The aerobic degradation of volatile fatty acids (VFA) is very likely the cause for this pH increase (Burton, 1992).

The evolution of daily emissions of NH_3 and CH_4 are shown in Figure 2. During the first phase, where no aeration was conducted, no statistical differences were obtained in emissions from any gas. However, during the second phase aeration increased NH_3 emissions and decreased CH_4 emissions. The increase in NH_3 emissions was attributed to the increase of slurry pH previously described. The formation of crust in control tanks, compared with aeration tanks (in which crust was not formed) may additionally explain the higher NH_3 emissions of NH_3. A slight effect of pH gradient reduction was also detected at the beginning of phase 2, according to previous research (Blanes-Vidal et al., 2012). During the short instants of aeration (2 minutes every 6 hours), most CH_4 was emitted to the atmosphere in the aerated tanks, but this quantity was still lower than the CH_4 emitted from control tanks.

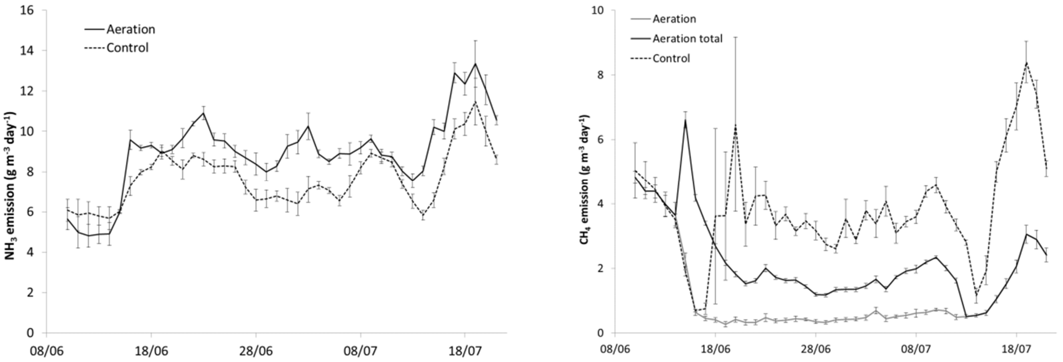

Figure 2. Evolution of NH_3 (left) and CH_4 (right) emissions during the experiment. In the aerated tanks, CH_4 emissions excluding the instants of aeration are also plotted (Aeration).

No effects of aeration were detected on CO_2 emissions, which remained constant, and on N_2O emissions, which could not be detected in both control and aerated slurry. On the contrary, spot emissions of H_2S were detected during the aeration moments. Mixing was considered a driving force of gas emission dynamics. Insoluble gases such as CH_4 and CO_2 generated in the slurry are retained in the slurry body as small bubbles and then released in relatively high amounts during the aeration moments. On the contrary, NH_3 did not show this behaviour, and the emission dynamics was more related pH changes both in the short term (pH gradient reduction due to mixing, leading to lower emissions) and in the short term (pH increase due to VFA removal, leading to higher emissions).

This study was conducted under particular conditions of slurry storage management and ambient conditions. Evidences collected in this study support the idea that similar results would be obtained under different scale and temperature situations. However, different slurry management could influence these results, so specific research would be needed to confirm the potential extrapolation to other management conditions.

3. CONCLUSION: Although slurry mixing reduced the gradient of pH in the slurry surface, this effect had a minor effect on NH_3 emissions when compared with the increase of slurry pH. As a consequence, NH_3 emissions increased. On the contrary, CH_4 emissions decreased by approximately 40%. No N_2O emissions were detected and therefore, this treatment reduced greenhouse gas emissions. In summary, short frequency aeration of stored slurry as tested in this study is not an option to mitigate NH_3 emissions. Specific research would be needed to confirm these results under different slurry management conditions.

Acknowledgements. North Wyke Farm and technical support staff. Mr. R. Knox, Tor Pigs, Devon, UK for providing slurry. Spanish Ministry of Education, Culture and Sports, in the framework of the State Programme to Promote Talent and Employability in R+D+I, Sub-program on Mobility of the Plan on Scientific and Technical Research and on Innovation 2013-2016, and Spanish Ministry of Economy, Industry and Competitiveness (Project AGL2014-56653-C3-2-R). Rothamsted Research is supported by the UK Biotechnology and Biological Sciences Research Council.

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GAS EMISSIONS FROM DEEP LITTER SYSTEMS FOR DAIRY CATTLE IN CONTRASTED FEEDING SITUATIONS

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ABSTRACT: Gas emission measurements from solid manure are scarce in the literature, and very variable according to litter management. The objective of this study is to acquire new knowledge about greenhouse gases and ammonia emissions at the barn level for dairy cows on a straw-based deep litter and contrasting diets based on maize silage (MD) or grass (GD). The experiment was conducted at two seasons (autumn and spring) leading to contrasted grass compositions. At each season, two groups of three dairy cows were housed in two mechanically ventilated rooms, on a straw-based deep litter accumulated under the animals during four weeks. Animal performances were recorded daily. Gas emissions were measured continuously with an infrared photo-acoustic gas analyser. Methane emissions (animals + litter) were higher on the MD diet compared with GD, especially in autumn, in relation with a higher DM intake. Ammonia emissions were greater on GD compared to MD, especially in autumn, in relation with an increasing excess of N in the grass. Ammonia emissions were more related to variations of milk urea content, as a reflection of urea excretion, than to N intake.

Keywords: Dairy cattle, solid manure, house, GHG, NH_3, urea

INTRODUCTION: French dairy systems are characterized by a large proportion of deep litters (Citepa, 2016). However, gas emission measurements from solid manure are scarce in the literature, and also very variable in relation with contrasted litter management (fresh straw addition frequency and amount, accumulation time, feeding…). In deep litter systems, manure is mixed with bedding material and accumulated for a few weeks in a thick layer where the oxygen level decreases with depth. This can result in several processes such as aerobic degradation of organic matter, urea hydrolysis, nitrification-denitrification, nitrogen immobilization and anaerobic degradation of organic matter (Jeppsson, 1999). The complex interactions among microbial, biochemical and physical processes lead to highly variable emissions of NH_3, N_2O, CO_2, and CH_4 (Webb et al., 2012). The modulation of the manure composition via changes in the diet could therefore have important consequences for gas emissions in deep litter systems.

The objective of this study is to acquire new knowledge about greenhouse gases and ammonia emissions at the barn level for dairy cows on a straw-based deep litter with contrasting diets: a maize silage (MD) and a grass-based diet (GD). The experiment was conducted in autumn (MDaut and GDaut) and spring (MDspr and GDspr) leading to contrasted grass compositions and climatic conditions.

1. MATERIAL AND METHODS:

1.1. Animals, treatments and experimental design: The experiment was conducted at the INRA dairy experimental farm in Méjusseaume near Rennes (France) in autumn 2014 and in spring 2015. At each season, two groups (different between seasons) of three Holstein dairy cows in late (in autumn) or mid (in spring) lactation were housed in two closed and controlled mechanically ventilated rooms, on a straw-based deep litter accumulated under the animals during four weeks. Fresh straw (40kg) was added daily.

At each season, one group received a maize-based diet (MD), the other group received a grass-based diet (GD), without inversion. The MD ration was a 75:25 mixture of maize silage: concentrate given to the cows twice a day (8:00a.m. and 6:00p.m.). The GDaut consisted of a 70:30 mixture of fresh grass and grass hay (to overcome poor grass production) whereas the GDspr was 100% fresh grass. Fresh grass was cut in the pasture in the morning and given to the cows in 5 different meals throughout the day. Hay was given once at 6:00p.m.. All rations were offered ad libitum (constant access to the trough; refusal between 5 and 10 % of feed offered) with continuous access to water.

1.2. Measurements:

<u>1.2.1. Feed composition and intake:</u> Offered and refused feed was weighed precisely and sampled every day to determine DM content (80°C, 48 h) in order to assess cow DM intake. Mean daily DM intake was calculated at the group level. Average samples of feeds were analysed for OM (ashing for 6 h at 500°C), N (Dumas method) and NDF, ADF and ADL (van-Soest method) contents (Table 1). Dietary PDIE and PDIN contents were calculated based on Inra (2007) recommendations.

Table 1. Composition of the maize-based (MD) and grass-based (GD) diets in autumn (aut) and spring (spr).

	MDaut	**GDaut**	**MDspr**	**GDspr**
DM, %	37.0	20.2	40.2	16.4
CP, % DM	15.3	17.9	14.9	17.8
NDF, % DM	45.3	55.1	36.2	50.7
UFL	0.95	0.89	1.00	0.93
PDIN, g/kg DM	102.8	116.6	99.2	116.0
PDIE, g/kg DM	96.7	97.1	97.1	98.9

<u>1.2.2. Milk yield and composition:</u> The cows were milked in the rooms twice a day (7:00a.m. and 5:00p.m.). Morning and evening milk samples were collected 3 days a week to analyze for protein and fat via infrared analysis. Milk N (Dumas method) and urea (colorimetric enzymatic reaction) contents were assessed for each cow once a week.

<u>1.2.3. Gas emission measurements:</u> Air samples were continuously collected in each isolated room at both air entrance and air extraction ducts so as to calculate a gradient. An infra-red photo acoustic analyzer (INNOVA 1412, Air Tech Instruments, Ballerup, Denmark) was used coupled with a sampler-dozer (INNOVA 1303) to measure concentrations of NH_3, CO_2, CH_4, N_2O, H_2O and C_2H_6O. This configuration was chosen to compensate for interferences between ammonia and other volatile molecules (e.g. ethanol; Hassouna et al., 2013). The flow rate in each experimental room had been determined previously with the tracer (SF_6) ratio method using the constant dosing approach (Baptista et al., 1999). Gas emissions were calculated by multiplying the ventilation rate (m^3/h/cow) and gas concentration gradients (mg/m^3) and were expressed as cumulated gas emissions per cow per day.

2. RESULTS AND DISCUSSION:

2.1. Animal production: In autumn, the cows, in late lactation, fed GD produced 10 kg less milk compared to the MD treatment (Table 2) in relation with a low intake (bad quality of the grass at the beginning of the autumn period). However, milk urea content was twice as high as a result of an increasing excess of degradable N in the grass-based diet during the experimental period (from 109 g PDIN/UFL in week 1 to 146 g PDIN/UFL in week 2) and low milk yields. In spring, the cows, in mid lactation, maintained higher DM intake and milk production on GD. Milk urea content was maintained at a low level (Table 1). Contrary to the autumn period, the PDIN content of the grass-based diet decreased rapidly (from 149 g PDIN/UFL in week 1 to 108 g PDIN/UFL in week 2).

Table 2. Intake and milk production for the maize-based (MD) and grass-based (GD) diets in autumn (aut) and spring (spr).

	MDaut	GDaut	MDspr	GDspr
DM intake, kg/d/cow	19.9 ±1.9	13.1 ±1.4	20.0 ±1.7	15.7 ±2.2
N intake, g/d/cow	495 ±44	410 ±80	483 ±33	446 ±89
Milk Yield, kg/d/cow	23.4 ±2.1	13.4 ±1.8	28.4 ±5.6	26.0 ±3.5
N in milk, g/d/cow	151 ±25	80 ±10	156 ±31	132 ±17
Milk urea, mg/dL	20.0 ±3.4	39.9 ±11.2	17.3 ±3.9	18.4 ±3.2

2.2. Gas emissions:

2.2.1. CO2 and CH4 emissions: CO_2 and CH_4 emissions were higher on MDaut compared to GDaut as a consequence of greater DM intake levels (Table 3). However, the emissions of both gases were much lower in spring despite of similar (for MD) or higher (for GD) intake levels, which could not be associated with contrasted environmental conditions (rooms maintained at 18°C for both periods). This difference remains unexplained.

2.2.2. NH3 and N2O emissions: NH_3 emissions were higher for GDaut compared to MDaut and quite close for MDspr and GDspr (Table 3), and consequently more related to milk urea content than to N intake (Table 2). For GDaut, NH_3 emissions increased over the accumulation time (up to 50 g/cow/day) probably as a result of the increasing excess of the grass degradable N which led to increasing urea excretion as indicated by milk urea contents (multiplied by two between week 1 and week 4, Figure 1). For GDspr, NH_3 emissions started to increase in week 1 but then stayed at a low level in relation with low urea flows at the animal level, reflection of the decreasing N content of the grass.

Table 3. Gas emissions for the maize-based (MD) and grass-based (GD) diets in autumn (aut) and spring (spr).

	MDaut	GDaut	MDspr	GDspr
CO_2-C, kg/d/cow	6.6 ±1.3	5.1 ±1.3	4.0 ±0.6	4.0 ±0.5
CH_4-C, g/d/cow	472 ±55	322 ±66	277 ±23	255 ±33
NH_3-N, g/d/cow	13.2 ±6.1	20.9 ±14.8	9.7 ±4.4	11.5 ±4.8
N_2O-N, g/g/cow	0.1 ±0.1	0.3 ±0.6	0.1 ±0.1	0.2 ±0.6

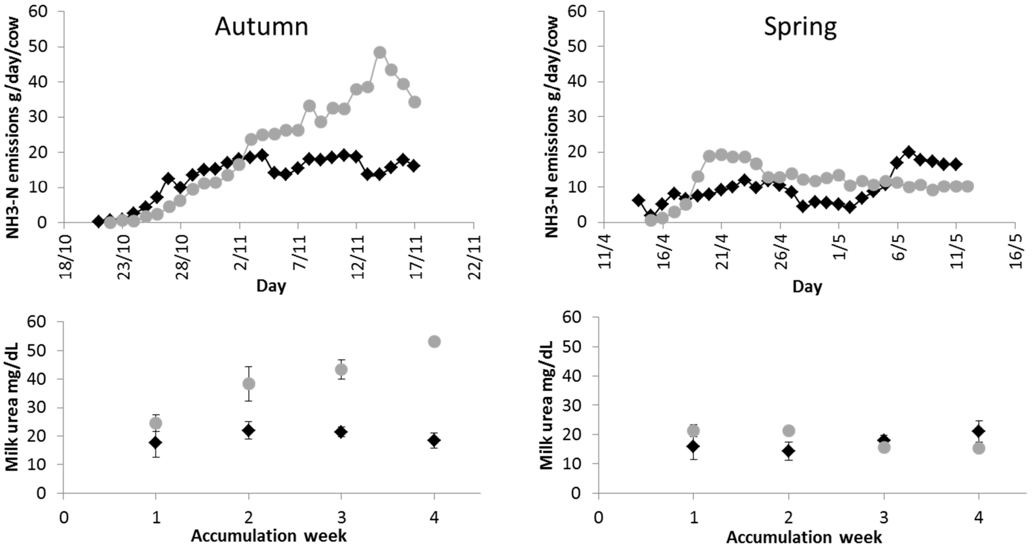

Figure 1. Ammonia emissions and milk urea contents for the autumn and spring periods for the grass-based (grey circles) and the maize-based (black diamonds) diets.

3. CONCLUSION: Gas emissions from deep litter systems were influenced by the nutrition of the cows both in terms of diet intake and N content. NH_3 emissions were actually more related to milk urea content, reflection of urea excretion, than to N intake.

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AMMONIA EMISSIONS FROM SLURRY STORES

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ABSTRACT: Emission measurements from slurry stores under environmental conditions are sparse. This might conflict with the needs of emission inventory calculations which rely on representative emission factors. Therefore, we quantified the emissions from a 1558 m^3 open storage tank containing dairy cattle slurry over one year. Ammonia (NH_3) concentrations were measured as continuous, line-integrated concentrations across the tank using a miniDOAS and with weekly exposed passive samplers in a vertical profile at the center of the tank. Moreover, meteorological parameters were measured and management-operations recorded. NH_3 emissions were determined by a simplified mass balance approach. Emissions from the uncovered slurry tank carried out over one year were on average 0.06 g NH_3 m^{-2} h^{-1} which compare well with data from the literature. The emission level responded in a plausible manner to important influencing parameters, e.g. natural crust at the slurry surface. At the end of April 2017, an impermeable plastic floating cover was installed. The measurements will be continued for one year after covering the tank. The present study provides a unique dataset in order to investigate emissions from slurry tanks and interactions thereof related to operations and meteorological conditions as occurring in practice.

Keywords: NH_3, Slurry, Storage, Measurement, Natural crust

INTRODUCTION: Emissions of reactive nitrogen (Nr) impair the quality of air, soil and water, ecosystems and biodiversity, and influence the release of greenhouse gases. Nr emissions have thus to be reduced (Sutton et al., 2011). In Switzerland, ammonia (NH_3) contributes by approx. two thirds to the total of Nr-emissions (Menzi et al., 2014). NH_3 released from livestock production contributes about 80% to the total ammonia load (Kupper et al. 2015). Therefore, it is largely agreed that mitigation measures have to focus on this sector. In order to restrict the emissions to a level which does not impair the environment a set of measures at all emission stages is required. Emissions from slurry stores contribute 10% to the NH_3 emissions from the livestock sector. Approx. 15% of the slurry storage volume is uncovered in Switzerland (Kupper et al. 2015). Covering open stores allow for a significant reduction of the emissions released therefrom (VanderZaag et al., 2015). However, emission measurements from slurry stores are sparse. Such investigations are mostly performed at the laboratory or the pilot scale where relevant factors influencing the emissions can differ from environmental conditions. This might conflict with the needs for establishing emission inventories and the characterization of effects related to emission mitigation measures which depend on reliable and representative measurement results. Here, we present results from a measurement campaign carried out at a real-world uncovered slurry storage tank. The measurements will be continued for one year after mounting an impermeable plastic floating cover.

1. MATERIAL AND METHODS: The NH_3 emissions from a 1558 m^3 open storage tank containing dairy cattle slurry were quantified over more than one year (i.e. from 2016-01-01 to 2017-04-18). Line-integrated NH_3 concentrations were measured across the tank using a miniDOAS (Sintermann et al., 2016) and averaged over 10 min. Passive samplers (PS) were exposed in a vertical profile at the center of the tank and replaced after one week. Background concentrations were obtained with PSs exposed for four weeks, respectively. The PSs were of the type Radiello (http://www.radiello.com) and exposed in triplicate. The heights of the instruments were as follows: miniDOAS: at the upper rim of the storage tank (reference height 0 m); three PSs were placed 1 m, 2 m, 3 m above and one PS 1 m below the reference height. Wind speed and temperature were measured at the levels of the PSs and of the miniDOAS. Additionally, wind direction, relative air humidity, precipitation and at 10 m above the ground, atmospheric turbulence was measured using a 3D sonic anemometer. Operations of the slurry tank, i.e. stirring, filling and discharging were recorded as well by continuous 10 min resolved webcam pictures. The level of the slurry in the tank was logged using a laser measuring device. Furthermore, the thickness of the natural crust was periodically measured (n=31).

NH_3 emissions were determined by a mass balance approach, i.e. a simplified integrated horizontal flux (IHF) method. The concentration (C) and wind speed (U) profiles were arbitrarily defined as follows: the NH_3 concentration at 9 m above the rim C(z=9m) was assumed to be equal to the inflow concentration (C_inflow), i.e. the measured background concentration. C was interpolated linearly between individual concentration measurement heights. The profile of U and the limits z(U=0) and U(z=9m) were obtained from extrapolation of wind speed by monotone piecewise cubic interpolation. Emission flows (F_{NH3}) were approximated from the resulting profiles as

$$F_{NH3} \approx \frac{1}{R} \int_{z_{surf}}^{z_{plume}} UC dz \qquad (1)$$

where R is the radius of the storage tank and the limits are given as z_{plume} = 9 m and z_{surf} = z(U=0). The product of the measured NH_3 concentration from the miniDOAS and the measured wind speed at 10 m height was related to the observed fluxes from the profile measurements by robust linear regression.

$$F_{NH3}= -0.0016+0.0006 *u*c \qquad (2)$$

where F is the flow in g NH_3 m^{-2} h^{-1}, u is the wind speed (m s^{-1}) measured at 10 m and c the NH_3 concentration in µg m^{-3} measured with the miniDOAS. EQ (1) was derived from the available measurement data.

2. RESULTS AND DISCUSSION: The NH_3 flux determined by the passive sampler mass balance and the miniDOAS concentrations at 10 m times the wind speed is shown in Figure 1. They fit well for most parts of the year and thus, the method can be considered as suitable. The determined average emission over the entire measuring period from 1st January 2016 to April 18th 2017 is 0.06 g NH_3 m^{-2} h^{-1} (Table 1). The concentration ranges determined for the different seasons coincide with the basic principles driving the release of ammonia with higher emissions in the warm summertime and lower NH_3 release during winter and transition period except for spring 2017. For the year 2016, the average emission amounts to 0.05 g NH_3 m^{-2} h^{-1} which is at the lower end of values found in the literature ranging from 0.04 to 0.44 g NH_3 m^{-2} h^{-1} (Kupper, 2016).

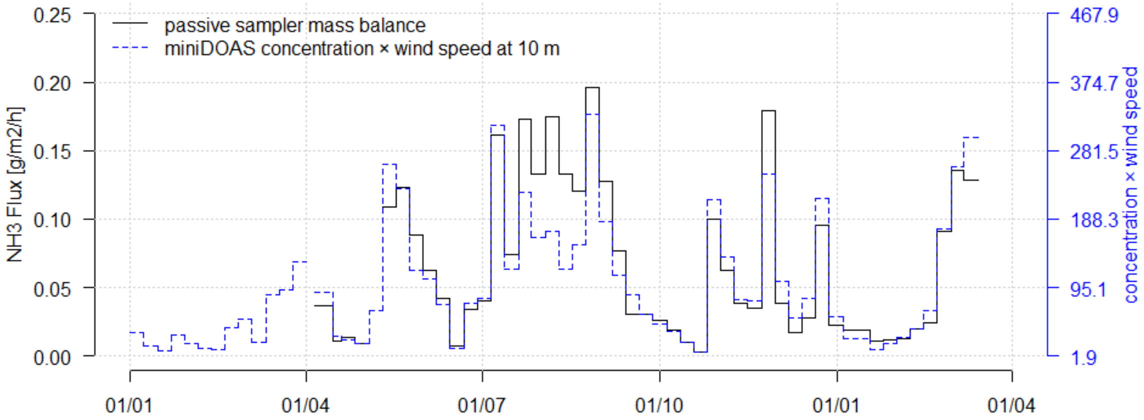

Figure 1. Comparison between the NH_3 flux (NH_3 m^{-2} h^{-1}) based on the passive samplers mass balance and miniDOAS concentrations at 10 m x wind speed as shown in Eq 2.

Table 1. NH_3 emissions (Em., average, range) from the uncovered tank in g NH_3 m^{-2} h^{-1}. Temp. is the average temperature (°C), rainfall the sum of precipitation (mm) and Nb the number of stirring events (Nb.) and the duration of stirring (h) of the slurry tank.

Measuring period **Begin**	 **End**	**Season**	**Em. average**	**Em. range** **g NH_3 m^{-2} h^{-1}**	**Temp.** **°C**	**Rainfall** **mm**	**Stirring** **Nb. / h**
2016-01-01	**2016-02-28**	Winter	0.01	0.00-0.21	8.2	195	1 / 5h
2016-03-01	**2016-05-31**	Spring	0.05	0.00-1.02	14.1	224	11 / 32h
2016-06-01	**2016-08-31**	Summer	0.08	0.00-1.06	20.2	165	21 / 25h
2016-09-01	**2016-11-30**	Fall	0.05	0.00-0.78	10.8	144	7 /14h
2016-01-01	**2016-12-31**	All	0.05	0.00-1.06	12.7	745	41/ 76h
2016-12-01	**2017-02-28**	Winter	0.04	0.00-1.07	0.8	114	4 / 23h
2017-03-01	**2017-04-18**	Spring	0.20	0.00-1.56	10.0	67	5 / 6h
2016-01-01	**2017-04-18**	All	0.06	0.00-1.56	10.9	909	49 / 105h

As found in most investigations (Kupper, 2016), emissions are largely influenced by the structure and the extent of a natural crust which constitutes an efficient barrier for the transfer of NH_3 from the slurry to the ambient air. It can be assumed that for a significant emission reduction, a crust thickness of approx. 10 cm is required (Misselbrook et al., 2005). As demonstrated by the crust layer measurements and the recordings of slurry tank operations, it takes about 14 days after the latest stirring until a crust of >10 cm thickness is formed. Emissions from periods of ≤14 days since the latest slurry stirring were only 50% as compared to corresponding periods of >14 days. Figure 2 shows that after slurry stirring emission peaks can be observed. This is also related the deletion of the crust when slurry is stirred and the loss of its action as a barrier for NH_3 release. It could also be demonstrated that the slurry level in the tank influences the emissions. At levels less than 1 m the emissions are on average smaller by 25% as compared to levels above 1 m. In the current study, a crust of more than 10 cm thickness did not form at a level of less than 1 m of slurry in the tank. The meteorological conditions, e.g. rainfall influenced the emissions as well (Figure 2). The surprising high emissions in spring 2017 can partly be explained by the high frequency of stirring, the relatively low level of slurry in the tank and the low occurrence of rainfall. Moreover, potential interactions between meteorology, the presence of a crust and the emission height remain to be analysed in detail.

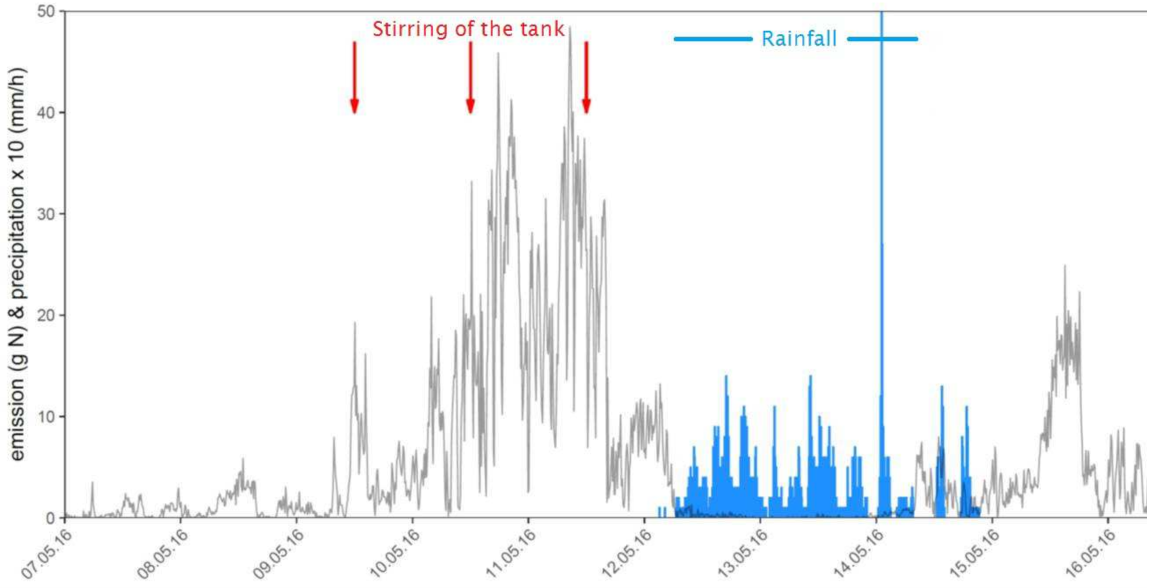

Figure 2. NH_3 flux in g N 10 min-1 from the storage tank as influenced by stirring of the slurry tank and meteorological conditions (e.g. rainfall).

3. CONCLUSION: Measurements from an uncovered slurry tank carried out over one year under real world conditions yielded average emissions of 0.06 NH_3 m^{-2} h^{-1}. The emission level responded well to important influencing parameters, e.g. natural crust at the slurry surface. The present study provides a unique dataset in order to investigate emissions from slurry tanks and interactions thereof related to operations and meteorological conditions as occurring in practice.

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GASEOUS EMISSIONS OF 3 TREATMENTS (CONTROL, COVERED, COVERED+COMPACTED) SOLID MANURE HEAP AT STORAGE

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ABSTRACT: In France, 46% of ammonia national emissions come from dairy and beef cattle farms (CITEPA, 2010). Storage represents nearly 13% of nitrogen losses (as ammonia) of the livestock in France, but only few studies on it. This study focus on solid manure that represent more than 80% of national cattle manure. Different practices have been tested to see their effects on gaseous emissions (CO_2, CH_4, NH_3, N_2O, H_2O): control heap (*cont.*), covered heap (*cov.*), compacted covered heap (*cov.+cont.*). Around five tons of solid manure per heap have been stored on a platform, temperatures have been followed at different heights (30, 60 and 90 cm). Gaseous emissions were followed during 48 hours every week for 14 weeks. Gas concentrations were measured at entry and exit of dynamic chamber with an infrared photoacoustic analyser (INNOVA 1412). Ventilation rate was controlled with Fancom mechanical fan. This study show that most of emissions N-NH_3, N-N_2O and C-CH_4 occurred during the first month, emissions are respectively from 4 to 12%, 0.075 to 0.15%, 0.3 to 3% of initial N and C present in the heap. N emissions of deep litter heaps are mainly on N_2 form. Compaction leads to a higher CH_4 emissions (10 times).

Keywords: GHG, NH_3, solid manure, cattle, storage

INTRODUCTION: From the environmental point of view, ammonia emissions are partly responsible for acidification and eutrophication. In France, agriculture contributes 97% to national ammonia emissions which 46% comes from bovine farms (CITEPA, 2010). Different regulations at international, European and national levels have been established to limit particulate emissions, including ammonia, and sign up for part in the National Health and Environment Plan (NESP). As part of the proposed measures to reduce gas emissions in agriculture, it is necessary to pay attention to their feasibility from the point of view of their environmental efficiency and of their relevance at the farmer scale. Emissions from storage, which represent nearly 13% of nitrogen losses (as ammonia) from the bovine livestock operation, has however been little studied in France. This is particularly the case of cattle solid manure whose emissions are ignored while 68.7 million tons of cattle manure are produced each year in France, representing 80% of the total mass of cattle manure. EMAFUM project, funded by ADEME, had three main objectives: (i) development of a simplified method for the measurement of cattle manure storage (modeling and intermittent measurements), (ii) acquisition of reference values on emission kinetics deep litter heap (DLH) in representative conditions of livestock, (iii) evaluating the effect on gas emissions of three manure management modes (control heap, heap covered by a geotextile covering, covered + compacted heap) of deep litter during storage. This study focused on point (iii) that is based on the most dry and compact category of manure ('FTC') that represented in 2010, 25% of the solid manure produced by dairy farms and 65 % of the solid manure produced by meat farms.

1. MATERIAL AND METHODS

1.1. Farm and manure characteristics: The solid manure studied comes from a Pays de la Loire dairy farm. During accumulation period, there were 69 Holstein dairy cows in 400 m² straw based loose housing (10 kg of straw/cow/day). Dairy cows were fed with maize silage, grass silage and concentrates (respectively 38 kg, 17 kg, 7 kg of raw matter per cow), and they produced 28 kg milk.day^{-1}.cow^{-1} during the accumulated period with an average of 6 months lactation stage. After removal from the barn, 5 tons of solid manure per heap have been stored on a platform from 13/02/2013 to 22/04/2013. Three storage modalities of this solid manure have been tested at the experimental farm of Derval: (i) Control (*Cont.*) manure stored in a heap, (ii) Covered (*Cov.*) with a polypropylene cover (Gangloff® Toptex) and (iii) Covered + compacted (*Cov. + Comp.*) with tractor at storage.

Figure 1: Heap shape at the beginning of storage from left to right : Cont., Cov, Cov. + Comp.

1.2. Gaseous emissions: Temperatures have been followed at different heights (30, 60 and 90cm) with thermocouples linked with a CR3000 (Campbell Scientific). Gaseous emissions were followed during 2 days (48 hours) every week for 11 weeks with dynamic chamber systems (Greenhouse structure covered by a plastic cover usually used to cover maize silage). Gas concentration were measured at entry and exit of dynamic chamber with an infrared photoacoustic analyser (INNOVA 1412). Ventilation rate was controlled with Fancom mechanical fan, and punctually controlled anemometer (TSI 8470, TH-industrie, Paris). During 1 week, from 27/02 to 6/03/13, heaps have been covered and SF_6 tracer gas has been introduced at entry to estimate and validate the ventilation rate of the fan. All along the trial, air entry size and ventilation rate have been adapted in order to keep a sufficient difference between entry and exit air concentrations to calculate the gradient concentration ($[Gas_{outlet}]$-$[Gas_{inlet}]$). Leachates were collected, weighted and analysed regarding rainfall during all the storage period. Gas emissions were calculated by multiplying concentration gradients and ventilation rates. Emissions between, two measurements points have been estimated with a linear interpolation.

2. RESULTS AND DISCUSSION: Ammonia emissions range from 4 to 12% total nitrogen originally present in the heap (table 1), probably related to the low ammonia nitrogen content of this type of effluent (11-34% of TAN – "total ammoniacal nitrogen" – TAN representing 35% of initial nitrogen). N_2O emissions ranged between 0.08 and 0.2% of total nitrogen initially present. Liquid losses of nitrogen (nitrate, ammonia) were less than 1% of the initial total nitrogen. The decrease in nitrogen of deep litter cattle manure occurs mostly in the form of dinitrogen (N_2-N ; 24-28% of the initial total nitrogen for the control and the covered pile, and 4% for the compacted treatment).

Table 1. Number of observations (n), emission factors EF (in % of TAN applied) and range in the data for various liquid manure application methods.

Treatment			**Cont.**	**Cov.**	**Cov. + comp.**
Mass	Manure initial mass	Kg	5060	5020	5100
	Manure final mass	Kg	3440	2774	3824
Gas losses	$N-NH_3$	$\%_{\text{initial\_mass\_totalN}}$	12	7	4
	$N-N_2O$	$\%_{\text{initial\_mass\_totalN}}$	0.1	0.08	0.2
	$N-N_2$	$\%_{\text{initial\_mass\_totalN}}$	24	28	4
	$C-CH_4$	$\%_{\text{initial\_mass\_totalC}}$	0.4	0.3	3
	$C-CO_2$	$\%_{\text{initial\_mass\_totalC}}$	41	26	27
Leachate losses	Total N	$\%_{\text{initial\_mass\_totalN}}$	0.7	0.6	0.7

This study shows that NH_3-N, N_2O-N and CH_4-C emissions occur predominantly during the first month of storage for deep litter heap (FTC), respectively in the range of 97 to 100%, 41 to 56% and 82 to 90% depending on the treatment (Figure 1).

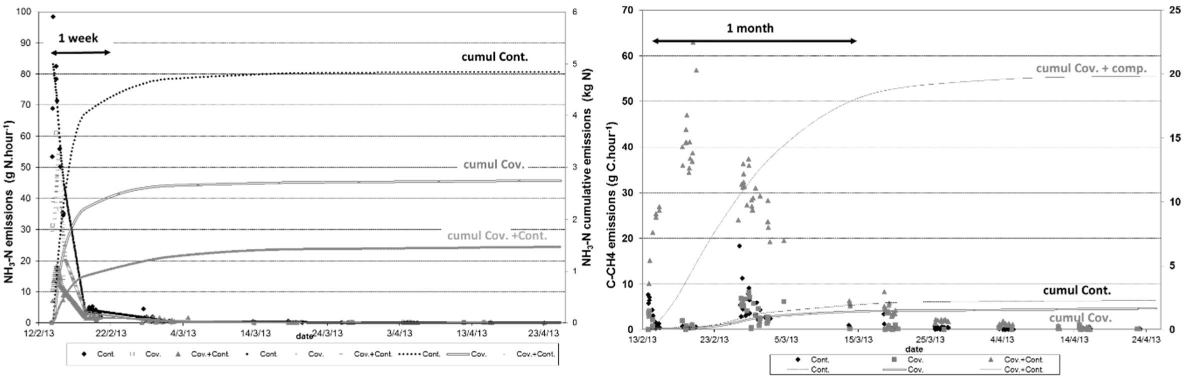

Figure 1. Cumulative and daily emissions during storage period of the 3 treatments (cont., cov. And cov.+comp.) of NH_3-N (left) and CH_4-C (right).

The treatments studied in this project confirmed the hypothesis of ammonia emission reductions by covering or compacting (Petersen & Sommer, 2011). The uncertainty on emission reduction (in % of initial total nitrogen) was less than 6%, but remained high considering the uncertainty about the initial composition of manure (above 20%) and the repeatability of pile setting up (complex geometrical shape, lack of turning equipment). Covering the pile induced a decrease in biological activity by limiting humidification from rain. This result should be confirmed with further measurements covering the variability of pile setting and climates (rainfall). Regarding GHG emissions, covering the pile did not reduce emissions. On the contrary, the compaction has a significant impact: nearly 10 times increase the amount of methane emitted. This is unacceptable to consider recommending compaction heap at storage. Staying at the scale of single storage is a bit simplistic, particularly at the level of ammonia that can be emitted after spreading, particularly when the manure is entered in the soil after 48h. Indeed, the control heap contains no more ammonia nitrogen at the end of storage, which suggests a limited volatilization during spreading. The covered heap had little bit less volatilization during storage, but it still contains 3 kg of NH_3 at the end of the period, which could be more easily volatilized during spreading.

3. CONCLUSION: Ammonia losses are for all treatments less than 12% of initial nitrogen. This study confirmed that solid manure (FTC) is a very heterogeneous product and sampling and characterization is hard. Moreover in France there is a very high diversity of solid manure types linked to farm practices (feed ration, type and amount of litter, type of housing, grazing, animal productivity,…), so further investigation are required to have an overview of diversity at national scale on the whole manure management chain.

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EVALUATION OF GHG AND AMMONIA IN THE PROCESS OF COMPOSTING CHICKEN CARCASSES IN ROTATING DRUMS

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ABSTRACT: The objective of this work was to evaluate the GHG and ammonia emissions in the composting of chicken carcasses in drums reactors. The experiments were developed in four rotating drums reactors with a volume of 4 m^3. The study comprised 4 treatments, regarding the time which reactor remained in pause between the rotation movements: 1 hour (T1), 2 hours (T2); 3 hours (T3) and 4 hours (T4). Gaseous concentrations were determined using a photoacoustic equipment (INNOVA 1412). It was verified that T4 presented higher C-CO_2 emission and T1 presented the highest N-NH_3 emission. For the emission of C-CO_2 and N-NH_3, a correlation with the pause time of the reactor was observed, demonstrating the existence of the relation of the emission of gases with the treatments used.

Keywords: accelerated composting, rotating drums reactors, gaseous emissions, chicken carcass.

INTRODUCTION: Composting is an effective method to solve the problem of dead animals on farms (Mukhtar et al., 2004), becoming an important technology for the disposal of these wastes (Price and Carpenter-Boggs, 2008) and is able to increase the efficiency of this process with the use of biological reactors (Misra and Roy, 2003). In southern Brazil, the implantation of these rotary drum type reactors is being encouraged as technology for disposal of dead animals in production systems. In this context, the objective of this work was to evaluate the GHG and ammonia emissions in the composting of chicken carcasses in drums reactors.

1. MATERIAL AND METHODS: The experiments were developed in batch mode in four rotating drums reactors, with a volume of 4 m^3 and a continuous ventilation system, which ensured the exchange of internal air. The study comprised 4 treatments, with respect to the time between the rotations, of 24 minutes, in which the reactor remains in pause: 1 hour (T1), 2 hours (T2); 3 hours (T3) and 4 hours (T4). Each reactor was loaded with 300 kg of crushed chicken carcass and sawdust added in a 1:1 ratio (carcass: sawdust), filling 50% of its volumetric load. For temperature monitoring, four ibutton type meters were used, mixed with biomass inside the reactor during the 21 days of the work. Samples of the decomposed material were collected for analysis of carbon (C), nitrogen (N), dry matter (DM), pH and phosphorus (P). The concentrations of CH_4, CO_2, N_2O and NH_3 in the air at the input and output of the reactor were determined using a photoacoustic equipment (INNOVA 1412). The emissions determined from the calculation principle of the concentration relations method (Paillat, 2005; Robin et al., 2010), which assumes that all carbon loss in the material during the composting process occurred through the emission of CO_2 and CH_4 (Equation 1). In order to calculate the emission, the concentration gradient of each gas between the output air and the reactor input air (Equation 2) must be known. This gradient correlates with the CO_2 emission (Equation 3), which is determined by the loss of carbon in the material (Equation 4).

$$\mathrm{Loss_C} = \mathrm{Emission_{C-CO_2}} + \mathrm{Emission_{C-CH_4}} \qquad (1)$$

$$\mathrm{G_{gas}} = \mathrm{M_{output}} - \mathrm{M_{input}} \tag{2}$$

$$\mathrm{Emission_{gas}} = \mathrm{Emission_{C-CO_2}} . \left(\frac{\mathrm{G_{gas}}}{\mathrm{G_{C-CO_2}}}\right) \tag{3}$$

$$\mathrm{Emission_{C-CO_2}} = \mathrm{Loss_C}/[1 + \left(\frac{\mathrm{G_{C-CH_4}}}{\mathrm{G_{C-CO_2}}}\right)] \tag{4}$$

Being $Loss_C$: materi loss of carbon in the mass of the material (kg); $Emission_{C-CO_2}$: C-CO_2 emission (kg); $Emission_{C-CH_4}$: C-CH_4 emission (kg); G_{gas}: concentration gradient for each of the gases (N-NH_3 ou N-N_2O) (mg/m^3); M_{output} : median of the concentrations observed in the reactor output air (mg/m^3); M_{input}: median of the concentrations observed in the reactor input air (mg/m^3); G_{C-CH_4}: C-CH_4 concentration gradient (mg/m^3), G_{C-CO_2}: C-CO_2 concentration gradient (mg/m^3). The emission of N_2 was determined by the difference between the amount of nitrogen lost in the mass of the material during the composting process and the sum of the emissions of N-NH_3 and N-N_2O.

2. RESULTS AND DISCUSSION: As regards temperature, for T1 and T2, the organic material remained on average for 6 and 7 days above 50 °C, whereas for T3 and T4 it was 10 and 13 days, respectively. The pH was similar for all treatments. At the beginning of the process, values of approximately 5.8 were obtained for all reactors, ending with values close to 7.1, presenting a range suitable for microbiological decomposition (Sesay et al., 1996). In all treatments, the CO_2 emission was responsible for approximately 99% of the carbon loss present in the decomposing material, characteristic of aerobic processes, with the rest of the carbon loss attributed to CH_4 emission, indicating the low formation of anaerobic zones (Paillat et al., 2005). In total, 31.03 kg C-CO_2 was emitted during the 21 days of experiment for the first treatment, while for T2, T3 and T4 the emission of C-CO_2 was 33.76 kg; 34.85 kg and 36.02 kg, respectively (Figure 1-b). The emission of C was higher in T4, which had a longer time of pause between the rotational movements of the reactor, while the treatment in which the reactor was programmed with the shortest pause time presented the smallest loss of C. A correlation between the C-CO_2 emissions and the pause time of the reactors (Figure 2), a logarithmic curve was obtained, with $r^2 = 0.99$, which shows that the emission of this gas is directly correlated with the time in that the reactor is at pause. This correlation is in agreement with the material temperature measurements, in which the reactors that had higher days at high temperatures were responsible for the higher emissions of C-CO_2, these two parameters being the result of the activity of the biochemical reactions in the organic material (Epstein, 1997). On the other hand, the losses due to NH_3 emission had the opposite behavior, because for the treatments with less pause time between the rotations (greater number of turns), the N-NH_3 emission was higher due to the contribution of the rotation process, which favors release of the gases present in the organic mass. The correlation between the total amount of nitrogen emitted in each reactor and the paused time of the reactors between the rotational movements was linear and negative, with $r^2 = 0.988$ (Figure 2). A total emission of 1.53 kg N-NH_3 was found for T1 and 1.26; 1.09 and 0.9 kg N-NH_3 for treatments T2, T3 and T4, respectively. The losses of N via ammonia emission represented 42.02%, 46.80%, 30.44% and 27.95%, and N_2 generation was responsible for the highest loss of this element (Figure 1-b). It was also observed that for all treatments, the highest emission of C-CO_2 and N-NH_3 occurred in the first week of experiment, a considerable reduction occurred in the subsequent days, along with the reduction of humidity, a factor that affects the biological activity and the emission of gases (Epstein, 1997). The high nitrogen emission is due to the favoring of the formation and volatilization of this gas due to the low C/N ratio used, which increased during the process (Tiquia and Tam, 2002).

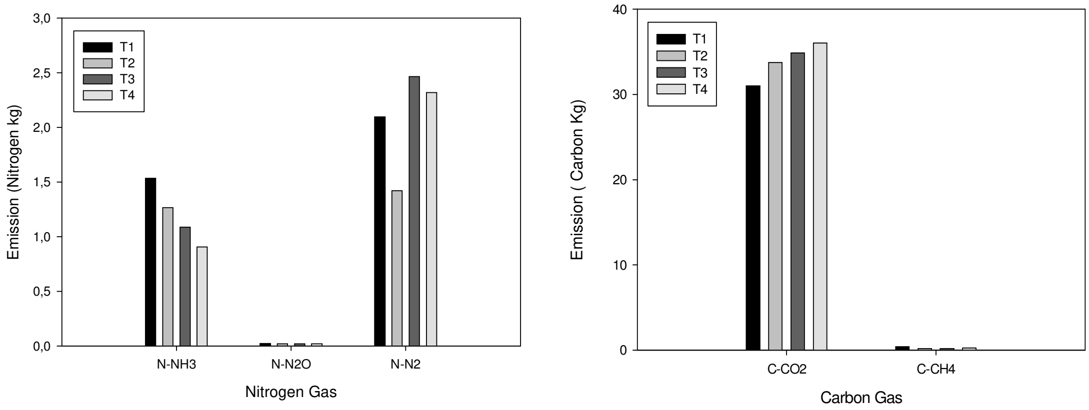

Figure 1. a) Total emission of nitrogenous gases b) Total loss of carbon.

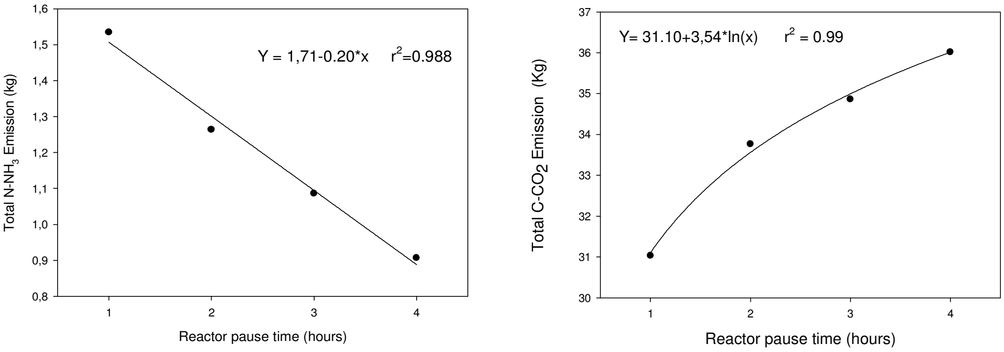

Figure 2. Correlation between the total emission (N-NH_3 and C-CO_2) and the pause time of the reactor.

Table 1 shows the mass balance of the reactors for carbon and nitrogen. The dry mass reduction (Table 2) was 16%, 18%, 19% and 20%, respectively for T1, T2, T3 and T4, being close to that found by Paillat et al. (2005), 20%. The difference between the mass of phosphorus in the material placed and withdrawn from the reactor was 1%, 2%, 3% and 4% for the reactors A, B and C, respectively, being these values below the maximum value recommended by Paillat et al. (2005), 10%, which demonstrates the confidence of the process.

Table 1: Material balance in the reactor for carbon and nitrogen.

Parameter	Carbon				Nitrogen			
Treatment	**T1**	**T2**	**T3**	**T4**	**T1**	**T2**	**T3**	**T4**
Input (kg)	136,26	136,26	136,26	136,26	9,30	9,30	9,30	9,30
Output (kg)	104.81	102.30	101.21	99.97	5.65	6.60	5.73	6.06
Loss (kg)	31.45	33.96	35.05	36.29	3.65	2.70	3.57	3.24
Loss (%)	23%	25%	26%	27%	39%	29%	38%	35%

Table 2: Material balance in the reactor for dry matter and phosphorus.

Parameter	Dry Matter				Phosphorus			
Treatment	**T1**	**T2**	**T3**	**T4**	**T1**	**T2**	**T3**	**T4**
Input (kg)	269.43	269.43	269.43	269.43	1.14	1.14	1.14	1.14
Output (kg)	226.93	221.50	219.13	216.45	1.15	1.12	1.11	1.10
Loss (kg)	42.49	47.93	50.30	52.97	0,01	0,02	0.03	0,04
Loss (%)	16	18	19	20	1	2	3	4

3. CONCLUSION: Accelerated composting in rotary drums proved to be an efficient alternative for the disposal of carcasses of dead chickens. it was verified that the longer the pause time of the reactor smaller the will be the emission of n-nh_3 and the greater the emission of C-CO_2**.**

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DUST, AMMONIA AND GREENHOUSE GASES EMISSIONS ASSOCIATED WITH THREE HOUSING TYPES FOR LAYING HENS

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ABSTRACT: The increasing public concern for animal welfare in different parts of the world pushed the poultry sector to progressively replace conventional battery cages (BC) for laying hens by alternative systems such as enriched cages (EC) and aviaries (AV). The aim of this study is to compare emissions of dust, NH_3, CH_4 and CO_2 from these three housing types. The experiment was conducted in twelve pilot-scale chambers fitted out with one of the three treatments. Each chambers housed 30 Lohmann LSL-Lite laying hens from 23 to 32 weeks of age. Equipment and housing conditions arrangement were performed in accordance with the European Directive 1999/74/CE. Aviaries were arranged in three levels with a wood shaving litter on the ground level. The emission measurements were continuously monitored and weekly means were statistically tested (proc MIXED, SAS). The results were expressed per hen and per day. Dust and NH_3 emissions were largely higher from AV compared to BC and EC with 342.9, 27.7 and 33.4 mg dust ($P<0.001$) and 759.2, 60.0 and 42.5 mg NH_3 ($P<0.001$) respectively. Greenhouse gas emissions were higher from BC compared to EC and AV with 75.0, 68.6 and 67.7 mg CH_4 ($P<0.001$) and 82.7, 68.6 and 80.1 g CO_2 ($P<0.001$) respectively.

Keywords: Dust, NH_3, CH_4, CO_2, Poultry, Battery cage, Enriched cage, Aviary

INTRODUCTION: The increasing public concern for animal welfare in different part of the world pushed the poultry sector to progressively replace conventional battery cage for laying hens by alternative systems such as enriched (or furnished) cages and aviaries. These alternative systems provide more space and include equipment allowing birds to perform specific behaviours like nesting, perching, scratching and pecking. These evolutions in the housing conditions will modulate air quality in the buildings and pollutant gas emissions to the environmental. Therefore, the aim of this study is to compare concentrations and emissions of CH_4, CO_2, NH_3 and dust from battery cages (BC), enriched cages (EC) and aviaries (AV) for laying hens.

1. MATERIAL AND METHODS: The experiment was conducted in twelve pilot-scale chambers (2.9 m^2 and 6.9 m^3) fitted out with one of the three treatments. Each chambers housed 30 Lohmann LSL-Lite laying hens. The experiment lasted 70 days from week 23 to 32 of hen's age. In BC chambers, hens were kept in six multi-deck battery cages (5 hens per cage, 492 cm^2 per hen). The EC chambers contained three decks cages (10 hens per cage, 780 cm^2 per hen) equipped with nest boxes (one nest for 5 hens), perches (15 cm per hen) and a scratching and pecking area (900 cm^2). In the AV chambers, the 30 hens had free access to a space arranged in three levels (1120 cm^2 per hen) with a wood shaving litter on the ground level, while the upper levels were made with metallic mesh and fitted out with nest boxes (three nests per level) and perches (15 cm per hen). The hens fed a commercial diet based on corn with ad libitum access to feed and water. Total dust concentration was determined by weighing the amount of dust collected on a filter with a continuous sampling rate of 2 L/min (one filter per chamber and per week). The emissions of NH_3 were measured by a non-dispersive infrared analyser. The emissions of CO_2 and CH_4 were analysed by gas chromatography. Gas emission measurements were taken continuously at 15 min intervals. For the statistical analyses, the weekly emissions were tested using a mixed model including the effect of housing condition (2 df) and the week of measurements (9 df) (proc MIXED, SAS 9.3, SAS Institute Inc., Cary, NC).

2. RESULTS AND DISCUSSION: Ambient parameters and gas emissions observed in the experimental chambers are presented in Table 1.

Table 1. Ambient parameters, concentration and emission associated with laying hens kept in battery cage (BC), enriched cage (EC) or aviary (AV)(SEM: standard error of the means; Significance: H: housing type; W: week of measurement H x W: interaction).

	Housing type				**Level of significance**		
	BC	**EC**	**AV**	**SEM**	**H**	**W**	**H x W**
Ambient temperature (°C)	19.8^{a}	19.7^{a}	20.3^{b}	0.1	<0.001	<0.001	0.954
Relative humidity (%)	28.5^{a}	26.5^{b}	28.5^{a}	0.5	0.007	<0.001	0.539
Ventilation rate (m^3 h^{-1} hen^{-1})	4.14^{a}	3.95^{b}	4.29^{c}	0.02	<0.001	<0.001	<0.001
Concentration (ppm)							
Dust (µg m^{-3})	277^{a}	346^{a}	3109^{b}	298	<0.001	<0.001	<0.001
NH_3 (ppm)	1.56^{a}	1.32^{a}	11.44^{b}	0.19	<0.001	<0.001	<0.001
CH_4 (ppm)	2.95^{a}	2.88^{ab}	2.82^{b}	0.02	0.004	<0.001	0.989
CO_2 (ppm)	1160^{a}	1099^{b}	1133^{c}	3	<0.001	<0.001	0.005
Emissions (hen^{-1} day^{-1})							
Dust (mg)	27.7^{a}	33.4^{a}	342.9^{b}	42.5	<0.001	<0.001	<0.001
NH_3 (mg)	60.0^{a}	42.5^{a}	759.2^{b}	11.5	<0.001	<0.001	<0.001
CH_4 (mg)	75.0^{a}	68.6^{b}	67.7^{b}	1.5	<0.001	<0.001	0.994
CO_2 (g)	82.7^{a}	68.6^{b}	80.1^{c}	0.6	<0.001	<0.001	0.375

$^{a,\ b,\ c}$: Values with different superscripts differ significantly (P<0.001)

Dust in poultry houses is composed of inorganic and organic compounds that originate from animals (feather and skin particles, dried fecal matter), feed components, building materials and litter. It also act as mechanical vector for microorganisms and toxins (molds, fungi, viruses, bacteria and endotoxins), causing deleterious health effects for the animals and workers and contributing to dissemination of pathogens in the environment (David et al., 2015a). In this trial, total dust concentration and emission were greatly higher for the AV system, with nearby tenfold values compared to CC and EC systems. In a comprehensive study carried out under commercial conditions, PM_{10} concentrations of 0.59, 0.44 and 3.95 mg m^{-3} were measured for BC, EC and AV, respectively (Zhao et al., 2015), and PM_{10} emissions of 15.7, 15.6 and 100.3 mg hen^{-1} day^{-1},respectively (Shepherd et al., 2015). Higher dust levels are clearly linked to the presence of litter. Factors that impact the amount of dust in aviaries include the characteristics of the bedding material (type, quantity, moisture), the climatic conditions (relative humidity, temperature, ventilation rate, air velocity), birds' activity and husbandry management (feeding system, light schedule, eggs collection system), with interactions between these factors (David et al., 2015a). Decrease in dust level can be achieved thanks to water spraying over the litter with reduction up to 64 %. Nevertheless, this technique is associated with proportional increase of NH_3 emissions (David et al., 2015a).

Ammonia in poultry buildings mainly originates from microbial degradation of uric acid of the droppings. It causes adverse effects regarding health of birds and workers, production performance and environment (David et al., 2015b). As observed for dust, NH_3 concentrations and emissions were the highest with AV. Zhao et al. (2015) reported NH_3 concentrations of 4.0, 2.8 and 6.7 ppm for BC, EC and AV, respectively, and NH_3 emissions of 82, 54 and 112 mg hen^{-1}

day^{-1} respectively. Other values reported in the literature for cages systems are between 66 and 198 mg hen^{-1} day^{-1} for BC and around 75 mg hen^{-1} day^{-1} for EC (Fabbri et al., 2007; Nimmermark et al., 2009; Costa et al., 2012; Fournel et al., 2012). In studies testing different AV systems, mean concentrations ranged from 5.0 to 15.5 ppm and mean emissions ranged from 277 to 569 mg hen^{-1} day^{-1} (Groot Koerkamp and Bleijenberg, 1998; Dekker et al., 2011; Costa et al., 2012). Nimmermark et al. (2009) reported the highest values with concentration up to 85 ppm and emission rate of 2100 mg hen^{-1} day^{-1}. Among the factors that affect NH_3 volatilization, the duration of dropping accumulation and the moisture content of manure play crucial roles (Groot Koerkamp and Bleijenberg, 1998). These factors are particularly deleterious for AV systems. Thus, ambient temperature, ventilation rate and relative humidity have to be properly controlled to avoid moisture accumulation on littered floor, especially during cold season. Choice for bedding material that increases the dry matter content of the litter, strategies to avoid water spillage, drying manure systems, housing design to encourage birds to lay their droppings on the belt and frequent scraping/removal of the manure are some of the techniques that can be used to reduce NH_3 emissions from AV systems (Groot Koerkamp and Bleijenberg, 1998; Dekker et al., 2011; David et al., 2015b; Shepherd, 2015).

Methane originates from the anaerobic bacterial degradation of organic matter occurring in the manure. The digestive tract is also a potential source of CH_4 but it is usually considered negligible for poultry. In buildings, the level of CH_4 is not use as indicator of air quality as seen its harmlessness in terms of hen or human health, however it is an important greenhouse gas that contributes to global warming. The emissions observed in the current trial were comparable to those measured in previous studies, with values around 70-80 mg hen^{-1} day^{-1} for cages systems, and from 35 to 150 mg hen^{-1} day^{-1} for AV systems (Fabbri et al., 2007; Dekker et al., 2011; Fournel et al., 2011; Shepherd et al., 2015). The variation in emission factors reported in the literature for AV systems could be attributed to different litter management (type, amount and surface of bedding material). Accumulation of droppings in the course of time and moisture content of the manure create favorable anaerobic conditions that could explain higher CH_4 releases from the litter.

The main source of CO_2 in poultry houses is the animals' respiration while the manure is responsible of 1 to 5 % of total emissions (Fournel et al., 2011; Shepherd et al., 2015). The mean CO_2 concentrations measured in this trial are relatively low compared to those reported by Zhao et al. (2015) with 2084, 2216 and 2475 ppm for BC, EC and AV, respectively. Dekker et al. (2011) presented values ranging from 1500 to 1550 ppm for three types of AV. The observed CO_2 emissions from this study fall within the range reported in literature with 68 to 85 g hen^{-1} day^{-1} whatever the housing system (Dekker et al., 2011; Fournel et al., 2011; Shepherd et al., 2015). In alternative systems, the higher space allowance and the possibility to experience several specific behaviours should have induced higher emissions associated with higher hens' activity, metabolic rate and respiration rate, but it seems be not confirmed. In the same way, the contribution of the litter to total emission seems not decisive in AV systems.

3. CONCLUSION: Alternative housing systems for laying hens were developed to promote animals' welfare. However, the welfare benefits could be counterbalanced due to detrimental impacts on air quality and environment, especially regarding dust and ammonia production. Thus, more research is needed to adapt or elaborate housing systems considering welfare, health, performance and economic factors.

Acknowledgements. Funding for this project was provided by the "Ministère de l'Agriculture, des Pêcheries et Alimentation du Québec (MAPAQ)" and the "Fédération des producteurs d'œufs de consommation du Québec (FPOCQ)". The technical support of Christian Gauthier and Michel Côté were greatly thanked. The professional support given by the CRSAD staff is also gratefully acknowledge gratefully acknowledge

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AMMONIA AND GREENHOUSE GAS EMISSIONS AT POST-WEANING COMMERCIAL PIG FARMS AT BRAZIL

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ABSTRACT: The aim of this study was to determine the gaseous emissions (ammonia and greenhouse gases) from four commercial post-weaning pig farms located at the west of Santa Catarina State in southern Brazil, during 14 months, considering four production cycles per each farm (26,695 piglets in total; housing period: 35 days). The emissions were estimated according to the concentration ratios method defined in the simplified methodology of measurement. The emissions measured at post-weaning farms (piglet·d^{-1}) were 0.42 kg CO_2, 1.07 g CH_4, 0.07 g N_2O and 0.42 g NH_3. The values obtained from the current study were similar in some cases to the results reported in the literature but also differed considerably when compared with other studies. This difference confirms the need to exercise caution when applying literature data to estimation of gas emissions. The results obtained in this study are expected to contribute both to the global greenhouse gases and to Brazil inventories.

Keywords: Piglets, post-weaning, natural ventilation, greenhouse gases, ammonia.

INTRODUCTION: Currently, intensive livestock production, and literature regarding same, is confronted with a serious lack of information regarding the real gas emissions from commercial pig farms mainly in tropical countries such as Brazil (Tavares, 2016). Thus, the aim of this study was to determine the gaseous emissions (ammonia and greenhouse gases) from four commercial post-weaning pig farms located at the west of Santa Catarina State in southern Brazil.

1. MATERIAL AND METHODS:

1.1. Farms and equipment: Four commercial post-weaning farms, similar in size and lodging capacity, were monitored and evaluated for 14 months considering a housing period of 35 days. Of a total of 36 production cycles evaluated only 16 was used to determine the emission factors for ammonia and greenhouse gases (4 production cycles per farm). The piglets were distributed randomly by sex in both sides of the housings buildings, each with pens for 40±2 piglets (number of pens varied according to the housing farm capacity). Every pen measured 3.2 x 4 m (12.8 m^2; 0.32 m^2 piglet^{-1}), had a partly slatted floor, a unique circular feeder and a pendulum nipple drinker with double exit. The manure produced was cleaned manually, at least one time per day, by the producers (dry cleaning). The farms were naturally ventilated through a system of double-sided curtain and contained a heating system (wood-fired boiler).

1.1.1. Post-weaning piglets**:** In total 26,695 piglets were housed at the four post-weaning farms chosen during the 16 production cycles monitored and evaluated. All piglets had a Landrace x Large White mother and a Landrace x Large White or Pietran boar father. The piglets (25.35±2.86 days old and 7.36±0.98 average BW) were fed ad libitum and during each production cycle, they had access to 5 different nutritionally balanced diets (corn and soybean; crude protein content ranging between 18.5% and 21.0%) produced by the agroindustry company and formulated according to National Research Council and Brazilian tables for poultry and pigs.

1.2. Water disappearance and manure production measurements: Were determined daily according to Tavares et al. (2014). Water use was measured by a total of 18 water meters (Unimag Cyble PN 10, Itron Inc., Liberty Lake, Washington) installed in all water delivery lines at farms chosen, which supplied each housing building. Total manure production was measured in round fiberglass tanks with 5 m^3 volume (Fibratec PRFV 819 and Fortlev, Araquari, SC, Brazil), installed between the housing buildings and the storage system in each farm. The manure produced and stored inside the housing buildings was transferred every day to the fiberglass tanks by gravity for its retention. Every day at 09:00 and 10:00 am the producer measured and recorded the water meters measures and manure depth inside the tanks, respectively. The manure produced was sampled weekly in each post-weaning farm and the physico-chemical characterisation of samples was performed at EMBRAPA Pigs and Poultry, Concórdia/SC, Brazil.

1.3. Gas emissions measurements: Were estimated according to the concentration ratios method defined in the simplified methodology of measurement (Paillat et al., 2005; Robin et al., 2010). The gas concentrations of air taken outside and inside of the post-weaning farms (CO_2, CH_4, N_2O and NH_3) were quantified by photoacoustic infrared spectrometry (INNOVA 1412®) (LumaSense Technologies, Inc., Denmark). The air sampling was performed one day per week amounting 10 samples per cycle (five weeks: morning and afternoon). Therefore, emissions were determined from the carbon mass balance default assuming that all losses occurred through the emission of CO_2 and CH_4 (Eq. 1). The median values of gas concentrations both inside ($M_{[Gas,\ int.]}$) and outside ($M_{[Gas,\ ext.]}$) the building were considered to obtain the averages of concentration gradients ($\bar{G}_{Gas}$) (Eq. 2; Eq. 3). Thus, the emissions for CO_2 and the different gas have been estimated according to the Eq. 4 and Eq. 5, respectively. Nitrogen emissions were determined assuming that all nitrogen losses are equal to the sum of N-NH_3, N-N_2O and N-N_2 emissions.

$$\text{Loss}_C = \text{Emission}_{C\text{-}CO2} + \text{Emission}_{C\text{-}CH4} \quad (1)$$

$$G_{Gas} = M_{[Gas,\ int.]} - M_{[Gas,\ ext.]} \quad (2)$$

$$\bar{G}_{Gas} = \text{Mean}\left[\left(G_{Gas,y};\ G_{Gas,y+1};\ \ldots \text{ with: } y=1, 2,\ldots y \text{ samples}\right)\right] \quad (3)$$

$$\text{Emission}_{C\text{-}CO2} = \text{Loss}_C / \left[1+\left(\bar{G}_{C\text{-}CH4} / \bar{G}_{C\text{-}CO2}\right)\right] \quad (4)$$

$$\text{Emissão}_{Gas} = \text{Emissão}_{C\text{-}CO2} \cdot \left(\bar{G}_{Gas} / \bar{G}_{C\text{-}CO2}\right) \quad (5)$$

2. RESULTS AND DISCUSSION: The emissions of CO_2, CH_4, N_2O and NH_3, determined from the carbon mass balance default assuming that all losses occurred through the emission of CO_2 and CH_4, are presented in Table 1.

Table 2 - Ammonia and Greenhouse gas emissions at post-weaning commercial farms.

Gas Emissions	Mean	σ[†]	Max.	Min.
CO_2 ($kg \cdot piglet^{-1} \cdot d^{-1}$)	0.42	0.06	0.50	0.34
CH_4 ($g \cdot piglet^{-1} \cdot d^{-1}$)	1.07	0.42	1.82	0.65
N_2O ($g \cdot piglet^{-1} \cdot d^{-1}$)	0.07	0.04	0.16	0.03
NH_3 ($g \cdot piglet^{-1} \cdot d^{-1}$)	0.67	0.24	1.09	0.35

[†] Standard deviation.

The emissions of CO_2 and CH_4 represented 99.3 and 0.7%, respectively, of the carbon losses calculated by the mass balance method (0.12 kg piglet^{-1}·cycle^{-1}). On average, CH_4 emissions were 1.07 g·piglet^{-1}·d^{-1} for a maximum housing period of 35 days. Regarding this gas, the literature presented emission values between 0.52 and 1.58 g·piglet^{-1}·day^{-1} considering forced-ventilation and fully slatted or bedded floor systems (Nicks et al. 2003; Cabaraux et al., 2009). The low emissions measured in the farms were coherent with the daily removal frequency of manure produced. The CO_2 emissions were, on average, 0.42 kg·piglet^{-1}·d^{-1}. This value showed consistency with results reported in the literature, independently of the conditions of the experiments [0.30-0.48 kg piglet^{-1}·d^{-1}; (Nicks et al., 2003; Cabaraux et al., 2009)]. The emissions obtained in this study were higher when compared to the values presented for experiments with fully slatted floor [0.30-0.34 kg piglet^{-1}·d^{-1}; Cabaraux et al., 2009] and lower, mostly for systems with bedded systems [0.33-0.48 kg piglet^{-1}·d^{-1}; (Nicks et al., 2003).

The emissions of NH_3 and N_2O estimated according to the concentration ratios method defined in the simplified methodology of measurement represented 42.8 and 4.5%, respectively, of the nitrogen losses by volatilization calculated by the mass balance method (54,80 g piglet^{-1}·cycle^{-1}). Assuming that all nitrogen losses are equal to the sum of N-NH_3, N-N_2O and N-N_2 emissions, it can be concluded that the amount of nitrogen volatilized not measured in the balance was approximately 52.7% (lost as elementary nitrogen: N-N_2). On average, NH_3 emissions were 0.67 g·piglet^{-1}·d^{-1}, for a maximum housing period of 35 days [9.6% of the excreted nitrogen (6.98 g·piglet^{-1}·d^{-1})]. The value obtained was lower than the results indicated at literature for fully slatted floor systems (Dourmad et al., 2015). Values available at literature also show that NH_3 emissions ranged from 0.38 to 3.45 g·piglet^{-1}·d^{-1} considering forced ventilation and fully slatted or bedded floor systems (Guingand, 2003; Cabaraux et al., 2009). Comparing the emissions obtained in this study with the values indicated for other experiments with fully slatted floor, these were consistent within the variability observed (Guingand, 2003; Cabaraux et al., 2009). The N_2O emissions were, on average, 0.07 g·piglet^{-1}·d^{-1}, which represented 1% of the excreted nitrogen. This value was coherent, but smaller than the values indicated in the literature for growing-finishing pig farms with fully slatted concreted floor [N_2O emission ranged between 2 and 4% of the excreted nitrogen (Kermarrec and Robin, 2002)]. In average, the emission obtained was higher when compared to the values presented for experiments with fully slatted floor [0.0 to 0.01 g·piglet^{-1}·d^{-1}; (Cabaraux et al., 2009)]. The nitrogen losses in its elementary form corresponded to 4.5% of the amount ingested daily by the piglets (18.54 g). These results were consistent with the values cited in researches carried out with fully slatted floor for pigs at growing-finishing phase (Kermarrec and Robin, 2002). The Figure 1 shows the carbon (a) and nitrogen (b) balances determined according to the mass balance default and the concentration ratios method.

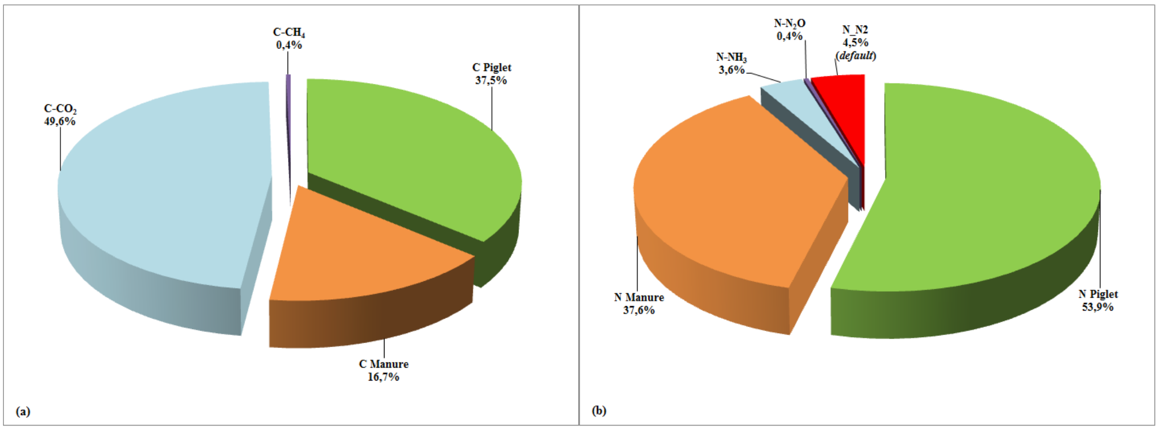

Figure 2- Carbon (a) and nitrogen (b) balances.

3. CONCLUSION: On average, the piglets at post-weaning commercial farms emitted 0.42±0.06 kg·CO_2 piglet^{-1}·d^{-1}, 1.07±0.42 g·CH_4 piglet^{-1}·d^{-1}; 0.07±0.04 g·N_2O piglet^{-1}·d^{-1} and 0.42±0.06 g·NH_3 piglet^{-1}·d^{-1}. Carbon emissions estimated were from the emissions of C-CO_2 (99.3%), mainly. Regarding the nitrogen emissions, the losses in their elementary form (4.5%) were notorious considering the amount ingested daily (18.54 g·piglet^{-1}). The volatilization rates observed in the study developed were low (≈12%) and it was associated to the high frequency removal of manure produced.

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Part 2 – Mitigation strategies

Mitigation strategies

ANALYSIS OF FACTORS AFFECTING AMMONIA AND METHANE EMISSIONS FROM PIG SLURRIES: SLURRY COMPOSITION AND DIETARY FACTORS

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ABSTRACT: Manure management system and diet modification are key options to mitigate gaseous emissions from pig slurry. In this study, feed and slurry samples from 72 commercial piggeries and from nutritional experiments were analyzed for chemical composition and NH_3 and CH_4 slurry emission potential.

For all samples emissions were related to slurry composition. NH_3 and CH_4 emissions from commercial farms were lower. Slurry degradation in pits might explain these differences. For commercial samples, it was not possible to relate gaseous emissions to diet characteristics, probably due to other factors driving the emission process (i.e. dilution, feed wastage, environmental conditions, etc.)

For slurries coming from experimental studies, clear relationships were found between diet and emissions. Feeds with higher crude protein and lower fibre contents led to lower NH_3 emission rates. An increase of 15% on crude protein and a reduction of 33% of acid detergent fibre led to a three-fold increase in NH_3 emissions. Energy balances mainly drove CH_4 emissions. If looking at the nutrient balance, the excess of nitrogen was excreted in urine leading to higher NH_3 emissions. The energy balance provided a similar picture. Animals retained similar amounts of energy, excreting as faeces the energy excess, thus increasing CH_4 emissions.

Keywords: Feeding strategies, NH_3, CH_4, Slurry, Nutrition balance

INTRODUCTION: Modifying pig slurry characteristics through diet management arise as a major technique to mitigate gaseous emissions (Aarnik and Verstegen, 2007). Several studies have reported the effects of changing diets on slurries nitrogen, volatile solids, pH, etc. The relationship between these parameters and ammonia (NH_3) and greenhouse gases (GHG) emissions is also evident. Moreover, when dealing with slurries under commercial conditions, many other factors arise as main drivers of emissions: dilution, feed wastage, removal frequency, pit depth, etc. The main aim of this work was to relate feed characteristics with NH_3 and CH_4 potential emissions from pig slurries with two different types of samples: commercial and experimental.

1. MATERIAL AND METHODS: A total of 109 pig slurry samples were evaluated in this study. Slurry samples were obtained from two origins: slurries obtained from slurry pits at commercial fatteners units (n=31) and reconstituted slurries obtained from experimental feeding assays of growing pigs (n=78). Commercial samples were obtained as follows: representative slurry samples were obtained by sampling a minimum of five two-liter aliquots at equidistant intervals during the discharge of slurry pits. The composite sample was thoroughly mixed and subsamples were taken for the corresponding analyses. Feed and slurry samples were analyzed for chemical composition and emission potential (only for slurries). Reconstituted slurries were obtained from the assays described by Antezana et al. (2015); Beccaccia et al. (2015a, b), which analyzed the effect of different sources of protein, fiber and fat on nutrition traits, slurry composition and gaseous emissions. All diets tested in these assays were formulated according to commercial standards (FEDNA, 2006). Urine and feces were collected separately in metabolism pens for three days and then slurry was reconstituted according to the original excretion ratio.

1.1. Experimental procedures, sample preparation and chemical analyses: Slurries and feed were analyzed for dry matter (DM), ash, fiber fractions (neutral detergent fiber (NDF) and acid detergent fiber (ADF), ether extract (EE), and total Kjeldahl nitrogen (TKN). Organic matter (OM) was calculated from the difference between dry matter and ash contents. Additionally, pH was measured in fresh slurries (from commercial farms) or immediately after reconstitution (reconstituted slurries)

1.2. Potential gaseous emissions: For each slurry sample, Biochemical Methane Potential (BMP) was determined by triplicate in a batch assay using 120 mL glass bottles following the methodology described by Angelidaki et al. (2009). NH_3 emissions were determined using an *in vitro* acid wet trap system similar to that used by Ndegwa et al. (2009)

2. RESULTS AND DISCUSSION

2.1. Effect of slurry origin on emissions: Statistically significant differences were found for all slurry composition parameters analysed between commercial and experimental samples. Higher TKN and EE contents were found for commercial samples while DM, VS and fibre fractions were found at higher shares in experimental samples. NH_3 potential emissions were found to be lower for commercial samples while BMP was not different. Water and feed wastage in commercial conditions seems to play a role on slurry composition and potential emissions.

2.1. Effect of diet on nutrient balances and slurry emissions: Due to the high variability and the presence of crossed effects on slurries composition and emissions, commercial samples were not considered for this analysis. Thus presenting results from 78 experimental samples. Samples were classified according to their emission potential for each gas (NH_3 and CH_4) in three groups (high, average and low emitters) and the nutrient balance was assessed for each case.

Attending to the nitrogen balance (Figure 1), it can be clearly observed as, independently of N intake (higher for the higher emissions group), N retention (as g N/kg weight gain) remains similar between the three groups, thus resulting in higher N excretion (in form of urinary N) for the high emitting group. The relationship between urinary N content of slurry and emissions has been extensively documented before.

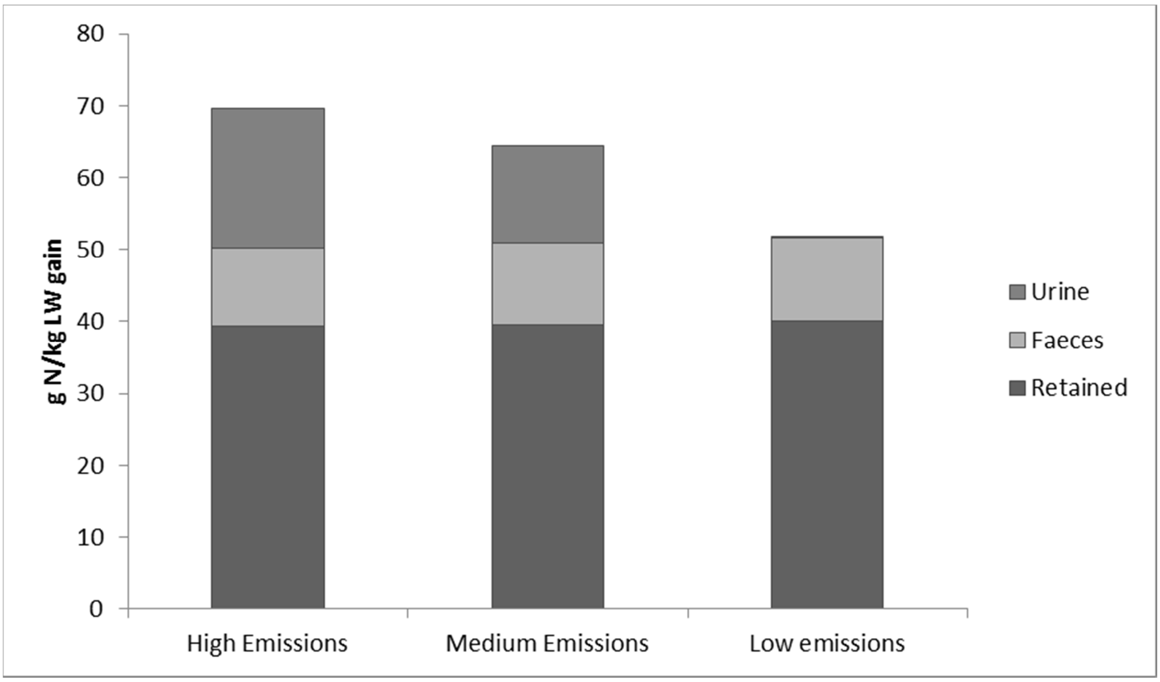

Figure 1. Use of Nitrogen by fattening pigs (g of N/kg of liveweight gain and NH_3 (g/kg liveweight) emissions from slurry.

A similar picture is found when looking at the energy (C) balance (Figure 2). Energy retention (MJ/ kg weight gain) is almost independent of intake and energy intake excess is excreted in slurry (mostly as manure), leading to a higher OM availability for methane emissions.

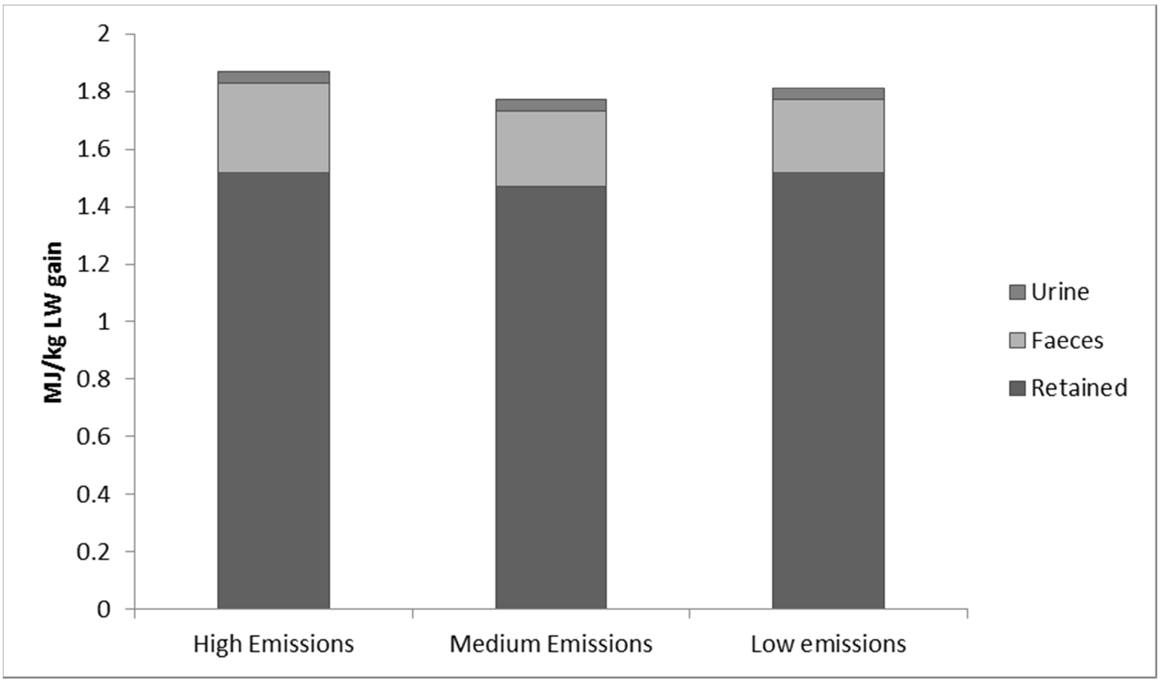

Figure 2. Use of Energy by fattening pigs (MJ/kg of liveweight gain and CH_4 emissions (L/MJ) from slurry.

3. CONCLUSION: Despite it is complicated to assess the effect of diets on emissions under commercial conditions, it can be concluded that adjusting feed composition to animal needs and maximizing nutrient digestibility is key to reduce slurry emissions.

Acknowledgements. Acknowledgements, if any, may be placed here.

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SOIL APPLICATION OF ACIDIFIED SLURRY AS ALTERNATIVE TO RAW CATTLE-SLURRY INJECTION TO MINIMISE GASEOUS EMISSIONS IN MEDITERANEAN CONDITIONS

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ABSTRACT: The objective of this study was to compare N and C emissions from two contrasting soils following band application of acidified cattle-slurry (ASS) or raw cattle-slurry injection (SI) in Mediterranean conditions. Band application of raw cattle-slurry followed by incorporation (SS) was also considered as the traditional method and the impact of acidified slurry incorporation in soil following band application was also tested (AS). For this, a double cropping system (maize followed by oat) was run over 3-years in 1 m×1 m plots from a sandy (S) and a sandy-loam (SL) soil. The NH_3 fluxes were measured by the dynamic chamber technique during the first 96 h after slurry application, while the N_2O, CO_2 and CH_4 fluxes were measured during the whole experiment by the closed chamber technique. The results showed that slurry acidification has no negative impact on N_2O emissions with similar values observed in SS, AS and ASS during both oat and maize growth while significantly higher values were observed in SI than in other amended treatments during maize growth . When considering cumulative GHG emissions, no significant differences were observed between SI, AS and ASS in both soils indicating that application of acidified slurry has no negative impact on GHG emissions. Thus, band application of acidified slurry can be considered as a good alternative to slurry injection to minimise gaseous emissions at field scale in Mediterranean conditions.

Keywords: Acidification, Cattle-slurry, Gaseous emissions, Injection, Mitigation strategy

INTRODUCTION: Nowadays, slurry injection is the recommended method to minimise NH_3 emissions but its impact on other gases as N_2O is not clear and such technique is not always applicable, namely in stony soils or small plots. Slurry acidification is efficient to minimise NH_3 emissions along the slurry management chain but application of acidified slurry is still limited to Denmark and other countries from North Europe (Fangueiro et al., 2015a). Information about the impact of acidified slurry application to soil on gaseous emissions (NH_3 and GHG) in Mediterranean conditions are still scarce or inexistent. Our main hypothesis is that band application of acidified slurry is almost as efficient as slurry injection to minimise gaseous emissions at field scale. Hence, the objective of the present study was to compare NH_3 and GHG emissions from two different soils following band application of acidified cattle-slurry (ASS) or raw cattle-slurry injection (H=100 mm) (SI) in Mediterranean conditions. Band application of raw cattle-slurry followed by incorporation (H=20 mm) (SS) was also considered as the traditional method and the impact of acidified slurry incorporation in soil following band application was also tested (AS). An unfertilised plot (Control) was included.

1. MATERIAL AND METHODS:

1.1. Experimental: The experiment was carried out at the Instituto Superior de Agronomia (Lisboa, Portugal) (Figure 1). A double-cropping forage system producing oat (November to

Mars) and maize (May to July) was run over 3-years (September-2012 to July-2015) in 1 m×1 m plots from a sandy (Haplic Arenosol) (S) and a sandy loam (Haplic Cambisol) (SL) soil. The rates of slurries applied were ca. 90 kg N ha^{-1} in November (oat crop) and ca. 170 kg N ha^{-1} in May (maize crop). The slurry acidification was performed by addition of concentrated sulphuric acid to reach a final pH of 5.5 (Fangueiro et al., 2015b). Experimental conditions used here were similar to those described in (Fangueiro et al., 2015c).

Figure 1. Location of the field experiment (latitude: 38.708059º, longitude: -9.185058º).

1.2. Measurements and data analysis: The NH_3 fluxes were measured during the first 96 h after soil amendment before the sowing of each forage crop, by the dynamic chamber technique using acid traps (0.05 M H_3PO_4). The N_2O, CO_2 and CH_4 fluxes were measured daily in the first 7 days after application and then every 3 days until harvest of each forage crop, by the closed chamber technique with gas concentration determination by gas chromatography (GC-2014, Shimadzu) (Fangueiro et al., 2015c). Data were subjected to analysis of variance and Tukey comparisons of means tests were carried out using the statistical software package Statistix.

2. RESULTS AND DISCUSSION:

2.1. Ammonia emissions: The average amount of NH_3 emitted from each treatment in each crop are shown in Figure 2. The results obtained showed that NH_3 emissions from SS treatment varied between 26 and 64% and 0.1 and 34% of total NH_4^+ applied in sandy and sandy loam soils, respectively (Figure 2). However, NH_3 emissions from AS and ASS treatments were always lower than 2.7% of total NH_4^+ applied in both soils during the 3-years experiment. Similarly, NH_3 emissions from SI remained lower than 1% of total NH_4^+ applied. It can then be concluded that AS incorporation is not needed to prevent potential slurry pH rising over time and consequently, potential NH_3 emissions in the days following application. As expected, higher NH_3 emissions were observed in SS from the S soil relative to SL soil (Figure 2), probably due to the sandy texture that enables more significant NH_3 exchange between the soil and the atmosphere as well as to the NH_4^+ fixation by clay in SL soil.

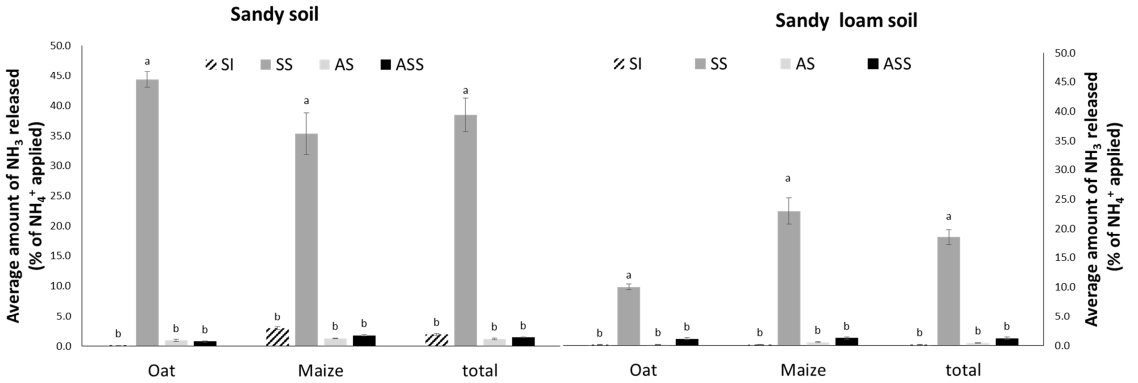

Figure 2. Average amount of NH_3 emitted during each crop growth and during the whole experiment. Error bars represent the standard error values used for comparison in the Tukey test at each crop (n=3).

2.2. Greenhouse gases emissions: The dynamics of N_2O emissions were different in both soils when comparing amended treatments (data not showed): SI led to higher and earlier peaks of N_2O relative to AS or ASS. During maize cycle, the highest ($p<0.05$) N_2O emissions were measured in SI but, during oat cycle, N_2O emission rates observed in SS, SI, AS and ASS were not significantly different ($P<0.05$) (Figure 3). Thus, it can be concluded that slurry acidification has no negative impact on N_2O emissions after soil application and that it can even decrease N_2O emissions relative to SI during maize growth. The cumulative GHG emissions observed in amended treatments (Figure 4) were not significantly different ($P<0.05$) during oat growth in both soils and during maize growth in the sandy soil. However, in the sandy loam soil, SI and AS led to significantly higher values than in SS. Hence, in this last case, it might be of interest to incorporate the acidified slurry applied on soil surface to minimize GHG emissions.

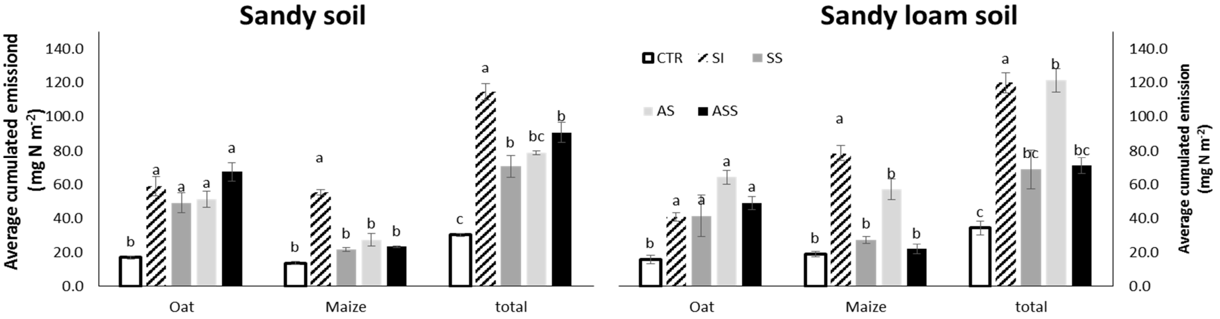

Figure 3. Average amount of N_2O emitted during each crop growth and during the whole experiment. Error bars represent the standard error values used for comparison in the Tukey test at each crop (n=3).

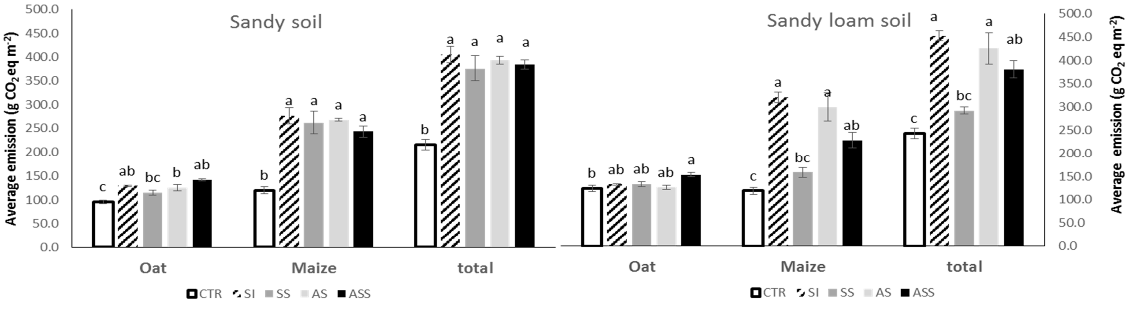

Figure 4. Average value of cumulative GHG emissions observed for each crop. Error bars represent the standard error values used for comparison in the Tukey test at each crop (n=3).

3. CONCLUSION: Band application of acidified raw slurry (AWS) is as efficient as slurry injection to minimise NH_3 emissions and there is no need to immediate soil incorporation. Raw slurry injection increased N_2O emissions during maize growth while AWS application led to emissions similar to non acidified slurry applied on soil surface. Furthermore, a delay or reduction/inhibition of nitrification occurred in soil amended with AWS. The increase of methane emissions relative to WSS observed in WSI and AWSS but not in AWSM indicated that AWS incorporation immediately after soil application might contribute to minimize CH_4 emissions. It can then be concluded that band application of acidified raw slurry followed by incorporation is a potential alternative to raw slurry injection relative to the gaseous emissions issue but an overall evaluation is still required to avoid potential pollution swapping.

Acknowledgements: The study was funded by project PTDC/AGR-PRO/119428/2010.

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INCLUSION OF OLIVE CAKE IN FATTENING PIG FEEDS: EFFECTS ON AMMONIA AND METHANE EMISSIONS

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ABSTRACT: Agro-industrial by-products used in animal feed constitute an interesting alternative to improve the sustainability of swine production. With this aim, a study of the inclusion of crude olive cake in diets for growing pigs, and its effects on slurry composition and, ammonia (NH_3) and methane (CH_4) emission was performed using 30 pigs of 76.1 ± 4.2 kg live weight. Five diets were formulated: a basal diet and four experimental diets including two levels (10% and 20%) of crude olive cake (COC) and partially defatted olive cake (PDOC). Total faeces and urine produced were collected for slurry chemical analysis and for the determination of *in vitro* NH_3 and CH_4 potential emission using metabolic cages. Results showed that substituting a conventional feed by 10 and 20% of olive cake reduced ammonium content and pH in the slurry and therefore the associated NH_3 emission. However, the potential CH_4 emission expressed per L of slurry and day were higher in those animals fed the olive cake diets.

Keywords: olive cake, Slurry, Swine, NH_3, CH_4.

INTRODUCTION: Nutritional management is acknowledged as a key strategy to mitigate gaseous emissions. In this regard, the use of agro-industrial by-products in animal feed can have a positive environmental impact because of enhanced nutrient recycling, thus increasing the profitability and sustainability of the livestock sector (Kasapidou et al., 2015). Benefits may arise from the reduction of environmental costs linked with the replacement of raw materials, but the corresponding changes in slurry properties and their emissions must be evaluated.

Olive cake is among the most important agro-industrial by-products in Mediterranean areas such as Southern and East Spain. It is highly available throughout most of the year and can be dehydrated, which increases its interest in monogastric species such as pigs. With respect to the composition and nutritional value, it depends from the oil extraction intensity. Its use can be nutritionally acceptable to pigs and is expected to be beneficial in terms of digestive physiology. However, there is lack of knowledge on slurry composition and gaseous emission associated with the inclusion of olive cake in animal feed.

In this context, an experiment was conducted to determine the nutritional value of two types of olive cake which varied in the extraction degree: crude (COC) and partially defatted (PDOC), focussing on the effects of its inclusion on slurry composition and ammonia (NH_3) and methane (CH_4) emissions.

1. MATERIAL AND METHODS: Five diets were tested, considering one basal diet, two diets substituting 10 and 20% of the mass by COC, and two diets substituting 10 and 20% by

PDOC, respectively. Thirty fattening pigs of 76.1±4.2 kg initial body weight were used in the experiment (6 animals per treatment). After an adaptation period of 14 days, feed intake was recorded and urine and faeces produced were collected in metabolism cages during 4 days for a digestibility assay. Finally, faeces and urine were collected for 3 days to generate reconstituted slurry for the gas emission assay. Representative samples were taken for chemical analysis. Biochemical methane potential (B_0) and NH_3 emissions were quantified *in vitro* according to Angelidaki et al. (2009) and Antezana et al. (2016), respectively. Data was analysed in a one-factor analysis of variance as a completely randomized design with type of diet as main effect by using PROC GLM of SAS (2008). The effects of diet were analysed as a factorial arrangement by using orthogonal contrasts with source and level of inclusion of OP as main factors.

2. RESULTS AND DISCUSSION: Table 1 shows the effects of including different levels of COC and PDOC in the diet on slurry (faeces + urine) excretion, initial characteristics and derived NH_3 emissions and B_0.

Slurry excretion and composition parameters changed with the inclusion of olive cake. Slurries from animals fed olive cake diets showed higher excretion rates, dry matter (DM) and organic matter (OM) contents. On the contrary, lower pH values and nitrogen content were found with the inclusion of COC and PDOC, with a linear effect of olive cake inclusion level ($p<0.05$) in all the parameters studied. No statistical differences were found in B_0 values of slurries obtained from different diets expressed in mL of CH_4 per g of OM. However, as OM in slurries increased with the inclusion of olive cake, higher CH_4 emissions were estimated ($p<0.05$) with the inclusion of olive cake when expressed in L of CH_4 per animal and day. NH_3 emissions decreased significantly with increasing proportions of olive cake in the feed. Total ammonium nitrogen (TAN) of slurry decreased with COC and PDOC inclusion. A significant reduction of urine and slurry pH was also detected with increasing inclusion levels of olive cake. The inclusion of both olive cakes at 20% reduced slurry pH by one unit in the COC treatment and 0.8 units in the PDOC treatment. The fibre content of olive cake may probably originate these differences. Effects on TAN and pH were the major forces to reduce NH_3 emissions expressed per L of slurry, as evidenced by multiple regression ($R^2 = 0.86$).

Table 1. Effects of including different levels of crude olive cake (COC) and partially defatted olive cake (PDOC) in the diet on slurry (faeces + urine) excretion, initial characteristics and derived NH_3 emissions and biochemical methane potential (B0).

	Diets[1]						
	Basal	**10_COC**	**20_COC**	**10_PDOC**	**20_PDOC**	**SEM[2]**	**P value**
Slurry excretion (kg/day)	2.23	2.54	2.77	2.98	3.17	0.249	0.05
Slurry characteristics							
DM (g/kg)	110.8	129.3	151.1	116.1	151.5	13.01	0.09
OM (g/kg)	81.6^{c}	$110.8^{a,b}$	120.5^{a}	$89.8^{b,c}$	122.1^{a}	10.42	0.01
Total ammonia N (g/L)	9.1^{a}	6.3^{b}	3.9^{c}	5.7^{b}	$5.2^{b,c}$	0.73	<0.001
Total Kjeldahl N (TKN, g/kg)	11.8	9.5	8.6	9.1	8.8	0.88	0.07
pH	8.61^{a}	8.26^{b}	7.68^{c}	$8.07^{b,d}$	$7.90^{c,d}$	0.103	<0.0001
Gas emissions							
Ammonia emission assay							
g NH_3 / kg slurry	1.76^{a}	$1.22^{b,c}$	0.97^{c}	1.35^{b}	1.01^{c}	0.096	<0.0001
g N-NH_3 / kg initial TKN	163.2^{a}	$138.1^{a,b}$	115.6^{b}	$142.0^{a,b}$	119.0^{b}	10.48	0.02
mg NH_3 / animal and day	358.9	355.7	268.6	392.9	303.0	32.87	0.09
Biochemical methane potential							
B_0, mL CH_4 / g OM	300.2	286.1	265.6	280.2	273.8	13.67	0.32
L CH_4 / animal and day	52.6^{c}	76.7^{b}	92.4^{b}	77.2^{b}	110.4^{a}	6.11	<0.0001

[1] 10_COC = 100g/kg crude olive cake; 20_COC = 200g/kg crude olive cake; 10_PDOC = 100g/kg partially defatted olive cake; 20_PDOC = 200g/kg partially defatted olive cake.

[a,b,c,d] Different letters in the same row indicate averages statistically different ($P < 0.05$).

[2] Standard error of means (n = 6).

3. CONCLUSION: In summary, substituting a conventional feed by 10 and 20% of olive cake reduced ammonium content and pH in the slurry and therefore the associated NH_3 emissions, being an interesting option in order to abate ammonia emissions from pig production.

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ACHIEVING A GREATER REDUCTION OF AIRBORNE EMISSIONS FROM SWINE BUILDINGS BY THE COMBINATION OF DIFFERENT TECHNOLOGIES

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ABSTRACT: Swine housing can emit substantial amounts of airborne contaminants such as odorous compounds, gases and bioaerosols. These contaminants can affect pig health as well as put both swine industry workers and rural communities at risk. Over the years, different strategies have successfully reduced some airborne contaminants, but few studies have characterized the combined effect of several technologies on emissions from pig buildings. The main objective of this study is to evaluate the reduction of odorous compounds, dust, gases and bioaerosols from the use of 3 strategies: manure separation, oil sprinkling and a biotrickling filter. Manure separation removed part of the ammonia, while oil sprinkling reduced dust emissions and both technologies reduced part of the odours. The biotrickling filter provided the best performance, but this system only treats air emitted from barns. Ideally all three technologies should be used together to protect both workers and rural communities.

Keywords: Swine, NH_3, Odours, Bioaerosols, Contaminant Reduction Technologies.

INTRODUCTION: Swine housing can emit substantial amounts of airborne contaminants such as odorous compounds, gases and bioaerosols. By their exposure to these airborne contaminants, workers can contract infections (Poggenborg et al., 2008) and are at risk for many other respiratory problems such as chronic bronchitis and asthma (Cormier et al., 2000; Iversen et al., 2000). Also, the risk of catching these diseases increases with the amount of time spent inside animal buildings (Radon et al., 2000) and is related to the concentration of dusts (total and respirable), endotoxins and ammonia (Von Essen et al., 2005). These contaminants can also be released in the environment by the exhaust system of pig buildings and put at risk the health of pork producers, their families and nearby communities (Thorne, 2007; Von Essen et al., 2005).

Many research teams have worked on ways to reduce gases, odours and dust emitted from pig farms. Within the existing technologies to protect the health of workers and nearby communities, three systems are particularly promising: manure separation, oil sprinkling and biological air treatment. These technologies used alone can remove part of the airborne contaminants, but few studies have looked at the combination of several technologies to provide a greater effect and to evaluate any synergistic effects. The main objectives of this study were 1) to evaluate the reduction of odorous compounds, dust, gases and bioaerosols from the use of the three airborne contaminant reduction strategies and 2) to determine the best combination of technologies.

1. MATERIAL AND METHODS:

1.1. Laboratory-scale Pig Chambers: Eight environmentally controlled bench-scale chambers housing 4-5 grower-finisher pigs from 25 to 85 kg were used to supply the contaminated air in this experiment. The chambers, which are 1.14 m wide, 2.44 m long and 2.44 m high, are located in the BABE laboratory, at IRDA, in Deschambault (Québec, Canada). Each group of pigs was kept in the experimental chambers for a period of 7 weeks; four replicates were performed.

1.2. Airborne Contaminant Reduction Strategies: Four pig chambers were equipped with V-shaped scrapers (see figure 1a) to provide manure separation in the temporary manure storage located under the slatted floor. While the liquid phase is drained by a small canal at its center, the solid phase is held on the inclined concrete surface and then removed periodically with a scraper. In the four other chambers, the manure was stored without separation in shallow pits underneath the slatted floors and was removed periodically. For dust removal, canola oil was sprinkled (see figure 1b) as a light drizzle inside four pig chambers on a daily basis at a dose of 10 ml m^{-2} d^{-1}. The sprinkling device was automated with an electric solenoid valve and a timer to ensure precision and repeatability. Six cross-flow ATUs (see figure 1c), were designed to treat the exhaust air from six independent pig chambers. Each ATU was filled with a structured plastic media from Jaeger Environmental (DURA-PAC XF68 PVC modular cross-flow media) with a surface area of 223 m^2 m^{-3}. The air flow rate was maintained at 68 L s^{-1} through a volume of 0.34 m^3 of packing material which provided an empty bed residence time (EBRT) of 5 sec. A diluted nutrient solution was continuously recirculated over the media at a rate of 20 L min^{-1} to ensure proper filter bed moisture. To maintain the performance of the system, part of the nutrient solution was removed periodically.

1.3. Analytical Method: Air samples from each pig chamber and ATU outlet were taken every 4 hours for ammonia (NH_3) measurement with a non-dispersive infrared (NDIR) analyzer (Ultramat 6E, Siemens, Germany). Every two days, certified calibration gases were supplied to the analyser for quality control purposes. Other physical parameters were measured every 15 minutes: air flow rate, air and water temperatures, relative humidity and pressure drop across the filter bed. Dust samples were collected inside the pig chambers and at the outlet of the ATUs using membrane filters at an air flow rate of 2 L min^{-1}. The filters were changed on a weekly basis. Measurements of odour concentration were performed using qualified panelists who evaluated the intensity of the ambient odour with a nine point scale of n-butanol as described in ASTM 544-99.

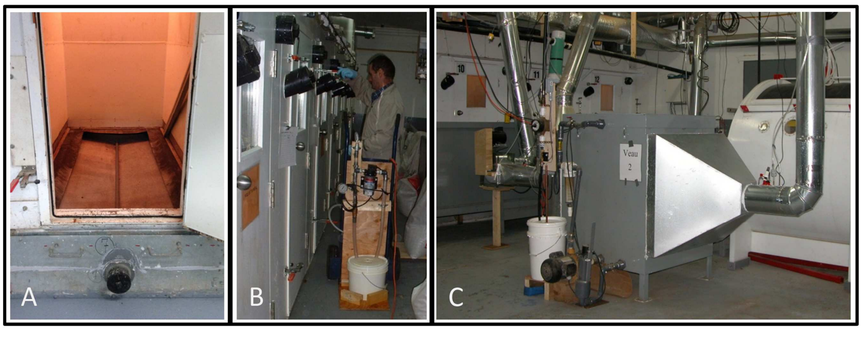

Figure 1. Technologies used in this study: a) v-shaped scraper installed in the temporary manure storage, b) oil sprinkling device in use, and c) one of the air treatment units.

2. RESULTS AND DISCUSSION: Figure 2 shows the average amount of ammonia emitted from the pig chambers and their related ATU for each combination of the technologies studied over the four replicates. The daily emissions are reported on the basis of the total mass of pigs raised inside each chamber over time. As expected, oil sprinkling had no effect on NH_3 emissions with an average value of 156 ± 20 mg NH_3 kg pig^{-1} day^{-1}, same average value as the control rooms. Manure separation with the v-shaped scraper had a significant effect (F probability < 0.01) on NH_3 emissions with an average value of 110 ± 8 mg NH_3 kg pig^{-1} day^{-1}. However, the best performance was obtained with ATUs (all combination of technologies considered) with an average emission of 44 ± 7 mg NH_3 kg pig^{-1} day^{-1}, equivalent to a reduction of 66 ± 3 %.

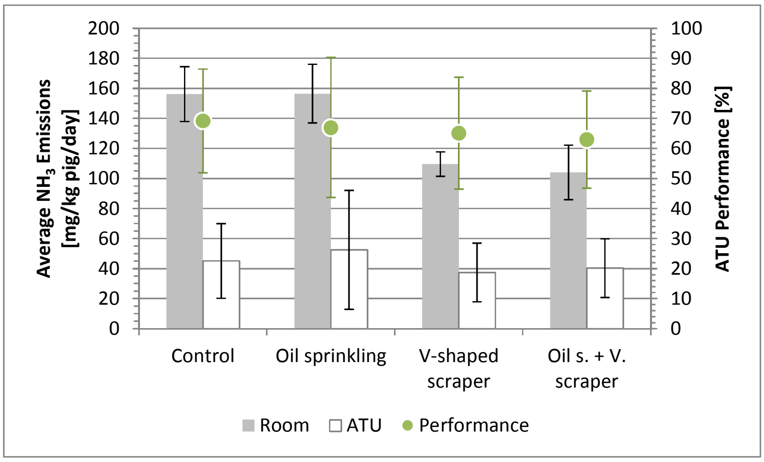

Figure 2. Average ammonia emissions and ATU performance for each treatment.

Figure 3 shows the average amount of dust emitted from the pig chambers and their related ATU for each treatment. For dust removal, the v-shaped scraper had no effect as compared to the control with average emissions of 0.3 ± 0.1 mg kg pig^{-1} day^{-1}. Oil sprinkling and the ATU had similar effects with emissions of 0.05 ± 0.03 and 0.03 ± 0.01 mg kg pig^{-1} day^{-1} respectively (F probability < 0.001). However, when the ATU and oil sprinkling were combined, the performance of the ATU dropped from 91 ± 2 % to 57 ± 16 %. The oil sprinkling removed most of the dust from the rooms and left only small particles (PM 2.5), there was therefore very little dust left for the ATU to remove.

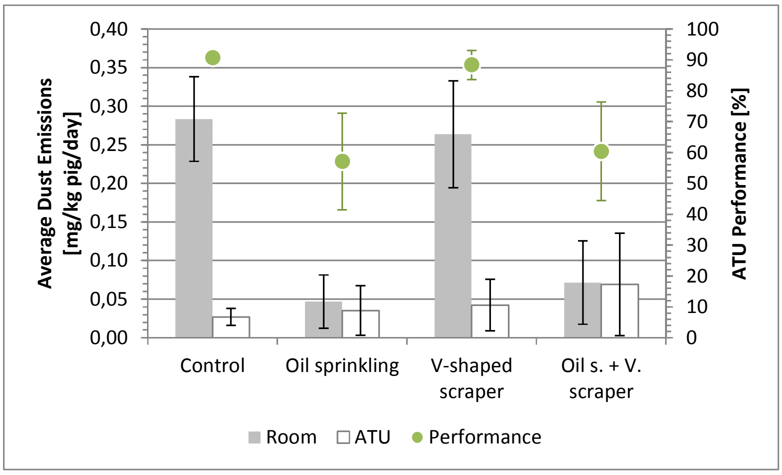

Figure 3. Average dust emissions and ATU performance for each treatment.

For odour intensity, both manure separation and oil sprinkling had similar effects with concentrations of 3450 ± 850 and 3700 ± 200 ppm butanol respectively, as compared to the control with 5900 ± 1100 ppm butanol. However, the combination of these systems didn’t provide additional odour removal. The ATU was able to reduce the odour to 1200 ± 200 ppm butanol. In terms of total bacteria, concentrations of *E. coli* equivalent genomes per m^3 of air were approximatively 10^8, 10^7 and 10^6 for the control, ATU and oil sprinkling respectively. The v-shaped scraper had no effect on total bacteria and combining both the oil and the ATU didn’t improve bacteria removal.

3. CONCLUSION: All the technologies tested in this project had a certain effect on either NH_3, dust, odour or bioaerosols, but the air treatment unit provided the most promising results. However, this technology only affects air emitted from barns and does not improve indoor air quality to protect worker health. Therefore, ideally all three technologies should be used in combination in order to protect both workers and rural communities. The next phase of the project will test the combination of these technologies in a commercial-scale barn.

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DEVELOPMENT OF AN EXCHANGE SCRUBBER: EXHAUST AIR CLEANING AND HEAT RECOVERY IN ONE PROCESSING STAGE

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ABSTRACT: Exhaust air treatment systems (EATS) in animal husbandry are cost-intensive. To reduce overall costs of livestock buildings with EATS, a recuperative heat exchanger (HE) was integrated into a trickle-bed reactor in order to clean exhaust air and utilize thermal energy from exhaust air and scrubbing water for heating of incoming outside air. During winter and spring, initial tests under practical conditions on a pig farm were carried out using the "exchange scrubber" in partial flow treatment. Relevant temperatures, air flow rates as well as power consumption were recorded.

While passing the HE, cool incoming supply air is heated up to the temperature level of the scrubbing water. In consequence, fossil fuel reserves are substituted, carbon dioxide emissions avoided, heating costs saved, and operating costs can be reduced. Supply air heating depends on temperature of outside air and scrubbing water. For outside temperatures below the scrubbing water temperature, the following applies: the lower the outside temperature, the higher the supply air heating and the heating output. Cooling effects could be observed at outside temperatures above the scrubbing water temperature. The coefficient of performance was 7.8.

Keywords: Mitigation strategy, Energy saving, Swine, NH_3, Odour

INTRODUCTION: Intensive animal husbandry contributes to air pollution, by emitting particulate matter (PM), ammonia (NH_3), and odour. In practice, exhaust air treatment systems (EATS) are applied on mechanically ventilated livestock buildings for pigs and poultry to reduce these emissions, e. g. biofilters, trickle-bed reactors (air scrubber), acid scrubbers and multiple stage techniques (Grimm, 2008; Van der Heyden et al., 2015). However, EATS are associated with high investment and operating costs (Grimm, 2008), which have to be borne by the plant operator. In order to reduce overall costs of a livestock building with EATS by saving heating costs (recovery of thermal energy), a new plant technology for reduction of emissions with simultaneous heat recovery from exhaust air and scrubbing water was developed as part of a research and development project. This plant technology was called "exchange scrubber", whereby this name arose from the terms "heat exchanger" and "air scrubber". It is a combination of a conventional biological trickle-bed reactor and a recuperative heat exchanger to create and use synergistic effects: Recovery of thermal energy of exhaust air and scrubbing water by transfer to incoming supply air to save heating energy in the barn, to conserve fossil energy sources; cleaning of exhaust air from PM, NH_3, and odour; reduction of total costs for livestock buildings with EATS by substitution of heating costs. The idea of the exchange scrubber is patented (Patent No. EP1815902).

1. MATERIAL AND METHODS: The exchange scrubber was examined under field conditions (partial flow treatment) in winter and spring 2015/2016. The livestock building was a mechanically ventilated and thermally insulated pig fattening house in Bavaria (South Germany) with 960 animal places. Supply air was first led into the central corridor and then above floor into the barn compartments. Exhaust air was removed by means of a central underflow suction. A part of the exhaust air was led into the exchange scrubber experimental plant. The internal floor area of the exchange scrubber was 2.3 m x 1.1 m, which results in a filter surface area of 2.53 m^2. The trickle-bed reactor technology used has already been certified by the German Agricultural Society (DLG) for livestock buildings with central above floor suction and is described in detail in the test report No. 6284 (DLG, 2015). A recuperative heat exchanger was integrated into the trickle-bed reactor upside the packing material. Both were sprayed by scrubbing water. The heat exchanger has been made of polyvinyl chloride (PVC) with a height of 0.6 m and a specific heat exchange surface area of 136 m^2 m^{-3}. The heat exchanger surface was turned. It was a cross-flow heat exchanger, i.e. exhaust air was led vertically through the heat exchanger, while outside air was led through horizontally. The heat transfer that ensued was convective over the PVC sheets exclusively.

During the examination time from November 26th, 2015 to April 5th, 2016, the following parameters were measured and recorded: temperatures of exhaust air (crude gas), outgoing air (clean gas), outside air, supply air, and scrubbing water (measuring interval: 5 min); electricity consumption of electric consumers (e. g. exhaust air fan, supply air fan, recirculation pump) by means of electronic electricity meters; air flow rates of exhaust air and supply air by use of calibrated measuring fans (measuring interval: 5 min). The air flow rate of supply air and exhaust air was adjusted to 2,255 m^3 h^{-1} and 2,763 m^3 h^{-1}, respectively.

In order to be able to compare the exchange scrubber with other technologies, the coefficient of performance (COP) was calculated according to VDI 3803-5 (2013), by relating thermal power delivered by heat recovery ($\dot{Q}_{HR}$) to electrical power required (P_{el}):

$$COP = \frac{\dot{Q}_{HR}}{P_{el}} \tag{1}$$

2. RESULTS AND DISCUSSION: In general, the heating performance of the exchange scrubber was mainly influenced by the outside air temperature and subsidiary by scrubbing water temperature. The lower the outside air temperature, the higher the heating performance and vice versa (Figure 1). When outside air temperature exceeded scrubbing water temperature, incoming outside air was cooled down by passing the heat exchanger unit.

During the examination time, the exchange scrubber consumed 2,889 kWh electrical energy (P_{el}) and delivered 22,620 kWh thermal energy ($\dot{Q}_{HR}$). This results in a coefficient of performance of 7.8 (Equation 1). The average monthly heating performance ranged between 6.5 kW and 8.5 kW (in terms of a constant supply air flow rate of 2,255 m^3 h^{-1}). The highest heating performance was 21.0 kW at an outside temperature of -18°C (Figure 1).

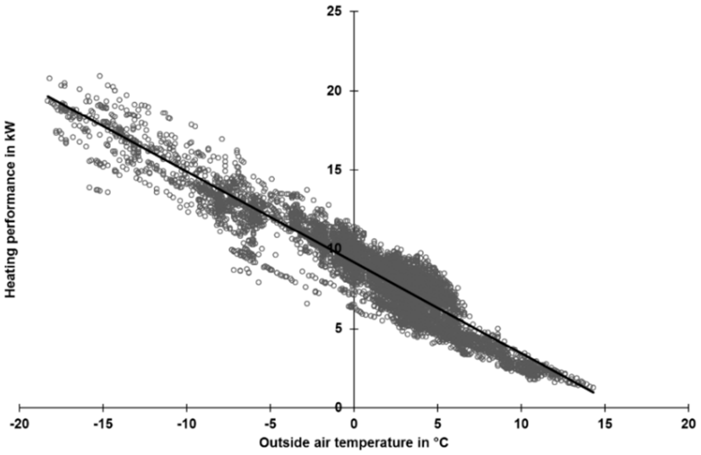

Figure 1: Heating performance of the exchange scrubber as a function of outside air temperature ($y=-0.57x+9.17$; $R^2=0.88$) in January 2016.

3. CONCLUSION: The technology of the exchange scrubber contributes to a more environment-friendly and energy-efficient animal husbandry and is positively assessed under various aspects; saving energy costs and with it reduction of operating costs (economical aspect); fossil fuel reserves are spared (sustainability); avoiding of carbon dioxide emissions and removal of PM, NH_3, and odour (ecological and environmental aspects); better air distribution on animal level (animal welfare). However, a detailed full cost accounting of the exchange scrubber has to be carried out. Because the previous investigations of the exchange scrubber are based on a partial flow treatment of the exhaust air with continuous air flow rates of exhaust and supply air, a long-term study of the plant is recommended for a well-founded economic evaluation of this technology. For that to happen, it is important that the entire ventilation of the livestock building as well as the cleaning of the exhaust air have to be carried out by the exchange scrubber. Further research is necessary to clarify how far the exchange scrubber can also be used to cool supply air in summer.

Acknowledgements. This project was carried out in close collaboration with Schönhammer Wärmetauscher und Lüftungstechnik GmbH (Mengkofen, Germany) and supported by the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the Parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE) under the innovation support programme (funding code 28-1-408 75.011-11).

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SOLID FLOORS WITH A SLOPE FOR RAPID URINE DRAINAGE: FIRST RESULTS FROM AMMONIA EMISSION MEASUREMENTS IN WINTER

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ABSTRACT: Rapid urine drainage from floor surfaces leads to a reduction in ammonia (NH_3) formation and release. This can be achieved in dairy housing by a combination of a solid floor with slope, a urine-collecting gutter and a special scraper with dung removal at frequent intervals. Emissions were measured on a practical scale in experimental dairy housing at Agroscope, Tänikon (Switzerland). The two spatially separated housing compartments allow comparable measurement conditions (e.g. climate). To determine emissions under natural ventilation, a dual tracer-ratio method with the two tracer gases sulfur hexafluoride (SF_6) and trifluoromethyl sulfur pentafluoride (SF_5CF_3) was used. Measurements over three seasons covered climatic variations throughout the year. First results of a four-day measuring period in winter 2015 show an NH_3 emission reduction of around 20% in the compartment with solid floors with slope and urine-collecting gutter compared to the reference with solid floors without a slope. Lower NH_3 emissions in the reduction variant were attributed to reduced amounts of urine on the floor surface with slope in comparison to the reference. Concerning live weight, food consumption, milk yield and milk urea content, there were only slight differences between the two herds. In addition, climatic conditions in both compartments were comparable with air temperatures from -2 to 12 °C.

Keywords: NH_3, dairy cattle, natural ventilation, tracer-ratio method, mitigation strategy

INTRODUCTION: Monteny (2000), Snoek et al. (2014) and Keck (1997) showed in model calculations and/or in studies on a pilot-plant scale that the presence and amount of urine on the surface of the exercise area significantly influences NH_3 emissions. Less soiling of the surface as well as rapid urine drainage from the urease-active exercise area to the covered slurry storage is therefore important. In the Netherlands in the 1990s, NH_3 emissions of solid floors with a slope and one or more urine-collecting gutters were investigated in a single-row cubicle housing system for dairy cattle. With a 20 to 50% reduction in NH_3, solid floors with a 3% transverse slope and a different number or positioning of urine-collecting gutters exhibited a significant effect compared to the reference variants of solid floor without slope (Braam et al. 1997a; Braam et al. 1997b; Swierstra and Braam 1995). Results of these studies are only partially applicable to Swiss housing systems, because they were determined on closed housings with forced ventilation and comparatively small floor areas.

The aim of this study was to quantify the NH_3 emission reduction of solid floors with slope (3%) and urine-collecting gutter in comparison to solid floors without slope under Swiss dairy housing conditions.

1. MATERIAL AND METHODS: Emission measurements on a practical scale were conducted in a new experimental housing built at Agroscope, Tänikon (Switzerland). The housing consists of two experimental compartments – each for 20 dairy cows – and a central section for milking, technical installations, office and analytics (Fig. 1) (Schrade et al. 2016). The two spatially separated housing compartments provide comparable measurement conditions (e.g. climatic conditions) on a practical scale. The emission reduction potential of abatement measures can thereby be quantified in relation to a reference variant.

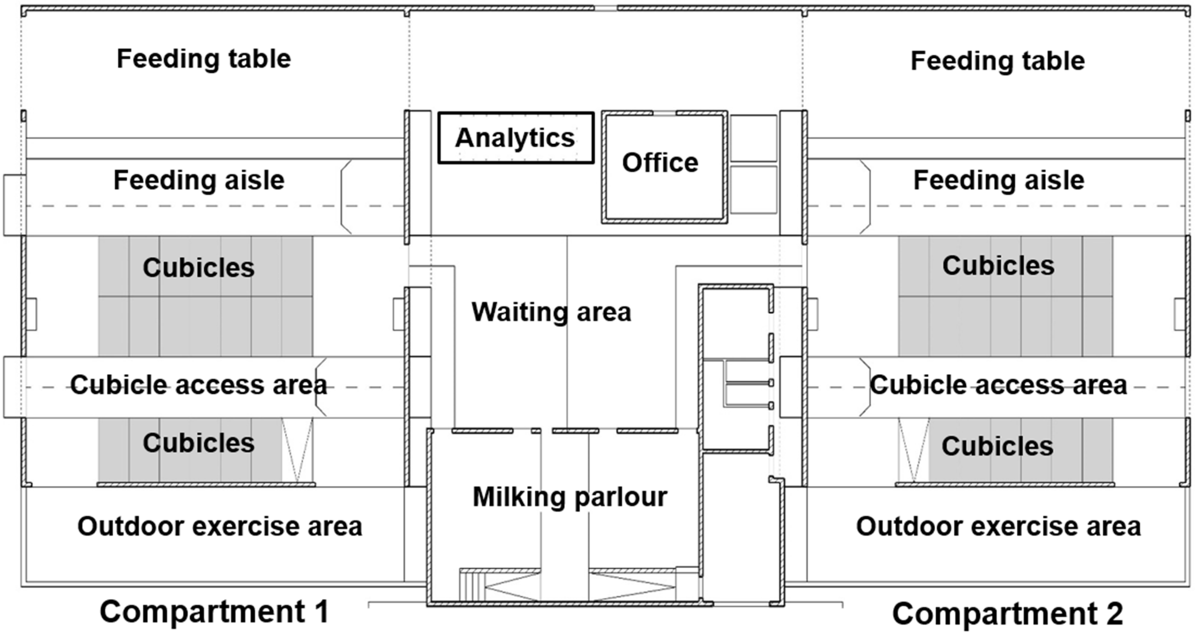

Figure 1: Schematic top view of the experimental dairy housing for emission measurements in Tänikon with two compartments (reduction and reference variant).

A dual tracer-ratio method employing two tracer gases SF_6 and SF_5CF_3 (Schrade et al. 2012) is used to determine emissions from the naturally ventilated housing. The diluted tracer gases (ppm-range) are dosed continuously through steel tubes with critical capillaries next to the aisles to mimic the emission sources. Integrative air samples are collected at a height of 2.5 m with a piping system consisting of teflon tubes and critical glass capillaries. The analytical instrumentation for NH_3 (CRDS, Picarro Inc., Santa Clara, CA, USA) and tracer gas analysis (GC-ECD, Agilent, Santa Clara, CA, USA) is located in an air-conditioned trailer in the central section of the housing. Besides NH_3 emissions, relevant meteorological parameters in the housing and the outside area, animal parameters (e.g. live weight, milk yield, milk composition, milk urea content, urine urea content), feed (quality and quantity, amount of trough residue), exercise area soiling (type, amount, composition), and ethological aspects (e.g. slipping events) are recorded. Measurements started in August 2015 and were conducted over three seasons covering climatic variations in the course of the year.

2. RESULTS AND DISCUSSION: This paper presents initial results of a four-day measuring period in winter 2015. During these four days, cows had no access to the outdoor exercise area. In both compartments, dung removal was conducted 12 times per day by an automatic scraper. As usually done during winter, curtains were completely closed. The average live weight of the individual cows was nearly the same (around 690 ±80 kg) in both herds. Concerning feed intake, milk yield and milk urea content, there were only slight differences between the two herds. Air temperature in both compartments followed the same temporal trend and ranged from -2 to 12 °C. NH_3 emissions exhibited clear daily patterns (Figure 1). NH_3 emissions of the reduction variant seemed to be lower than those of the reference variant. First emission calculations showed a reduction in NH_3 emissions of around 20% in the compartment with solid floors with 3% slope and urine-collecting gutter compared to the reference without slope. These results confirm the NH_3-reducing effect of rapid urine drainage from flooring with a transverse slope that was observed in studies in the Netherlands in the 1990s (Braam et al. 1997a; Braam et al. 1997b; Swierstra and Braam 1995).

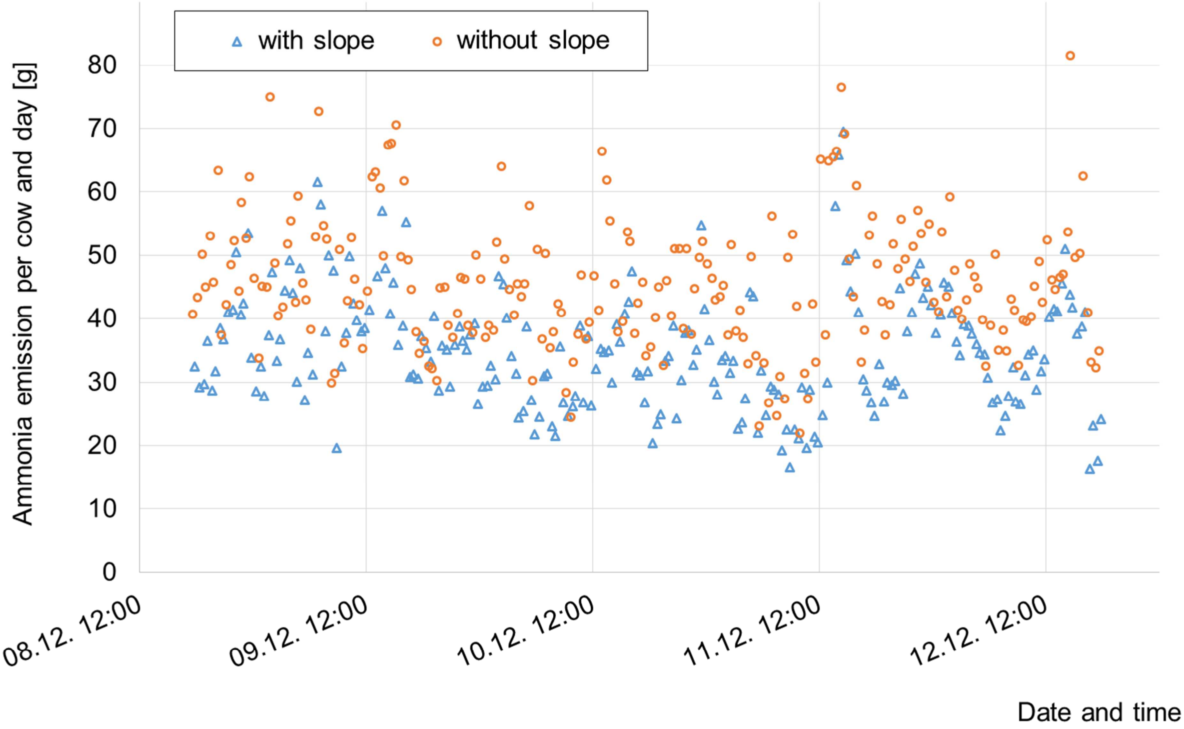

Figure 2: Comparison of NH_3 emissions for solid floors with 3% slope vs. solid floors without slope in winter 2015.

The amount of urine on the floor surface in the reduction variant with slope was also clearly reduced in comparison to the reference without slope (Figure 3).

Figure 3: Exercise area soiling in the compartment with 3% slope (left) and the reference without slope (right).

3. CONCLUSION: Rapid urine drainage from solid floors seems to reduce NH_3 emissionsMeasurements conducted in experimental housing over four consecutive days in winter 2015 display an NH_3 emission reduction of around 20% for solid floors with a 3% slope and urine-collecting gutter compared to the reference variant without a slope. The measurements in both housing compartments were conducted simultaneously and hence under comparable climatic conditions. The tracer-ratio method using two different tracer gases SF_6 and SF_5CF_3, the dosing and sampling design, and the analytical setup demonstrated its capability for comparative emission measurements. The average NH_3 mitigation potential will be evaluated including results from summer and autumn measurement periods. Results will be interpreted with respect to additional parameters (e.g. meteorological data, exercise areas' soiling, animal data) and using statistical analysis. In addition, evaluation of the other measurement periods and parameters may yield information on the relationships between NH_3 and CH_4 and/or CO_2 emissions.

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COMBINED EXHAUST AIR TREATMENT AT A LAYING HEN FACILITY FOR MITIGATION OF DUST, AMMONIA AND ODOUR

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ABSTRACT*:* Exhaust air treatment systems for animal husbandry, especially for poultry housing, have become more and more important in the recent past. In some cases they are mandatory in approval procedures for new animal husbandry buildings. Yet farmers as well as engineers are still faced with some difficulties while using available techniques. Particularly efficient odour removal is very challenging especially at poultry housing facilities. Special focus of this research project is on applicability of dry filters for dust removal and the use of additive compounds for possible improvement of the biological filter reducing odour emissions. A special facility for partial treatment of a two-storey barn's (40,500 laying hens, located in North Rhine-Westphalia, Germany) exhaust air was used for this research. The exhaust air treatment system consisted of three different filter stages. Over three 24-hour-periods data were collected. During this measuring periods 93.4% of the total suspended particulate matter and 85.7% of the ammonia were removed out of the exhaust air and odour intensity was lowered by a mean of 80.9 OU m^{-3}. The data collected at this point suggest that this exhaust air treatment system may be appropriate for efficient mitigation of dust, ammonia and odour emitting out of a laying hen barn. Similar data recording procedures are needed for a certification process, which is a prerequisite for practical use on farms.

INTRODUCTION: In Germany, almost 12 billion eggs were produced in barns with a minimum of 3,000 animal places in 2016. That sums up to an increase of 1.5% compared to the previous year (Destatis, 2017). Exhaust air treatment systems for the mitigation of ammonia, dust and odour emissions are increasingly being demanded in poultry farming in Germany for the approvability of the sites. Various factors, as for example ventilation or management, influence the amount of emissions from different husbandry systems, as Demmers et al. (2010) report. Currently there are only few tested systems due to challenges with high dust loads especially at laying hen barns and a high variability of the ventilation rate at broiler fattening facilities. The aim of the current investigation is the development of a suitable system for an efficient exhaust air treatment with a special focus on different filling materials inside the biofilter.

1. MATERIAL AND METHODS: The investigation was conducted at a two-storey aviary laying hen barn with 40,500 animals located in North Rhine-Westphalia, Germany. For ventilation the barn was equipped with 16 ventilators installed inside an exhaust air tower at the gable end of the building. Supply air inlets were located on the eaves sides of the barn. For summer ventilation, additional supply air fans at the roof ridge could be switched on to complement the air exchange rate during extreme weather conditions. A partial flow of the exhaust air was treated by a purification system consisting of three stages:

- First stage: physical cleaning using dust filter StuffNix (Big Dutchman AG, Vechta, Germany)
- Second stage: chemical cleaning via chemo-scrubber MagixX-B (Big Dutchman AG, Vechta, Germany)

- Third stage: biological cleaning via biofilter based on paper pads

Dust, ammonia and odour concentrations were measured both in raw and clean gas. The dust concentrations were recorded using aerosol spectrometers (Model 1109A, Grimm Aerosol Technik GmbH, Ainring, Germany). To measure the concentrations of ammonia, a photoacoustic multi-gas monitor (INNOVA 1412 in combination with multiplexer 1309, LumaSense Technologies A/S, Ballerup, DK) was used (n=144 measurements per day and measuring point). Odour samples were taken on site and analysed at the olfactometry laboratory (n=4 samples per day) using an olfactometer (TO 8, ECOMA, Weyhe-Dreye, Germany). Furthermore, the air volume flow as well as temperature and humidity were recorded continuously.

The data were collected in three measurement campaigns in August and September 2016 as well as in February 2017, so that both summer and winter situations could be recorded.

2. RESULTS AND DISCUSSION: The total dust concentration could be reduced by an average of 93.4% (Table 1). The average concentration of ammonia was reduced from 3.24 ppm to 0.46 ppm by the use of the exhaust air treatment system, which sums up to a reduction of 85.7%. The average mitigation of the odour intensity was 80.9 OU m^{-3}. Furthermore, no raw gas odour was detected in a clean gas sample at any of the three measurement campaigns.

Table 1: Mitigation performance of the exhaust air treatment system

	Raw gas	**Clean gas**	**Mitigation**
Total suspended particulate matter (µg m^{-3})	901.9	58.7	93.4 %
Ammonia (ppm)	3.2	0.5	85.7 %
Odour (OU m^{-3})	118.3	37.4	80.9 OU

The results obtained in the present study suggest that this system is suitable for efficient mitigation of dust, ammonia and odour at a laying hen facility. Due to the expansion from one to three stages, the dust removal performance was enhanced. In an earlier investigation of the system's first stage, the dry filter "StuffNix", a mitigation of 67% of the total suspended particulate matter was measured (Strohmaier and Büscher, 2016). Another earlier study conducted with this filter showed a retention of 72% of total suspended particulate matter (Mostafa and Büscher, 2011). These mitigation values were outnumbered by the average separation efficiency of 93.4% (Table 1) in the multi-stage exhaust air treatment system.

3. CONCLUSION: A special focus in the present research project is on the reduction of odour. This goal has been achieved by the use of paper pads inside the biological filter. Both a significant reduction of the odour intensity as well as the absence of raw gas odour in the clean gas were determined. However, it should be noted that the mean odour concentrations in raw gas have already been very low (Table 1). In further investigations of the exhaust air treatment system at a broiler fattening barn, higher odour loads in the raw gas are to be expected (Verein Deutscher Ingenieure, 2011). In further procedures of the research and development project, the investigations are to be continued with particular attention to different filter materials for the biological cleaning stage at the broiler fattening facilities.

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EFFECT OF A HOP (HUMULUS LUPULUS L.) EXTRACT ON THE METHANE YIELD AND MILK PRODUCTION OF DAIRY COWS

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ABSTRACT: In this study the in vivo methane (CH_4) reduction potential of a hop (Humulus lupulus L.) extract in dairy cattle was explored. Ten highly productive Holstein Friesian cows were involved in this trial. In the pre-treatment period of six weeks none of the ten cows received the extract. In the following treatment period of six weeks eight cows (treated cows) received the hop extract (400 mg day^{-1}) and the two remaining cows (reference cows) did not. CH_4 emissions were measured in open-circuit chambers, at the end of both periods. No treatment effect was found for dry matter intake (DMI; p=0.27), nor for the absolute CH4 emissions (p=0.20). However, for CH_4 yield per kg DMI a trend (p=0.07) for reduction is observed, because the average values for the treated cows are exactly the same in both periods (21.6 g CH_4 kg-1 DMI), whereas for the reference cows, there was an increase in CH_4 yield (20.3 to 21.3 g CH_4 kg^{-1} DMI). The milk production of the treated cows was more persistent (p<0.05). Therefore, hop reduced CH_4 emission intensity per kg of milk produced (p<0.01).

Keywords: GHG, CH_4, Dairy cattle, Mitigation strategy, Hop

INTRODUCTION: Livestock plays an important role in climate change, as it is responsible for a significant amount of greenhouse gas emissions (Hristov et al 2013). Of particular interest is the enteric fermentation of ruminants in which methane (CH_4) is produced (Hristov et al 2013). The use of feed additives for lowering enteric CH_4 emissions, has been widely investigated (Hristov et al 2013). Plant bioactive compounds or plant secondary metabolites are such feed additives (Hristov et al 2013). Hops, the female flowers of the hop plant (Humulus lupulus L.), have been used for centuries as a flavouring and antibacterial agent in beer (Sakamoto et Konings 2003). The hop compounds thought to be responsible for the antibacterial activity are the α- and β-acids (Sakamoto et Konings 2003). Significant CH_4 reductions with hop were found in vitro (Narvaez et al 2011). In vivo confirmation of these results, however, is still lacking. The key research question of this study was whether or not the addition of a hop extract to a dairy cow diet leads to a reduction of the enteric CH_4 emissions.

1. MATERIAL AND METHODS: The experiment was carried out at the research facilities of ILVO (Flemish research institute for agriculture, fisheries and food). All animal handlings and sampling procedures were approved by the Animal Ethics Committee of ILVO (EC 2014/239).

1.1. Animals and diet: Ten Holstein Friesian cows in mid-lactation were selected for this experiment. Two out of the ten selected cows were assigned as reference cows to account for possible time effects. The remaining eight cows were divided in two groups of four treated cows. The groups were balanced for parity, days in milk (DIM), milk production, milk composition and feed intake (Table 1), one week before the first measurements were carried out. All cows received the same basal diet that consisted of 310 g kg^{-1} DM maize silage, 350 g kg^{-1} DM pre-wilted grass silage, 90 g kg^{-1} DM pressed sugar beet pulp and of 250 g kg^{-1} DM concentrates. Three types of concentrate were used: a balanced compound feed rich in starch, soybean meal, and formaldehyde-treated soybean meal. The supply of concentrates was calculated individually, according to 105% of the animal requirements for energy (VEM - feed unit lactation (Van Es 1978)), true protein digestible in the small intestine (DVE), and to a rumen degradable protein balance (OEB) of 130-150 g day^{-1} (Tamminga *et al* 1994), based on preliminary chemical analyses of the different feed components.

Table 1: Average lactation number, days in milk (DIM), daily milk production (MP), milk fat, milk protein and dry matter intake (DMI) for the reference and the treated cows one week before the first measurements.

	Lactation number	**DIM**	**MP (kg/day)**	**milk fat (%)**	**milk protein (%)**	**DMI (kg/day)**
Reference cows (n=2)	2.5	166	29.7	3.91	3.37	21.2
Treated cows (n=8)	2.1	144	30.9	4.05	3.28	21.5

1.2. Measurements: The experiment lasted for 15 weeks and was divided in an adaptation period (3 weeks), a pre-treatment period (6 weeks) and a treatment period (6 weeks). During the treatment period treated cows (n=8) received 400 mg hop extract cow^{-1} day^{-1}, incorporated in 1 kg of the balanced concentrate. At the end of both the pre-treatment and treatment period, the cows were housed in open-circuit chambers (OCC) for five days, to measure the individual CH_4 and CO_2 emissions. Because the number of OCC was limited (n=6), the measurements were staggered with one week. Reference cows stayed for two consecutive measurements in the OCC, with a two-day break in between, while cows from the treated groups were housed in the OCC for five days of measurements . Emissions were measured by using a Non-Dispersive Infra-Red analyser (MGA3500 Multi-Gas Analyser, ADC Gas Analysis Limited, UK). Air inlet and outlet was sampled and ventilation rate was continuously measured (Fancom, NL). The cows were milked twice daily (07:30 am and 05:30 pm) and they received at the same time the roughage mixture. Their concentrates were given four times per day (07:30 am, 11:00 am, 03:00 pm and 05:30 pm) on top of the roughage mixture.

1.3. Statistics: Data were averaged for each measurement week per cow. Data were analysed by using a linear mixed model in R 3.3.1 for Windows with group (control and treated cows), period (pre-treatment and treatment period) and their interaction as fixed effects and cow as random effect. A significant interaction effect equals a significant treatment effect.

2. RESULTS AND DISCUSSION: Table 2 shows the average values of daily individual dry matter intake (DMI), milk production (MP) and CH4 emissions in pre-treatment and treatment period for both groups.

Table 2: Average daily individual dry matter intake (DMI), milk production (MP) and CH4 emission in pre-treatment (PRE) and treatment (TRTM) period for both groups.

	Reference cows		**Treated cows**		**p-value group x period**[1]
	PRE	**TRTM**	**PRE**	**TRTM**	
DMI (kg/day)	19.9	19.2	20.4	19.9	0.27
MP (kg/day)	29.2	26.4	26.4	26.4	*
g CH_4/d	404	408	442	430	0.20
g CH_4/kg DMI	20.3	21.3	21.6	21.6	0.07
g CH_4/kg MP	14.1	15.4	17.4	16.6	**

[1] interaction effects are indicated with *, ** or ***, depending on the level of significance ($p<0.05$, $p<0.01$ and $p<0.001$, respectively).

2.1. Dry matter intake and milk production: No effect on the DMI was found, as both groups had a lower DMI in the treatment period compared to the pre-treatment period. Interestingly, the hop extract had an effect on the MP, which – as expected – decreased for the reference cows with progressing lactation stage from the pre-treatment to the treatment period, while MP remained constant over both periods for the treated cows. Given that the decreased MP of the reference cows may represent the natural decline in MP as stage of lactation proceeds, the hop extract may be responsible for the more persistent MP of the treated cows. There are several possible explanations for this result: first of all it is possible that the α- and β-acids in hop act as ionophores (Sakamoto et Konings 2003) and in this way are able to increase animal productivity. Moreover, next to the presence of α- and β-acids, the hop plant also contains phytoestrogens (Chadwick *et al* 2006). These phytoestrogens are mainly known for their negative effects on the fertility of ruminants (Adams 1995), but not much is described about the effect on MP of dairy cows.

2.2. Methane emissions: No direct treatment effect could be observed for daily CH_4 production and when expressed as CH_4 yield per kg of DMI, only a trend is observed. However, due to the persistent MP of the treated cows, hop extract addition reduced CH_4 emission intensity per kg of produced milk. As CH_4 emissions per unit of animal product (i.e. emission intensity) is the most accurate way to express and compare emissions, the increased animal productivity is an effective way to reduce greenhouse gas emissions from livestock (Hristov *et al* 2013).

3. CONCLUSION: Despite the fact that several in vitro studies gave evidence for a CH_4 mitigating effect of whole hops or hop extracts, this was not the case in our in vivo study. However, this in vivo study did show positive effects on the milk production. Because of the limited number of cows in this study, future research will include more animals in order to confirm (or deny) the effect of the hop additive on the milk production.

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Mitigation strategies

International Symposium on Emission of Gas and Dust from Livestock

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Saint-Malo, France

Part 3 – Modelling

Modelling

ANALYSIS OF THE MAXIMUM POTENTIAL OF AMMONIA EMISSION, FROM LAYING HENS MANURE, THROUGH THE DYNAMICS OF SYSTEMS.

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ABSTRACT: World egg production in 2015 was estimated at 71.5 million tons. The projections for 2030 correspond to a production of 86.8 million tons of eggs. Globally, this gain represents increased demand. In Brazil, this gain in production may be met using vertical cage systems for laying hens. These systems are composed of tiers of overlapping cages with manure belts beneath each tier. There can be tiers of cages, typically 6 to 12. In this housing model, a higher density of hens is obtained per unit barn floor area, which consequently leads to higher manure concentrations. The production and emission of ammonia (NH_3) from laying hen manure depend on several factors, such as temperature, relative humidity of air, moisture content of manure, crude protein in the feed, efficiency of ration formulation, and others. This work aimed to create diagrams that interrelate physical, chemical and biological factors with the production and emission of NH_3 from laying hens, as well as to use system dynamics to propose a maximum NH_3 emission potential. A causal diagram was created relating the NH_3 generation steps. These data were analyzed by the Vensim program, and it's possible to determine a maximum emission potential for this gas, equal to 64.5% of the total nitrogen excreted by the hens.

Keywords: NH_3, Manure, Vensim.

INTRODUCTION: Environmental factors, such as temperature and relative air humidity, and handling, such as crude protein levels and feed energy, may influence the rate of uric acid excretion of laying hens (Hsu et al., 1998). Mahmoud et al. (1996) reports that high temperature stress causes physiological changes in laying hens, damaging the acid-base balance and leading to reduced nutrient absorption.

It is observed the possibility of interacting through mathematical equations, the influence variables (temperature, moisture content and feed composition) and inferring the maximum amount of uric acid that can be excreted by laying hens. Based on these data, it would be possible to estimate the maximum potential of ammonia generation and emission into the atmosphere from the production of eggs.

In spite of all the efforts of the scientific community to establish protocols for measurement and quantification ammonia emissions from livestock farms, there aren't still baseline parameters to compare the measured emissions, typically express in grams ammonia per unit time per bird. The proposition of an index of maximum ammonia emission potential, which varies according to the the environmental and handling characteristics is necessary to provide a benchmark for comparing emission levels. With this benchmark potential emission level, it is possible to evaluate the magnitude of what is being emitted by installation. The knowledge of how each process stage of animal production influences the maximum potential of ammonia generation and emission makes it possible to make changes in the management animals, and can suggest means of providing reductions in ammonia emissions into the atmosphere.

An appropriate tool for this sort of analysis is System Dynamics (DS), which can be defined as a language where it's possible to more accurately express existing chains of events in nature (Villela, 2007). By using diagrams (causal or flow and inventory) it is possible to graphically describe and perform the equation of a productive system, thus allowing a clear analysis of its dynamic complexity (over time), and the interrelationships between each stage.

From the early 1980s onwards, numerous applications of DS have emerged in agroecological systems. Trenbath (1989) proposed a simple four-variable model where it was possible to verify the interaction between trees and soil and to accurately calculate the need for fallow. When Van Noordwijk (2001) made changes to the original model, it was possible to determine maximum productivity values while keeping the system sustainable. Van Noordwijk et al. (2001) proposed a more specific simulation, in which forest felling was considered and the effect of burning of the forest remains on the minerals present in the soil. It was observed that for certain nutrients, such as nitrogen, there was loss, but for others there was an increase in its availability in the system, as was the case of phosphorus.

From the above, it can be seen that DS can be an important tool in the analysis and equation of the interrelations of the process of excretion of uric acid by laying hens. This analysis was performed when the environmental and management parameters were changed, to which the animals are submitted.

1. MATERIAL AND METHODS: System Dynamics (System Dynamics) is above all, a language allowing to express, more properly, existing chains of events in nature. Through the use of diagrams a graphical system system representation is constructed.

VenSim® is a computer program that was used to generate the desired diagrams. The database that will feed the Vensim consisted of a literature review of pre-existing studies, which are summarized below.

HSU et al. (1998) realized that there is a significant influence of nitrogen excretion rate (in the form of uric acid) in laying hens compared to the ambient temperature. According to Vogels and Drift (1976), the increase of the ambient temperature allows higher values for the decomposition rates of uric acid, causing greater potential of generation and emission of NH_3, with a strong increase between 20 and 30 °C, which can be observed in Figure 3.

The pH of manure is another factor that has significant influence to determine the loss of nitrogen from waste to the atmosphere as ammonia (Gay & Knowlton, 2009). The pH range between 8 and 9 enhances the formation of NH_3 from the above two processes. The variation of moisture content of laying hens manure on the degradation of uric acid was studied by Koerkamp (1994).

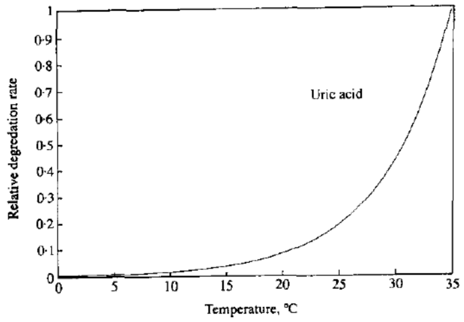

Figure 3: Temperature effect on the degradation of uric acid

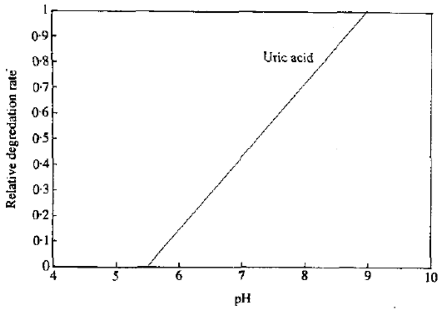

Figure 4: pH effect on the degradation of uric acid

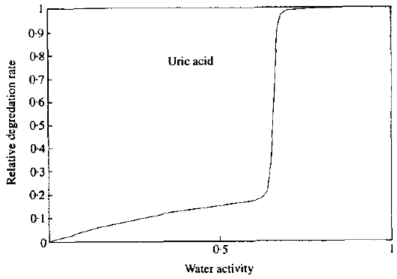

Figure 5: Moisture content effect on the degradation of uric acid

The effect of variation of the moisture content of laying hens on uric acid degradation can be seen in the graph presented in Figure 3 presented by Groot Koerkamp (1994).

These were some of the main influence factors, on the degradation of the acid, used to feed the model generated by Vensim.

2. RESULTS AND DISCUSSION: The data gathered from literature reviews were entered in the causal diagram constructed in Vensim. Then we generate a new diagram, termed a ‘flow-stock’, as depicted in Figure 4.

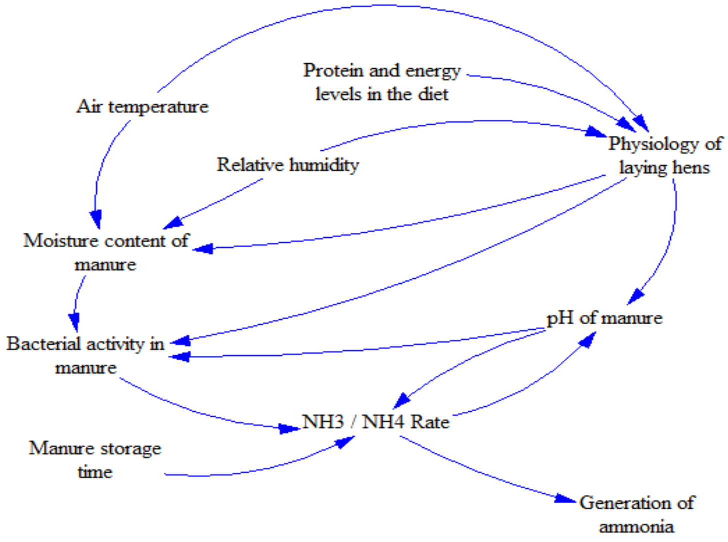

Figure 6: Diagram generated by VenSim

Maximum values were used to potentiate ammonia generation in the diagram generated by VenSim. These values were taken from the literature, as in previous studies (influence of temperature on uric acid degradation, moisture content of waste, pH, among others). The objective was to create the worst possible situation where the maximum amount of nitrogen Total, found in the manure, was converted to ammonia.

The simulation predicted that the maximum percentage of 64% of total nitrogen found in the manure has the potential to be converted to ammonia. Recalling that this condition is hypothetical and provides the maximum potential emission (according to the literature review and presented previously).

The percentage of 64% of the total nitrogen present in the conversion of laying hens in ammonia waste was obtained by the analysis conducted by Vensim to the parameters in the interrelations provided to the program.

3. CONCLUSION: The system dynamics is presented as a tool to combine the factors affecting the generation and emission of ammonia from the manure of laying hens and to predict the maximum quantity of ammonia that can be generated for a set of conditions.. Additional studies to adjust the displayed flow model and inventories are being conducted. By using this tool, we can predict how much will be the maximum emission of ammonia using the local environmental and management conditions, and to assess potential emissions reduction strategies.

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EFFECT OF FEEDING STRATEGIES ON METHANE EMISSIONS OF DAIRY COWS EVALUATED BY MIR SPECTROMETRY

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ABSTRACT: Reduction of methane emissions by 20% is one of the objectives of the Horizon 2020 policies of the European Commission. Yet livestock is considered responsible for 18% (dairy) and 55% (beef) of agricultural enteric methane emissions. It is thus necessary to improve the liability and the eased assessment of the cattle emissions on a large scale to determine levers of action to decrease them and quantify the impacts of these actions. The aim of this study was to estimate methane emissions of a dairy herd by MIR spectrometry and to follow up the cows on an individual basis during the winter period. Different concentrate compositions supplementing the total mixed ration (TMR) given to the herd were tested regarding their effect on predicted methane emissions. No effect was statistically noted and factors which might have influenced this result are discussed hereafter.

Keywords: methane, methane prediction, mitigation strategy, dairy cattle

INTRODUCTION: Livestock is considered to contribute significantly to green-house gases (GHG) emissions by producing enteric methane during ruminal fermentation. The dairy and beef sectors are estimated respectively responsible for 18% and 55 % of enteric methane emissions (Tubiello et al., 2014). Yet, a reduction of GHG emissions by 20% is required by the European Commission to comply with Horizon 2020 objectives. To reach this objective, it is necessary to develop methods of methane assessments liable and applicable both on an individual basis and on a large scale. The potential of mid infra-red spectra analysis to predict methane emissions has been largely highlighted (Vanlierde et al., 2015). The possibility to follow up individual cows and herds by this non-invasive and cheap method might be useful to evaluate the impacts of mitigation strategies. The aim of this study was to assess the impact of feeding strategies on methane emissions by following up the methane emissions on an individual basis of a dairy herd over a 138 d-period corresponding to the winter period. Increasing the starch content or the fat content of cows' ration has been described as effective to lower methane emissions expressed in g.kg dry matter intake^{-1} (compound rich in starch – rich in fat) and in g. d^{-1}(compound rich in fat). Both strategies were tested: during the first trial a concentrate rich in starch (32%) was provided to the cows and in the second one the concentrate fat content was increased from 4% to 9%. Results of the MIR predictions are presented and discussed.

1. MATERIAL AND METHODS

1.1. The study was conducted for 138 days at the Experimental Farm of University of Liège (Liège, Belgium) on a herd of 54 Holstein dairy cows milked by an automatic milking system Lely A3.

1.2. Experimental design:The cows received a total mixed ration (TMR) whose composition was 30% maize silage, 35% grass silage, 11% beet pulp silage, 6% brewers, 7% dried forage (hay+straw) and 11% a mixed compound rich in protein (35% PB). The TMR was completed by concentrates of variable composition (Trial 1:AT2: Fat: 4%-Starch 32% - Trial 2:AT3: Starch 21.7% -Fat: 9%) supplied at milking. Zootechnical performances and methane emissions of groups receiving these 2 concentrates were compared with those of a group receiving a control concentrate (AT1: 4% Fat – 18 % starch). Thus, the herd was randomly divided into 2 groups of at least 16 cows balanced with regards to DIM, lactation number and MY. Provided concentrate (kg.cow^{-1}.day^{-1}) was individually calculated on basis of DIM and lactation number. Each feeding trial was divided into 2 periods. Each test period lasted for one month, including a 2-weeks transition period and milk samplings during the 3^{d} and 4th week. During the first period (Period 1), one group received the control concentrate (AT1) and the other, the tested one (AT2 or AT3). After 1 month, the groups were switched so that the control group received the tested feed and inversely (Period 2). Each cow became thus her own control. Description of the groups at the beginning of each trial is presented on Table 1.

Table 1. Description of the groups tested during the 2 feeding trials.

	Trial 1 **Concentrate rich in starch**		**Trial 2** **Concentrate rich in fat**	
	AT1	AT2	AT1	AT3
Nbr of cows	16	17	17	17
Days in milk	119 ± 108	116 ± 124	97 ± 79	83 ± 54
Lactation number	2.5 ± 1.6	3.0 ± 1.8	2.6 ± 1.7	3.1 ± 1.8
Milk yield (kg.cow^{-1}.d^{-1})	22.7 ± 7.0	22.9 ± 9.4	31.1 ± 6.9	33.2 ± 7.0
Concentrates (kg.cow^{-1}.d^{-1})	3.4 ± 1.8	3.4 ±1.8	5.3 ± 1.7	5.1 ± 1.7

1.3. Measurements and analysis. During the trials, milk samples covering a 24-h period were collected at least 2 times per measurement period by mid-infrared (MIR) spectrometry to quantify the milk composition (% F and % P) and to obtain the milk spectrum (2–3 samplings/ period/cow). Methane emission (g methane.day^{-1}) was estimated using the equation developed by Vanlierde et al., 2015 from the recorded milk spectra. A repeated model was used to compare daily methane emissions (g methane.day^{-1}), methane emissions.kg^{-1} produced milk and methane emissions.kg energy corrected milk (ECM) $^{-1}$ of the groups. Fixed effects included in the model were: group, period, period X group and DIM. The repeated statement was based on the cow identification. Descriptive statistics and the repeated models were computed using SAS 9.3 software.

2. RESULTS AND DISCUSSION: Results showed a large range of variation in MIR methane emissions among observations (448 ± 57 g.day^{-1}; min: 246 g.day^{-1}; max: 582 g.day^{-1}). Cows were then classified on basis of their emission rate, considering a cow as low emitter for methane emission < 413 g.cow$^{-1\cdot}$day^{-1}, and high emitter for methane values > 487 g.cow$^{-1\cdot}$day^{-1}, those values corresponded to 25% and 75% quantile of the MIR methane values distribution. It appeared that one cow being low emitter at one time could be high emitter in the following period independently from the tested concentrate (Figure 1).

2.1. Results of the feeding trials: No statistically significant decrease in methane emissions (Tables 2-3) could be detected during the feeding trials. However in the trial 2, methane.kg milk^{-1} and methane.ECM^{-1} were numerically lower in the group receiving the concentrate rich in fat. Different factors could be invoked: the inter-individual differences and the standard error of calibration and of cross validation, respectively estimated at 66 g.day^{-1} and 70 g.day^{-1}might have interfered with the effects of the tested compound (Vanlierde et al., 2016). The concentrate to roughage ratio could have been too small to influence markedly the ruminal fermentation. The length of the measurement period (138 days) induced in some cows prolonged lactations with lower MY and lower concentrate consumption that might have been insufficient to impact methane emissions. Late lactation stages caused significant differences in methane emission rates.cow^{-1}day^{-1}. This effect is reported and taken into account in the prediction equation (Vanlierde et al., 2015).

Table 2. Results (LSMeans ± SE) of the first feeding trial.

N= 99	AT1	AT2	Group	Period	DIM
Milk yield (kg.cow^{-1}.d^{-1})	28.2 ± 1.3	24.4 ± 1.3	*	ns	ns
ECM (kg.cow^{-1}.d^{-1})	26.5 ± 1.3	23.3 ± 1.3	trend	ns	ns
Methane (g.cow^{-1}.d^{-1})	427 ± 9	425 ± 10	ns	*	**
Methane (g. kg milk^{-1})	17.2 ± 0.7	19.5 ± 0.7	*	ns	***
Methane (g.kg ECM^{-1})	17.5 ± 0.7	20.3 ± 0.7	*	ns	***

Abbreviations: AT1: control concentrate – AT2: concentrate rich in starch. ECM: energy corrected milk; ***: $p<0.001$;**: $p<0.01$; *: $p<0.05$; trend: $p=0.1$; ns = not significant. Effect of interaction group X period was ns and thus not showed.

Table 3. Results (LSMeans ± SE) of the second feeding trial.

N = 167	**AT1**	**AT3**	**Group**	**Period**	**DIM**
Milk yield (kg.cow^{-1}.d^{-1})	28.1 ± 1.3	31.0 ± 1.4	trend	ns	ns
ECM (kg.cow^{-1}.d^{-1})	27.6 ± 1.3	29.8 ± 1.4	ns	ns	ns
Methane (g.cow^{-1}.d^{-1})	461 ± 7	459 ± 7	ns	ns	*
Methane (g.kg milk^{-1})	17.4 ± 0.8	15.9 ± 0.9	ns	ns	ns
Methane (g.kg ECM^{-1})	17.8 ± 0.8	16.6 ± 0.9	ns	ns	ns

Abbreviations: AT1: control concentrate – AT3: concentrate rich in fat. ECM: energy corrected milk; ***: $p<0.001$;**: $p<0.01$; *: $p<0.05$; trend: $p=0.1$; ns = not significant. Effect of interaction group X period was ns and thus not showed.

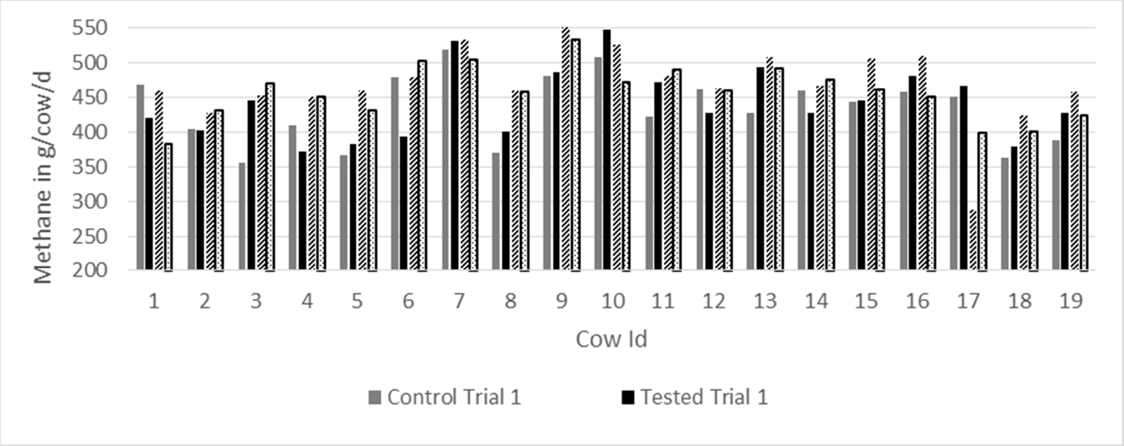

Figure 1: Variations of predicted methane on the same cows throughout the trials

3. CONCLUSION: In this study, MIR spectrometry analysis was used to predict methane emissions of a herd on an individual basis over a period corresponding to the winter period. No effect of the concentrate composition was highlighted. Further study is needed to investigate the implication of the different evoked factors susceptible to have influenced this result.

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INNOVATIVE DATABASE AND ITS POTENTIAL TO REALISE LARGE SCALE STUDY TO QUANTIFY THE IMPACT OF DIET COMPONENT ON CH4 EMITTED DAILY BY DAIRY COWS

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ABSTRACT: Diet composition (**DC**) is one of the main levers to reduce methane (**CH_4**) emissions from cattle. Anyway, neither DC nor individual CH_4 emissions are available in the classical performance recording databases. Through collaboration with the feed company Dumoulin S.A., a new type of database has been built including DC at herd level, zootechnical data, milk MIR spectra and through this last one, the individual CH_4 prediction. The objective was to realise a first exploratory analysis on this very novel database based on more than 6,800 records from 1,260 cows and 10 different Belgian farms. Correlations and models have been calculated to estimate the influence of diet components on the CH_4 emissions. The first conclusions highlighted that high fat, digestible proteins and "sugar and starch" levels in the diet permit to reduce CH_4 emissions through intensification. Fat seems to combine a great impact at ruminal level.

Keywords: CH_4, dairy cows, milk, mid infrared, diet composition

INTRODUCTION: Agriculture and more especially cattle breeding are notably concerned by the worldwide intent to reduce greenhouse gases (**GHG**) emissions. The main levers of action to reduce CH_4 emissions from cattle at the animal level are through breeding (de Haas *et al.*, 2011) and adaptation of the DC (Beauchemin *et al.*, 2008). Investigations on the impact of global DC on CH_4 emission are always complicated because of the small number of animals used during those trials and because of their specificities on some feeding parameters without considering the global diet. Moreover detailed DC is rarely available in the classical performance recording databases, as are daily CH_4 emission from dairy cows. Recent advances in the estimation of CH_4 from milk mid infrared (**MIR**) spectra (Vanlierde *et al.*, 2016) make this data available in routine at least once every 6 weeks through milk recording in Walloon Region of Belgium allowing the organisation of large scale studies on dairy cows. Otherwise through collaboration with the feed company Dumoulin S.A., DC data were also available from 10 Walloon commercial farms between January 2014 and June 2015. Indeed the composition of the diet given to the herd has been recorded: feedstuff (%DM) included in the basal diet and average amount (kg/day) of production concentrate; and their composition: fat, proteins, energy, NDF, "sugar + starch" levels, *etc*. Moreover zootechnical data were also available (breed, days in milk (**DIM**), lactation number, milk yield, *etc*.). The DC of those farms differed mainly in terms of main forages types (grass silage *vs.* corn silage). The objective of this study was to use this novel and innovative database to evaluate the influence of the diet nutrient composition on the level of MIR CH_4 emissions.

1. MATERIAL AND METHODS

1.1. Creation of the database: The first important step was to assign the corresponding milk MIR spectra to each zootechnical and DC combination through the cow ID and the date of measurement. Then the equation developed by Vanlierde et al. (2016) has been applied to the MIR spectra to obtain an individual estimation of CH_4 emissions (g/day).

1.1.1. Cleaning regarding spectral and equation specifications: Regarding conditions of application of the CH_4 equation, only test-days from cows with a DIM between 5 and 365 (limits included) were kept in this study (779 discarded data). On another hand, only the spectra with a variability covered by the calibration set of the equation (estimated with standardized Mahalanobis distance, global H distance < 5) (863 discarded data) were considered. Around 6,800 records (predicted CH_4 linked with diet and zootechnical data) from 1,260 different cows were usable.

1.1.2. Cleaning regarding DC and zootechnical information: In this specific case, it has been decided to focus on data from November to March (around 3,450 data left) to remove the grazing data which are not easy to evaluate at nutritional level in terms of quantity and quality. Moreover, 3 herds have been removed because an automatic concentrate dispenser was used. Indeed a variation up to 6kg of concentrates between animals could occur and this information is not detailed even if this parameter influences deeply the individual level of CH_4 emission. The herds considered are fed with TMR. At the end, 2,498 data have been considered.

1.1.3. Estimation of the theoretical DMI: As the dry matter intake (**DMI**) is a significant information regarding the level of CH_4 emissions but was not recorded in this context, a theoretical DMI has been estimated by the amount of diet required to fulfill the digestible proteins (Tamminga et al., 1994) and net energy requirements for the observed milk production, according to the Dutch feeding standards. On the other hand cows at the beginning of the lactation are in negative energy balance (**NEB**) and so, do not cover those needs. This is why the percentage of cows under and above 70 DIM (supposed in NEB) is also considered.

1.2. Animal and herd levels: Regarding the DC, for each test-day (maximum once a month per farm) the same diet is allocated to all cows. The levels of each component of this DC are calculated for one theoretical animal which is representative of the herd at a precise time. It implies that DC information is at herd level and there is no distinction regarding the individual differences. However the CH_4 predictions to link with DC and zootechnical details are available on animal basis. To be as precise as possible regarding diet composition, only herd level will be detailed in this first approach. The zootechnical information has been averaged for the animals considered in each herd at each test-day (N=44).

1.3. Correlations and models: The units for CH_4 emissions vary in function of the general purpose. Three of them have been considered: g CH_4/day (i.e., reflecting the global GHG emission), g CH_4/kg of milk (i.e., economical production) and g CH_4/kg of theoretical DMI (i.e., animal's efficiency). Correlations have been calculated at herd level between CH_4 emissions and the main characteristics of the studied diets: "sugar and starch", fat, energy, digestible proteins and NDF levels, with the purpose to observe the influence of DC on CH_4 emissions.

2. RESULTS AND DISCUSSION: After the different cleaning processes, 2,498 records from 754 different cows observed in 7 distinct farms have been considered in this work.
Correlations observed at animal level (Figure 1) have mainly highlighted that digestible proteins, fat and "sugar and starch" contents of the diet could reduce methane emissions through intensification of milk production. Indeed a negative correlation was observed between those diet components and CH_4 in g/kg of milk. More than the intensification aspect, the important negative correlation observed between the fat level and CH_4 in g/day and more especially in g/kg of DMI shows that fat influences the CH_4 emissions through an impact at rumen level. Indeed, lipids are not fermented in the rumen so their addition reduces methane emissions per kg of DMI (Johnson and Johnson, 1995). Besides this general effect, some lipids like medium-chain fatty acids decrease methanogen numbers while polyunsaturated fatty acids have a toxic effect on cellulolytic bacteria that produce H^+ ions (Nagaraja et al., 1997), and protozoa (Doreau and Ferlay, 1995). These effects on the flora lead to a decrease of the acetate:propionate ratio and depend of the quantity of lipids used. Finally, to a less extent, biohydrogenation of the polyunsaturated fatty acids could impair methane emissions through hydrogen consumption (Martin et al., 2010).

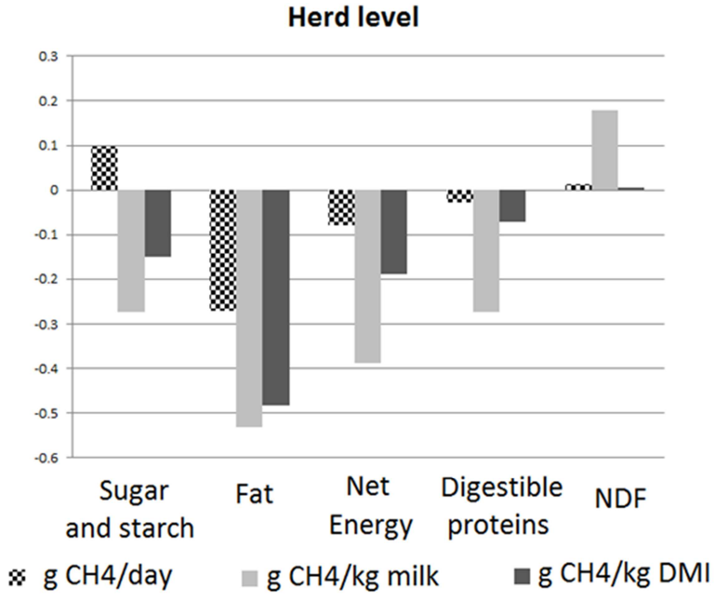

Figure 1. Correlations observed at herd (N=44) level between five characteristics of the diet (g/kg DM) and the CH_4 emissions in different units.

3. CONCLUSION: Because this dataset has not been collected for the study purpose, the analyse to assign a variation regarding CH_4 emissions to a variation of a specific diet component or a combination of diet components require beforehand a consequent cleaning of the dataset. Indeed several interdependencies existed between diet components. Anyway the first analyses permitted to conclude that high fat, digestible proteins and "sugar and starch" levels in the diet permit to reduce CH_4 emissions through intensification. Fat seemed to combine a great impact at ruminal level which makes this diet component particularly interesting in a global objective to reduce CH_4 emissions.

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Modelling

International Symposium on

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Part 4 – Measurement methods

Measurement methods

VERIFICATION OF EMISSION-REDUCING PROCEDURES IN NATURALLY VENTILATED COW HOUSES BY USING OPTIMISED MEASUREMENT METHODS – REVISION OF THE VERA TEST PROTOCOL “HOUSING SYSTEMS”

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ABSTRACT: To meet the challenge of performing comparable and valid emission measurements in naturally ventilated animal houses, the VERA test protocol for “Housing and Management Systems” (2011) has been revised based on the latest studies and an exchange of experts. The revised protocol offers guidance ranging from the selection of a suitable test location to correct measurements with artificial or metabolically produced tracer gases allowing an evaluation of the environmental performance and operational stability of emission-reducing procedures in livestock husbandry. To validate the revised method and assess the measurement uncertainties, a plan for an inter-laboratory test has been initiated.

Keywords: House, Inventory, Measuring method, Environmental evaluation, Verification.

INTRODUCTION: Making the environmental efficiency and operational stability of emission-reducing procedures transnationally comparable by using uniform and scientific test procedures was the objective of the Verification of Environmental Technologies for Agricultural Production (VERA) initiated by Germany, Denmark and the Netherlands in 2008.

The challenge involves performing comparable and valid emission measurements in naturally ventilated animal houses, as they are common practice in cattle farming, and standardising them has not been achieved in a satisfactory manner in recent years due to the insufficiently described and validated measurement methods. Furthermore, inter-laboratory studies to develop a reliable assessment of the measurement uncertainties for emission measurements in livestock husbandry systems are necessitating new initiatives.

1. MATERIAL AND METHODS: The development of the revised test and verification standard is based on the connection of expert knowledge and several scientific studies in Denmark, the Netherlands, Germany, Belgium, France and Switzerland. In this process, not only were literature studies consulted, but also a direct exchange involving experts with technical knowledge of the relevant issues was initiated and supported, as this is common practice during the creation of international standards.

The coordination of the new standard was mainly supported by the relevant agricultural or environmental ministries of the interested countries. This setup was also applied for the planning of an inter-laboratory investigation in order to improve the assessment of measurement uncertainties when measuring ammonia in the agricultural environment of an animal house.

2. RESULTS AND DISCUSSION:

2.1. Revised test standard: A revised test standard for naturally ventilated animal houses has been created on the basis of completed studies and with the participation of scientists from various European countries. The results have been summarised in terms of a revision in the new version of the VERA test protocol for “Housing and Management Systems”. The focus is on testing ammonia, odour and dust emissions from livestock houses, measuring and respecting parameters which are related to the emissions (e.g. ventilation rate, CO_2, temperature) or to other factors such as the level of production (e.g. animal weight and density, manure parameters, feed) and the operational stability of the system in the test (e.g. uptime of system, consumption of electricity, water, chemicals). The latest findings from other European research projects evaluating the application possibilities and limits of various measurement methods for ammonia, dust and odour were considered for the revision.

To allow flexibility in the selection of the measurement methods and simultaneously assure high measurement quality, it was agreed to abandon the earlier approach based on a list of allowed measurement principles. This has been replaced by an approach with defined unique ‘reference methods’ for each of the primary measurement parameters. The selected measurement methods must have been validated against reference methods in a standard procedure based on laboratory and field comparisons.

Reference methods are now defined for:

Ammonia: Impinger system
Odour: dynamic olfactometry according to EN 13725;
(Total) Dust: gravimetric measurement according to the relevant EN standards;
Air volume: fan-wheel anemometer or emission values derived from tracer gas.

2.1.1. Measurements for naturally ventilated buildings: Primarily, the revision discusses comprehensively the specific measurement conditions for naturally ventilated animal houses, ranging from the selection of a suitable test site to the correct definition of adequate measurement methods, such as those with artificial (e.g. SF_6) as well as with metabolically produced tracer gas (CO_2) and their explicit measurement conditions and requirements. Moreover, the correct processing and statistical evaluation of the data is presented and explained to assure the environmental effect of the technology investigated.

The key alterations to the previous test protocol and the major requirements for the measurements according to the revised VERA standard are as follows:

Measurement methods

Case-Control design: As this test design is known to minimise non-system factors and allow a direct comparison, this remains the preferred option in the revised test protocol. The maximum deviation for a case-control approach in terms of variation in e.g. animal weight or other aspects is defined. Use of a 'fixed case-control' or an 'on-off' approach may be alternative test designs if specific requirements are respected and other test conditions can be kept similar during the measurement periods. This can help to prevent the need for a multi-side approach, which is a more expensive option, as measurements at a minimum of four (instead of two) different test sites become necessary.

Emission patterns: Emissions can vary significantly depending on the animal weight and growth. Therefore, this effect must be considered in the planning of the test. Three types of 'growth' are defined as: stable (e.g. in dairy cows), linear increase (e.g. in fattening pigs) or exponential increase (e.g. in broilers). The sampling has to be performed in several periods of equal length depending on the growth type.

Sampling points: To gain valid results with the CO_2 balance method, selecting the right sampling points is crucial. The distance between the sampling point and the side wall or an outlet opening, the minimum number of sampling points, and the height of the sampling line in order to minimise the effect of animals, cubicles and other obstacles are described.

Other sources and ingoing air: At least one sampling point outside the house at all open side walls at a distance of at least five metres is necessary to measure the gas concentration of the ingoing air. Other sources can influence the concentration of pollutants already in the ingoing air and need to be considered both in choosing the right measuring point for the outside air measurement and in calculating the emission value.

Sampling frequency: A minimum of six measurement periods of at least 24 hours distributed over one year is still the demand for a VERA test. The distribution depends on the emission pattern. The exact number of measuring days must be determined based on an analysis of the power of the test design.

Calibration, validation, on-site verification: Quality management in terms of testing by 'good laboratory practice' is emphasised more clearly. Any calibration and verification procedures must fulfil the requirements of ISO 17025 (2005) and be documented and reported.

Calculation of the emission value: To derive the best estimate of the emission value from the test data, the completeness of the data set has to be evaluated and the mean emissions calculated, taking the emission pattern into account. When the CO_2 tracer ratio method is used, the calculation has to follow the rules of the International Commission of Agricultural and Biosystems Engineering (CIGR). An open Excel calculation tool is planned to assure equally correct use of the equations needed.

2.1.2. Agronomic requirements – common baseline: In addition to the measurability of a test site, the representativeness of a test site is of utmost importance to allow the best possible transferability of the test results to other countries and to other farms. The Annex of this revised test protocol provides a comprehensive summary of agronomic requirements for an emission test in the three countries and includes a 'common baseline' of the standard animal housing conditions. For dairy cows, the loose housing with cubicles was found to be the highest common denominator for a 'standard housing system.

To give an example of relevant criteria for the definition of agronomic requirements, Table 1 shows the demands for a suitable test location for dairy cows.

Table 1. Agronomic requirements for a test location (VERA, 2017).

Criterion (Excerpt)	Example: Dairy cows
Animal occupation rate	90–100%
Herd composition	>70% of house must be occupied by cows
Housing system in use before test	>2 months
Production level	≥ 25 kg energy corrected milk per cow and day
Feed composition	≥ 50% roughage, 160–180 g CP per kg dry matter

Naturally, only test farms with a production that complies with all national regulations on animal welfare, total environment, occupational health and safety and, if relevant, food safety for e.g. feed additives are acceptable. To allow the classification of the test results attained, the national emission factors of the VERA member countries were summarised for different animal categories and housing and management conditions.

2.2. Plan for an inter-laboratory test: To validate the measurement methods and to improve the assessment of measurement uncertainties, an inter-laboratory test with research and commercial laboratories will be planned. The first step will focus on the comparison of the measurement devices for NH_3, CO_2 and accompanying parameters upon use in a standardised gas measuring chamber with a mixture of different gases representing typical farm conditions. Furthermore, one measurement point in an animal house will be used to compare different measurement methods and instruments. In standard instrument calibration regimes, interference of other gases is usually not considered. The conditions of an animal house, however, require the measurement instruments to be in control of such incidences. Thus, the new setting is crucial to evaluate measurement uncertainties under on-farm conditions.

3. CONCLUSION: The final version of the revised VERA test protocol will be made publicly available on the VERA website from mid-2017. The outcome of the inter-laboratory test will be included in the next revision. In the meantime, other studies and new research project are already based on this new standard and following the VERA test methods.

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QUANTIFICATION OF SMALL SCALE NITROUS OXIDE EMISSIONS AND COMPARISON WITH FIELD-SCALE EMISSIONS OF A ROTATIONAL GRAZING SYSTEM

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ABSTRACT: The present study investigated the contribution of fresh dung and urine patches and other background areas to the total N_2O emissions of a grazed pasture system in Switzerland. For this purpose small-scale chamber measurements were compared to field scale eddy covariance measurement of N_2O fluxes. It was found that urine patches are strong hotspots of N_2O emissions and contribute a dominant share (about 60%) to the overall pasture emission during grazing periods. A simple up-scaling showed a fair agreement of average emissions observed by the two methods. Short-term deviations between the methods indicate a strong effect of soil moisture conditions.

Keywords: N_2O, grazing, chamber method, eddy covariance method, urine patches

INTRODUCTION: While grazed pastures are considered as advantageous for the animal welfare as well as for a minimised NH_3 emission (Voglmeier et al., this issue), they are potentially strong sources of the greenhouse gas nitrous oxide (N_2O), particularly for productive systems with additional fertilisation application (Flechard et al., 2007). The uneven spatial distribution of the excretion of the grazing animals can lead to local emission hot-spots. Especially urine patches can result in a high local nitrogen surplus, which can only partly be taken up by nearby plants (Moir et al., 2011). The strong spatial and temporal variability of the gaseous emissions represents an inherent problem for the quantification of gaseous emissions from pastures. For this reason, micrometeorological methods that integrate emissions over a larger domain like the eddy covariance (EC) method are well suited to quantify the total N_2O emissions of grazed fields. In contrast, chamber methods are better suited to study the underlying processes and to measure the spatial and temporal variability of individual emission sources (urine and dung patches). We present first results of a pasture field experiment with grazing dairy cows in 2016 where N_2O fluxes were measured continuously with the EC method during the entire grazing season and with a manual chamber on selected days.

1. MATERIAL AND METHODS: The experimental site is located in the Pre-Alps of Switzerland at the research farm Agroscope in Posieux. The pasture was managed as an intensive rotational grazing system and therefore was divided into 11 paddocks that were grazed by 12 dairy cows subsequently with a full cycle length of about 20 days. Field-scale emissions were obtained continuously with the EC technique using a three-dimensional ultrasonic anemometer (HS-50, Gill Instruments Ltd., UK) mounted at 2 m above ground in combination with a fast response quantum cascade lasers (QCL, Aerodyne Research Inc, Billerica, USA) for N_2O quantification. Data from both instruments were recorded synchronously at 10 Hz. Small scale emissions of N_2O from dung and urine patches as well as from 'background' surface areas were quantified on multiple days after grazing using an optimized chamber technique. These so called 'fast box' measurements (Hensen et al., 2006) also made use of the fast QCL instrument for N_2O detection and allowed to measure a flux value within 60-120 s. The measurements were carried out on selected intensive observation areas within the pasture. The appropriate interpretation of the fast-box measurements required information about the location and distribution of the excreta patches of the grazing cows. While fresh dung pads could be identified visually, urine patches were detected using a soil dielectric conductivity sensor. It was manually operated with a spatial resolution of 0.25 m. Figure 1 shows an example of the obtained distribution of dung and urine patches shortly after a grazing phase. The dielectric conductivity turned out to be a very distinctive indicator for the presence of urine in the soil during more than 10 days after deposition.

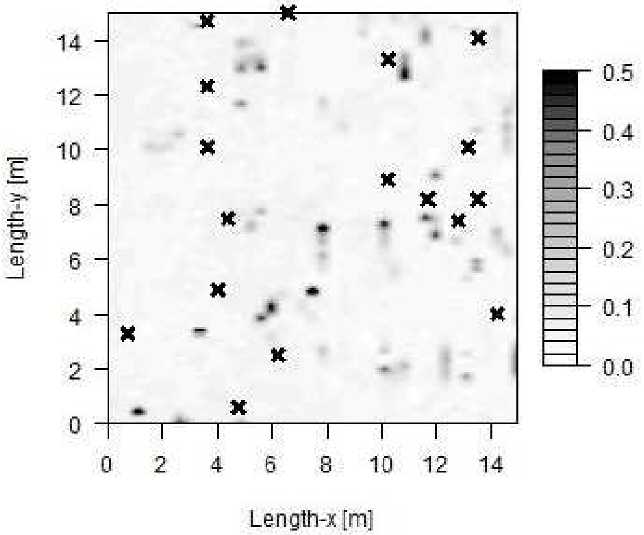

Figure 1. Distribution of fresh dung pads (crosses) and urine patches represented by increased soil dielectric conductivity (gray scale with units of dS m^{-1}) on a 15 x 15 m intensive observation sub-plot.

2. RESULTS AND DISCUSSION: More than 1000 individual flux measurements with the fast-box were performed on 46 days between July and October 2016. The resulting average small-scale N_2O emission fluxes are plotted in Figure 2 as a function of time since last grazing (corresponding to the age of investigated urine and dung patches). Directly after grazing, urine patches showed by far the highest emissions, more than an order of magnitude higher than dung patches and background pasture areas. However the urine patch emissions exhibited an approximately exponential decay with an e-folding time of 13 days, while there were only minor temporal changes for dung pads and background areas. It has to be taken into account that the displayed values are averages over space and time (different grazing rotations) with different weather and soil conditions. Therefore the scatter of individual values was high.

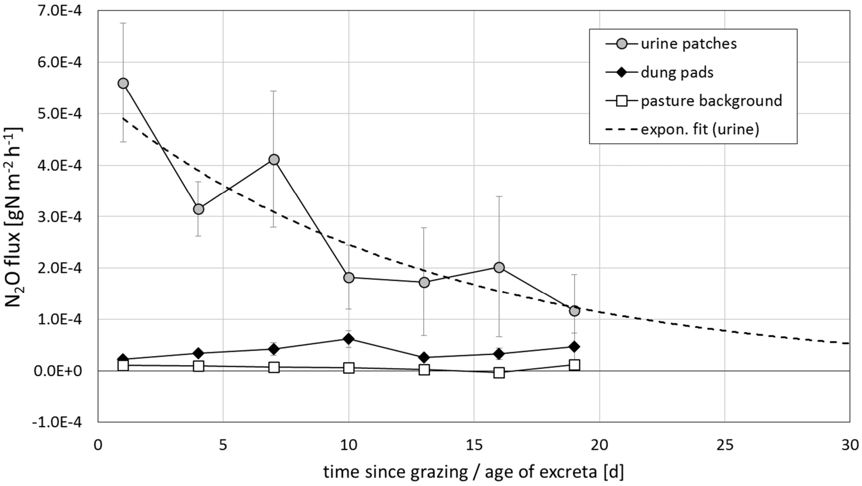

Figure 2. Average N_2O emissions for urine patches, dung pads and other areas (background) of the pasture observed by the fast-box measurements between July and October 2016 plotted as a function of time since the last grazing period (age of excreta). Vertical bars indicate the standard error for each time class.

In order to estimate the integral contribution of the three pasture surface sources (urine patches, dung pads, and background area) to the total N_2O emission, a simple upscaling calculation was made. It is based on rough estimates of the number of urine and dung patches deposited per cow and grazing day. Using typical values for N excretion for the local cow type (see Felber et al., 2016) and a typical literature value of 20 g N for the content of a single urination event (Misselbrook et al., 2016) resulted in an average number density for urine patches of 500 ha^{-1} d^{-1}. For dung pads a 25% higher number density was assumed. When integrated over a 30-day period, this resulted in average N_2O emission contributions from the different sources of 78 g N_2O-N ha^{-1} (urine), 18 g N_2O-N ha^{-1} (dung), and 40 g N_2O-N ha^{-1} (background). Thus for grazing periods (including the following regrowth) urine patches contribute more than half to the pasture emissions, but the other sources are not negligible.

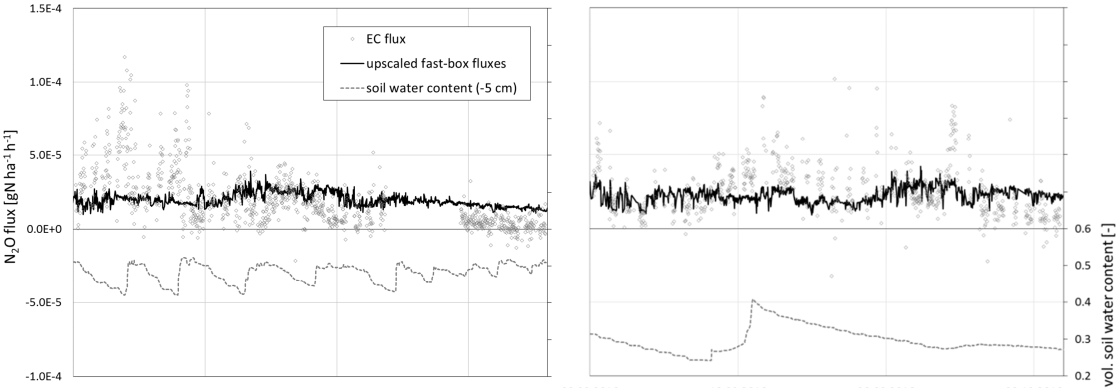

Figure 3. Comparison of half-hourly N_2O fluxes measured by EC and up-scaled fluxes based on fast-box measurements for two periods with grazing activities (upper panels), and corresponding soil water contents (lower panels).

For comparison of the fast-box results with the field-scale EC emission measurements, the fast-box measurements were up-scaled to the EC footprint area (Häni, 2017) with the simple assumptions described above for each half hour. The results for two monthly periods are shown in Figure 3. The emissions derived by the two methods show a satisfying agreement concerning their average magnitude. However, the variability of the up-scaled fast-box fluxes is generally small, as it is mainly caused by the temporal decay of urine contributions (see Fig. 2). The EC fluxes, in contrast, exhibit a much larger variation that is related to changing soil water content. Fluxes are smallest for very low and very high soil water content and highest in between.

3. CONCLUSION: Manual fast-box and continuous EC flux measurements have been performed on a grazed pasture. It was found that urine patches are strong hotspots of N_2O emissions and contribute a dominant share to the overall pasture flux during grazing periods. A simple up-scaling leads to fair agreement of average emissions observed by fast-box and EC. Deviations between the methods can be attributed mainly to the effect of soil moisture conditions, which was not considered in the fast-box up-scaling method applied here. This needs to be improved in a more detailed evaluation. For deriving excreta-specific N_2O emission factors, a (conceptually) well defined approach to separate the longer term effects of excreta and other fertilisation activities will be necessary.

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QUANTIFYING AMMONIA EMISSIONS FROM FARM-SCALE SOURCES USING AN INTEGRATED MOBILE MEASUREMENT AND INVERSE DISPERSION MODELLING METHOD

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ABSTRACT: We installed a high-frequency NH_3 analyser within a vehicle for mobile measurements. We used the mobile platform to measure concentration gradients downwind of a poultry farm, making multiple traverses across the plume. The concentration rise above background was used to determine the emission rate by applying an inverse dispersion model, where each plume traverse yielded a snapshot emission estimate. The individual emission estimates were averaged over each measurement period and compared against a reference mass balance method, where the agreement over three separate periods was between 20-30%, indicating that this new mobile measurement and inverse modelling method is promising. However, the plume-to-plume variability associated with the emission estimates was high, and the emission estimates have a large standard deviation. The most important uncertainty in this example was NH_3 dry deposition, where a large fraction (between 16-56%) of emissions was deposited before reaching the downwind concentration receptor.

Keywords: NH_3, Poultry, House, Measurements, Modelling

INTRODUCTION: The inverse dispersion method concerns the use of a dispersion model to simulate the transport and turbulent mixing of an air pollutant downwind from a source of emissions, which can diagnose the emission rate when combined with field measurements of downwind concentrations. This technique allows emissions from a source to be determined remotely, and very little information concerning the nature of the source is needed (only knowledge of source-receptor geometry is required). The inverse dispersion method requires knowledge of the background (or upwind) concentration, to determine the influence of the source on downwind concentration fields. In addition, a concentration measurement must be located within the “plume” downwind of the source, thus the placement of concentration receptors relative to the source and prevailing wind direction is a critical consideration. A solution to this problem is to surround the source with sufficient measurement systems (typically open-path with an optical path of the order of 50-100 m) so that the problem to determine the inflow-outflow concentration difference is mathematically over-determined, and independent of wind direction (e.g. Flesch et al. 2013). Clearly, this approach requires access to at least 2-3 measurement systems, which may not be available to researchers in all circumstances. An alternative approach is to apply a mobile sensing approach, where one analyser could resolve the concentration fields upwind and downwind from a source from a mobile platform, with the advantage that upwind and downwind concentrations are measured by the same analyser. This paper describes, and explores the potential for, such a methodology combining vehicle-based mobile measurements and inverse dispersion modelling, applied to our knowledge for the first time to the specific case of NH_3 emissions, in which dry deposition downwind of the source must be accounted for (Bell et al., 2017). The MOPED (MObile Plume measurements for Emission estimates by inverse Dispersion) method was implemented at to determine farm-scale emissions from a single poultry housing building (1000 m^2, 11800 broilers) with a NH_3 analyser mounted within a vehicle to continuously measure the ambient NH_3 concentrations while traversing the study sites. An in-house mass balance (MB) method was also applied to quantify the emissions independently and provide a reference.

1. MATERIAL AND METHODS

1.1. Mobile measurements: The off-axis integrated cavity output spectrometer (Fast Trace Ammonia Analyzer, Los Gatos Research Inc, Mountain View, CA, USA) determines the NH_3 mixing ratio from high-resolution absorption spectra obtained by a mid-infrared quantum cascade laser (QCL) tuned around 9.67 µm (Leen et al. 2013). The LGR-FTAA instrument was operated inside of a van which had been modified to provide the alternating current required to power the analyser, air pumps, computer and GPS systems. Ambient air was sampled by a dry vacuum scroll pump (Edwards XDS35i, Crawley, UK) through the cavity cell (internal pressure 100 Torr) at a rate of 25 SLPM via a 2-m long heated and insulated ½ inch PFA inlet line, through the side of the vehicle at a height of 2.2m. A teflon-coated aluminium particle cyclone (URG-2000-30EHB, URG corp, Chapell Hill, NC, USA) was fixed at the front end of the inlet to minimise dirtying the sampling system, removing most of the PM fraction above 1µm.

Repeat plume measurements were made downwind of the chicken farm, where each traverse of the plume recorded the concentration rise above background (ΔC), enabling the emissions to be determined by the inverse dispersion method. The background concentration was taken as the 5th percentile of the concentrations measured during each plume run. The 1Hz measurements were integrated as a function of distance along the plume transect, providing a unique line-averaged concentration measurement for each plume run, the start and end coordinates of which were input to the dispersion model.

1.2. Inverse dispersion modelling: The bLS-R model (Häni, 2017), is a backward Lagrangian stochastic (bLS) model that is based upon the bLS dispersion theory described by Flesch et al., (2004); however bLS-R has an additional function which computes the effect of dry deposition on gas concentrations. The bLS-R package provides functions to set up and execute the model within the R statistical software. The model calculates the dispersion coefficient $\boldsymbol{D}$ (s m^{-1}), used to derive the flux emitted from the source area ($\boldsymbol{Q}$, µg m^{-2} s^{-1}), by the measured rise in concentration above background ($\boldsymbol{\Delta C}$) (Equation 1).

$$Q = (\Delta C) * D^{-1} \tag{1}$$

where D is retrieved by the model from the number of source area interactions (N_{source}) and the thousands of trajectories (N) released backwards in time from the receptor locations (Equation 2).

$$D = \frac{1}{N}\sum_{N_{source}} \left|\frac{2}{w_0}\right| \tag{2}$$

The following input data were measured using an on-site ultrasonic anemometer (Gill WindMaster Pro, 2m height), averaged at 10 minute intervals: friction velocity ($u *$), Monin-Obukhov length (L), and the standard deviations of the rotated wind vector components ($\sigma_u, \sigma_v, \sigma_w$). The wind direction was determined at a 1 second averaging interval and the mean wind direction for each plume was determined. In addition, the geometry of the "peak" (position of maximum concentration on plume traverse) relative to the source was used to determine the wind direction, as we may assume that the position of the plume centreline downwind from the source will indicate the mean wind direction. The surface roughness was estimated as the crop height*0.15. The site was suitable for the inverse dispersion method as the surrounding landscape was topographically homogenous (winter cover crop 10-20cm height). The spatial dimensions of the source area and the line-averaged plume measurements were also specified. As the duration of the plume traverses was shorter than the 10 minute meteorological averaging periods, some of the plumes shared the same set of inputs (with the exception of wind direction).

1.3. Emission measurements by mass balance: In addition to emission estimates by the MOPED method the emissions from the broiler housing building were determined by an in-house mass-balance (MB) method (Phillips et al., 2001), to provide a reference. The in-house method combined indoor-outdoor NH_3 concentration gradient measurements using an INNOVA gas analyser coupled with a sampler-doser (INNOVA 1312 and 1303). The ventilation was determined by three methods, first of which was the recorded ventilation rate by the mechanical ventilation system, the second involved a heat balance model (CIGR, 2002) and the third was to determine the ventilation rate using an SF6 tracing method (Phillips et al., 2001).

2. RESULTS AND DISCUSSION

2.1. Plume measurements: In total, 61 plume measurements were made downwind from the chicken farm, on five separate days, between 10:00 and 13:00 GMT on each day. A plume measurement constitutes one full traverse of the plume, recording the rise in concentration above background directly downwind of the source and the lateral spread of the downwind concentrations due to dispersion. Three of the measurement days (12/01, 31/01, 01/02) took place during southerly winds, therefore downwind measurements were made along the road to the North of the housing unit. From 26/01-27/01, the wind direction was ESE, thus the mobile measurement system had to move to the western side of the map to find the plume. During these days, plume measurements were made along the western road which runs North-South (Figure 1). The fetch distance between the source and the measurement locations was of the order of 200-260m when measuring along the northern road and 520-580m when measuring along the western road.

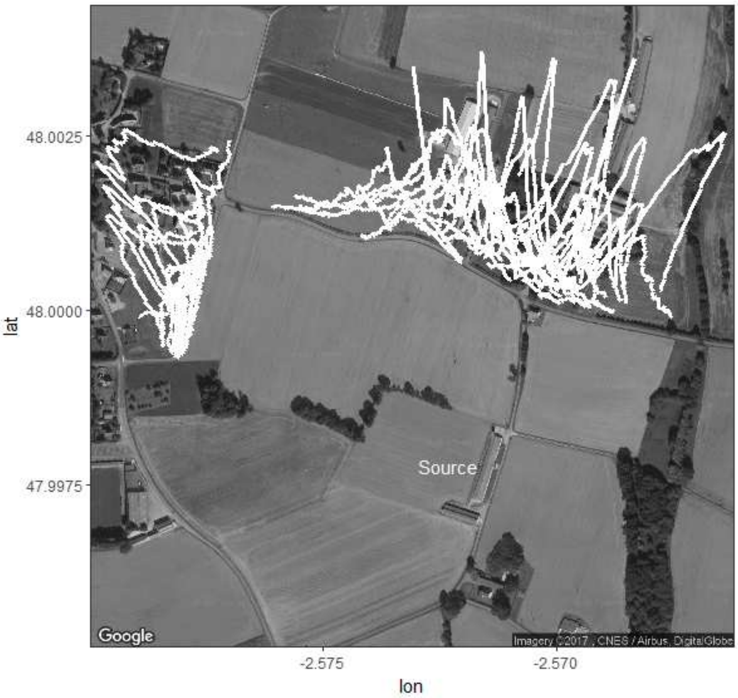

Figure 1. Plume measurements downwind of the poultry housing building, showing the rise in concentration above background (ΔC) measured on each run (60 plume measurements over five separate days). The amplitude of the plume reflects the magnitude of the concentration levels, while the orientation is a function of the wind direction.

2.2. Emission estimates: Each plume measurement could provide an emission rate for the building, however due to stochastic variability in atmospheric dispersion; the accuracy of any one interval is limited, even under ideal circumstances (Flesch et al., 2004). Therefore we take the average of a number of individual estimates over a certain period, and compare against the reference mass-balance method. For the comparison between the two methods, the data was first filtered to include periods where both the MOPED and MB systems were in operation. Afterwards, a further filter was applied to remove periods where there was rainfall, as there was a strong indication that the plume concentration measurements were depleted in NH_3 due to wet deposition/washout, which we cannot account for using the dispersion model. The rainfall filter was very restrictive, removing all of the plume measurements made on 31/01 and a significant fraction of measurements on 27/01 and 01/02/ (50% of total plumes).

The average MB and MOPED emission estimates are given in Figure 2 and Table 1. There are three scenarios (heat balance, ventilation records, and SF_6 tracer ventilation values) shown for the MB emissions and four shown for the MOPED emissions (deposition sensitivity scenarios). The bLS emission estimates are highly sensitive to deposition, where the fastest dry deposition parameterisation (Rc min 2) led to average values that are between 31 and 138% higher than the simulations without including deposition (nodep scenario). The fraction of NH_3 deposited downwind of the source will depend upon the fetch distance between the source and receptor, which accounts for the greater sensitivity to deposition on the 26^{th} and 27^{th} January as plume measurements were made along the more distant western road (520-580m downwind). Additionally, the fraction of emitted NH_3 that is deposited will be strongly influenced by the resistance of the canopy layer to deposition (R_c), as the presence of water films on the canopy surface is an efficient sink for NH_3, while very dry conditions or fertilisation of the canopy surface can inhibit deposition (Spindler et al., 2001; Bell et al., 2017). The three deposition scenarios (Rc min 20, Rc min 10, and Rc min 2) provide an uncertainty range around this problem, as each describes the canopy resistance to deposition as a function of relative humidity (RH) (Equation 2, Spindler et al., 2001), however the parameter $R_{c,min}$ was set at 2, 10 and 20 to modify the strength of the humidity response across a realistic range.

$$R_c = R_{c,min}\, e^{\{(100-RH/12\,)\}} \tag{3}$$

The MB emission estimates vary depending upon the selection of the ventilation rate used to calculate the emissions. The mass balance heat emission rates are systematically lower (22-27%) than the mass balance ventilation emission rates. This may be due to the heat balance model (CIGR, 2002), which may be underestimating the heat output of the broilers as the animals now grow more quickly due to advances in breeding (P. Robin, personal communication, 2017). However, it is also conceivable that the mechanical ventilation system can overestimate the ventilation rate of the building. The SF_6 tracer method was not continuous throughout the measurement period, with missing data on 27/01/2017 and 01/02/2017, however on 26/01/2017 the emissions calculated using the SF6 tracer ventilation rate are similar (within 20%) to the other methods.

Since assuming no dry deposition for NH_3 is unrealistic, we consider the three deposition scenarios to be the more accurate emission estimates. The three deposition scenarios provided a plausible range of emissions considering the uncertainty associated with the R_c estimation. Due to the estimation of R_c and potential errors associated with bLS model assumptions (Flesch et al., 2004) we can state that the uncertainty associated with the MOPED method in this experiment is at least 20-30%. Had there been suitable downwind measurement locations nearer the source the sensitivity to R_c estimates would be lower. The MB and MOPED emission estimates on each measurement day agree within 20-30%, therefore the MOPED method appears to produce robust emission estimates relative to the MB reference. However, the standard deviation of the MB emission estimates are significantly higher than the MB emission estimates, indicating a low precision for the MOPED method in this particular example.

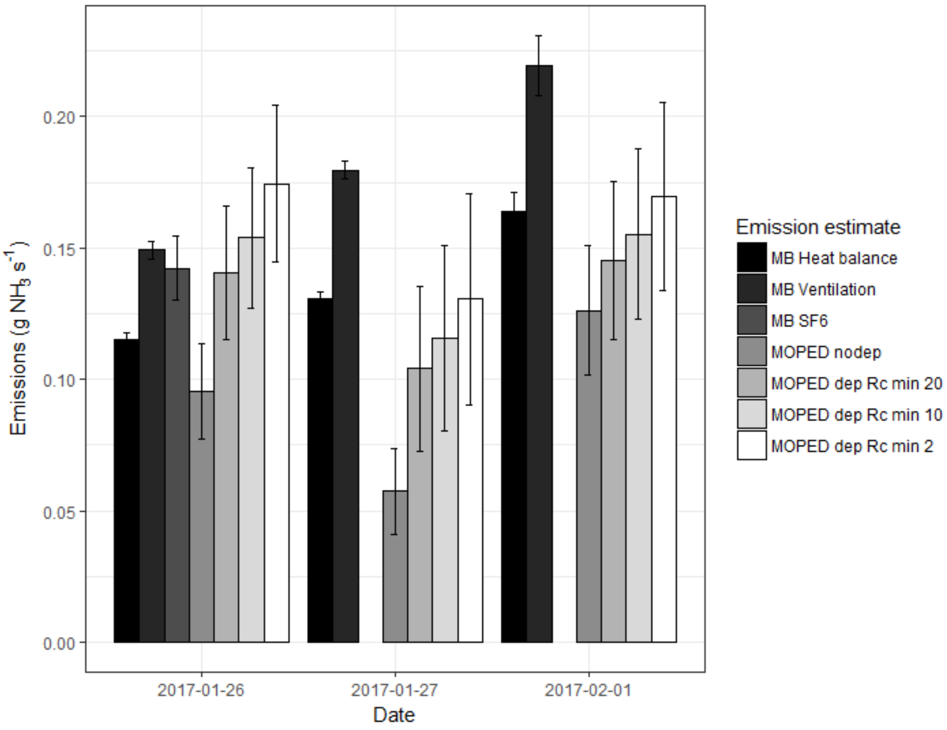

Figure 2. Average emissions estimated by MOPED and mass balance methods. The mass balance estimates show three scenarios depending on the emission rate applied (heat balance model, ventilation records or SF_6 tracer). The MOPED emission estimates (bLS) indicate four scenarios for deposition: nodep – assuming no deposition; dep Rc min 2-20: with deposition and a minimum canopy resistance of 2, 10, and 20 s m^{-1} to explore the sensitivity of emission estimates to dry deposition. Error bars indicate the standard deviation of the emission estimates.

Table 1. Average NH_3 emissions (Q, g NH_3 s^{-1}) from the housing unit determined by the MOPED and MB methods. Different scenarios investigate the sensitivity to MB ventilation rate and MOPED dry deposition selections. The standard deviation (SD) of the emission estimates are also given.

Date		**26/01/2017**		**27/01/2017**		**01/02/2017**	
Emission estimate		**Q (g s^{-1})**	**SD (g s^{-1})**	**Q (g s^{-1})**	**SD (g s^{-1})**	**Q (g s^{-1})**	**SD (g s^{-1})**
MOPED	**nodep**	0.1	0.04	0.06	0.03	0.13	0.05
	dep Rc min 20	0.14	0.05	0.1	0.06	0.15	0.06
	dep Rc min 10	0.15	0.05	0.12	0.07	0.16	0.07
	dep Rc min 2	0.17	0.06	0.13	0.08	0.17	0.07
MB	**SF_6**	0.14	0.03	-	-	-	-
	Ventilation	0.15	0.01	0.18	0.01	0.22	0.02
	Heat balance	0.12	0.01	0.13	0.01	0.16	0.02

3. CONCLUSION: The MOPED method offers very significant practical advantages for determining emissions from farm-scale sources. Most importantly of which, no intrusive measurements are required inside of the building, while the mobile platform provides considerable freedom to choose downwind measurement locations based upon the prevailing wind direction. However, an individual plume measurement provides a "snapshot" of the emissions, while we recommend that repeat traverses of the plume are made to provide an average emission rate. Although plume-to-plume variability was high, the averaged emission rate for the MOPED method agreed with the MB emission estimate for the same period to within 20-30%, indicating that this new method is promising. The most important uncertainty with the MOPED method in this example was NH_3 dry deposition, where a large fraction (between 16-56%) was dry deposited before reaching the downwind concentration receptor. In addition, there was evidence that rainfall led to significant washout and wet deposition which depleted downwind concentrations, therefore the emission estimates presented here contain only periods where there was no rainfall.

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ASSESSING AMMONIA REDUCING TECHNIQUES IN BEEF CATTLE BY THE USE OF AN EMISSION BARN

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ABSTRACT: Due to changing policy, interests have grown in finding mitigation measures for nitrogen emissions for animal husbandry. To enable research on potential mitigation measures for beef cattle, the Animal and the Technology and Food Sciences unit of the Institute for Agricultural and Fisheries Research (ILVO) built a deep litter emission barn. The barn consists of four identical mechanically ventilated deep litter compartments, that can house seven cows each (double muscled Belgian blue). Every compartment is equipped with a windbreak curtain on the inlet and two outlet fans to ensure adequate ventilation. The NH_3 concentration in the outgoing air is sampled at every fan and analysed using a cavity ring-down spectroscope (Picarro G2103). The airflow rate is determined by the use of free running impellers on the fans. In a first trial, a reference treatment was implemented in all compartments to assess the variation in NH_3 emission inherent in the emission barn. Variation between compartments was shown, which was caused by an animal effect. To manage this animal effect in future research, the experimental set-up must consist of two measuring periods and only one treatment per trial, with a cross-over of the treatment over the groups. The variation inherent to differences in compartments disregarding the observed animal effect was limited.

Keywords: NH_3, emission barn, beef cattle, mitigating strategy.

INTRODUCTION: An important bottle neck for the conservation of protected nature in Flanders is the deposition of acidifying and eutrophying substances through the air. Those substances are mainly originating from agriculture, traffic and industry. In Flanders, a Programmatic Approach on Nitrogen or PAN is being developed to decrease the nitrogen deposition on these protected nature areas. Each livestock farm received a label according to its contribution to nitrogen deposition on a nearby nature reserve and indicating the relative reduction of NH_3 emissions that is needed. In case a reduction of NH_3 emissions is needed, farmers can choose from a list of approved NH_3 reducing measures whereby each reducing measure has a specific percentage of reduction. Until now, only one measure has been approved for beef cattle. In literature, bedding material as a NH_3 mitigating strategy was investigated but mainly for dairy cattle on small scale in mechanically or naturally ventilated barns (Jeppsson, 1999; Powell et al., 2008; Gilhespy et al., 2009). To enable research on additional potential reducing measures for beef cattle, the Animal and the Technology and Food Sciences unit of the Institute for Agricultural and Fisheries Research (ILVO) joined forces and have built a deep litter mechanically ventilated emission barn. In a first trial, the reference treatment was implemented in all compartments. The objective of this study was to assess the variation in NH_3 emission between the compartments in the emission barn.

1 MATERIAL AND METHODS: The emission barn consists of four identical mechanically ventilated deep litter compartments, that can house seven cows each (double muscled Belgian blue). Every compartment is equipped with a feeding fence, manure alley, deep litter area with a slope of three percent, one windbreak curtain on the inlet and two fans to ensure adequate ventilation. The NH_3 concentration in the outgoing air is sampled at every fan and analysed using a cavity ring-down spectroscope (Picarro G2103) with a measurement time per fan of five minutes. The airflow rate is determined by the use of free running impellers on the fans and is logged every ten seconds. The air temperature and relative humidity in each compartment are measured and logged continuously. Bedding thickness and temperature is measured three times a week before new bedding material is added.

In the reference trial, 28 cows were assigned to four groups according to live weight, age and parity to equalize the groups in total kg of live weight and parity days. Groups were randomly assigned to the compartments and all compartments were subjected to the same reference treatment. All groups were fed the same roughage based ration consisting of corn silage, grass silage and straw, supplemented with a fixed amount of concentrates and had ad libitum access to water. Bedding material, i.e. straw, was added on Monday, Tuesday and Friday (6 kg/day/animal). The manure alley was cleaned once a week. In the first measuring period, NH_3 concentrations were measured for three weeks. Subsequently, the animals were alternated between compartments to investigate the effect of animals on emissions. The group in compartment 1 alternated with the group in compartment 4, and the group in compartment 2 alternated with the group in compartment 3. Bedding material was not removed during the alternation. In the second measuring period, NH_3 concentrations were measured for one week.

2 RESULTS AND DISCUSSION: The results of the first and second measuring period are presented in Figure 1. The evolution of the concentration of all compartments was similar. Compartment 1, 2 and 3 were equivalent in level of NH_3 emissions, while the NH_3 emission levels of compartment 4 were consistently higher. The average concentrations of compartment 1, 2, 3 and 4 during the first measuring period were 1446 ± 702, 1523 ± 643, 1478 ± 627 and 1903 ± 847 ppb respectively. To investigate the effect of the animals on the emissions, the group in compartment 4 was alternated with the group with the lowest emissions, compartment 1 and the group in compartment 2 alternated with the group in compartment 3 at day 19. At day 20, NH_3 emissions of compartment 1 increased, while NH_3 emissions decreased in compartment 4. After day 21, compartment 2, 3 and 4 were equivalent in level of NH_3 emissions, while compartment 1 had higher NH_3 emission levels. The average NH_3 concentrations of compartment 1, 2, 3 and 4 during the second measuring period, excluding transition period (day 20 and 21), were 2664 ± 630, 2179 ± 428, 2166 ± 519 and 2187 ± 440 ppb NH_3 respectively.

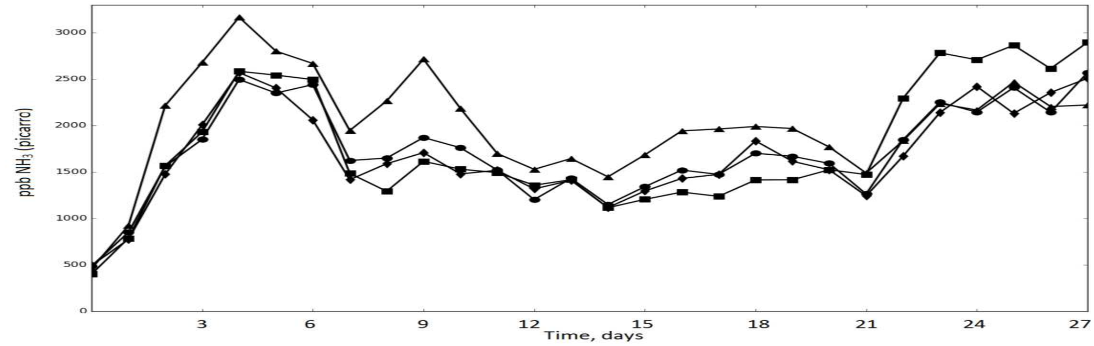

Figure 1: Daily average ammonia concentrations of the four compartments in first and second measuring period: ■—■ compartment 1, ●—● compartment 2, ◆—◆ compartment 3, ▲—▲ compartment 4.

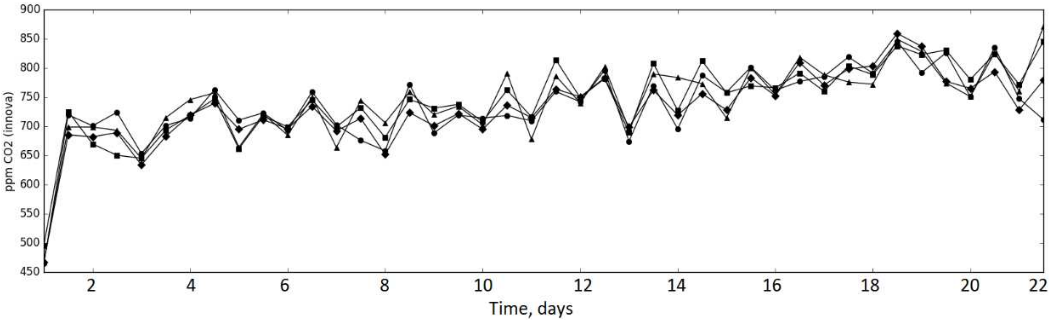

Figure 2: Daily average CO_2 concentrations of the four compartments in first measuring period: ■—■ compartment 1, ●—● compartment 2, ◆—◆ compartment 3, ▲—▲ compartment 4.

Due to a logger error, the airflow rates of the free running impellers were only logged for approximately half of the first measuring period. The airflow rates show a similar average airflow rate in all compartments i.e. 4405 ± 47, 4631 ± 39, 4591 ± 66, 4552 ± 82 m^3/h. The small differences between these flow rates could not explain the larger NH_3 concentration differences between the compartments. The CO_2 concentration in each compartment, which was continuously measured, shows a similar evolution and no major concentration differences were found between the compartments during the measuring period (Figure 2). No major differences were found in temperature and relative humidity between the compartments, which indicate no differences in climate conditions in all compartments during the measuring periods. Therefore, the differences in NH_3 concentration was caused by the animals, which was supported by the decrease of NH_3 emission levels of compartment 4 and increase of NH_3 emission levels of compartment 1 after the alternation. To manage this animal effect in future research, the experimental set-up must consist of two measuring periods with a cross-over of the treatment over the groups.

3 CONCLUSION: The reference trial revealed that the variation between compartments was caused by an animal effect. Future experiments must, therefore, consist of two measuring periods, with a cross-over of the treatment over the groups. Consequently, each experiment can only consist of the control treatment in two compartments and one treatment in the other two compartments.

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MONITORING SULFUR PROCESSES IN SWINE MANURE WITH ISOTOPE LABELLING AND PTR-MS

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ABSTRACT: The Biological processes that cause emission of reduced sulfur compounds from livestock production are problematic due to odour nuisance. A better understanding of the microbial processes influencing reduced sulfur compounds emissions may lead to strategic abatement technologies. In this study, we developed a method to monitor sulfur processes in swine manure using ^{33}S isotope labelling and Proton-Transfer-Reaction Mass Spectrometry (PTR-MS). We validated our method in biological triplicates in batch reactors and successfully traced the reduction of $^{33}SO_4^{-2}$ to $H_2{}^{33}S$ and its further methylation to $CH_3{}^{33}SH$ with PTR-MS. Addition of methionine and cysteine affected the ratio of emitted $H_2{}^{33}S$: $H_2{}^{32}S$ and it was possible to calculate the origin of H_2S based on the isotope pattern. H_2S methylation was responsible for 30% of the CH_3SH formed and the remaining CH_3SH came from methionine degradation. Sulfate reduction inhibitors reduced the H_2S emissions with 96% indicating that most of the H_2S comes from sulfate reduction. This study provides a high time resolution method for determining the contributing sources to- and production rate of sulfurs from swine manure and is applicable in other substrates.

Keywords: Sulfur, emission processes, method, PTR-MS, isotope labelling

INTRODUCTION: Livestock production is responsible for gas emissions of ammonia, methane, volatile organic compounds and reduced sulfur compounds (Amon, Kryvoruchko et al. 2006). These compounds evaporate from animal manure in the barn and when land spreading and have environmental impact in the form of eutrophication, particle formation and odor nuisance. The major contributor to odor nuisance is reduced sulfur compounds (Feilberg, Liu et al. 2010), which constitute mainly hydrogen sulfide, methanethiol and to a lesser extent dimethyl sulfide. The microbial processes involved in the production of reduced sulfur compounds have been elucidated in earlier studies on bio solids and marine sediments (Jørgensen 1977, Higgins, Chen et al. 2006), which found that sulfur originates from sulfate reduction, cysteine degradation and methionine degradation. However, a proper method for monitoring these processes and determining the dominant pathways has been absent. In this study we provide a novel method for monitoring the sulfur processes in swine manure with a high time resolution Proton-Transfer-Reaction Mass Spectrometer and isotope labelled sulfate. By adding quantitative amounts of $^{33}SO_4^{-2}$ to the swine manure, the reduction of sulfate to hydrogen sulfide can be distinguished from the degradation of cysteine and methionine to hydrogen sulfide and methanethiol respectively. In this study the isotope pattern of hydrogen sulfide and methanethiol was monitored with the novel method combined with inhibitors to assess sulfate reduction, cysteine degradation and methionine degradation.

1. MATERIALS AND METHODS. Swine manure was collected from a storage tank from finishing growing pigs at Aarhus University, Foulum. It was sewed through a 6 mm metal grid to remove straw and large particles, then split into 10L aliquots and stored at 5 °C until experiment initiation. Before experiment initiation the manure was analyzed with respect to sulfate-, ammonium- and volatile fatty acids concentration by ion chromatography, turbidity kit and gas chromatography respectively. Dry matter content and pH was also measured.

The experimental setup consisted of three reactors with 200 mL sewed swine manure, which had a nitrogen headspace exchange rate of 200mL/min through the reactor lid. The flowrate was controlled with mass flow controllers (Broncks) and the manure was stirred quietly with magnet stirrers to avoid pH gradients building up. The outlet flow was diluted with nitrogen before being detected with a High Sensitivity Proton-Transfer-Reaction Mass Spectrometer (PTR-MS) (Ionicon Analtik, Innsburg). The PTR-MS switched between reactors through a five-way valve and measured 4 min at each reactor and a background signal yielding a total cycle time of 16 min. During the experiments the manure was chemically altered by injection through the headspace with dissolved Na^{33}SO$_4^{-2}$ (Sigma Aldrich, Copenhagen, Denmark), L-Cysteine (Sigma Aldrich, Copenhagen, Denmark) or L-methionine (Sigma Aldrich, Copenhagen, Denmark).

2. RESULTS AND DISCUSSION. The swine manure had a dry matter content of 4.6 % w. Sulfate and ammonium was present in 3.9 mM and 4 g/L respectively. The swine manure contained mostly acetic acid (6 g acetic acid/L) and to a lesser extent propionic - and butyric acid (2-and 1.7g/L).

The method relied on isotope labelled sulfate ($^{33}SO_4^{-2}$) reduction to take place. In Figure 1, isotope labelled sulfate was added in different concentrations after 18 h, which gave rise to increased isotope labelled hydrogen sulfide (m/z 36) emissions.

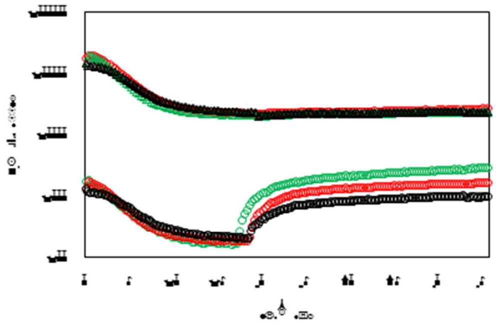

Figure 7. The concentration of $H_2{}^{32}S$ (Δ) and $H_2{}^{33}S$ (○) in the effluent gas of three replicates where different amounts of $^{33}SO_4^{-2}$ (10% green, 5% red and 2.5% black of total sulfate) was added after 18 h

The ratio between $H_2{}^{33}S$ and H_2S increased from approximately 0.87% to 4.25%, 7.27% and 12.25% in approximate accordance with the amount of SO_4^{-2} added. The total hydrogen sulfide emissions rate was equivalent to 1.0 ± 0.1 mM/day from triplicates. In

Figure 2, cysteine and methionine was added after 41 h influencing the ratio between $H_2{}^{33}S$ and H_2S differently.

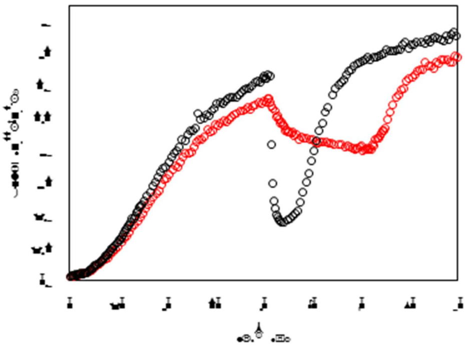

Figure 8. The ratio of $H_2{}^{33}S$ and $H_2{}^{32}S$ in the effluent gas. Methionine (○) and cysteine (○) was added to separate reactors after 41 h.

When cysteine was added the ratio declined quickly, whereas methionine affected the ratio less but over a longer period of time. This was most likely due to methionine being degraded to methanethiol prior to demethylation to hydrogen sulfide.

Figure 3 presents the methanethiol emission rate after BES addition. From the isotope pattern of methanethiol the contribution to methanethiol from hydrogen sulfide methylation was also determined.

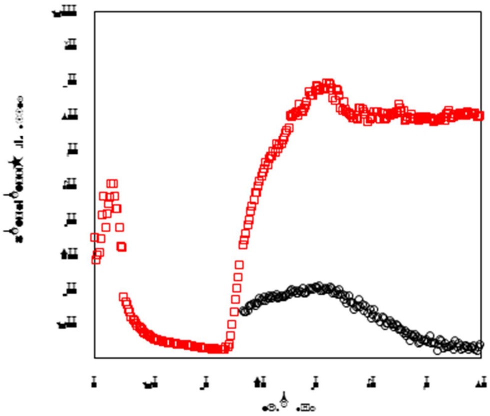

Figure 9. The total methanethiol effluent concentration (□) and the methanethiol originating from hydrogen sulfide methylation (○). BES was added after 25 h to increase methanethiol concentration and decrease the uncertainty.

The contribution from hydrogen sulfide methylation was approximately 30% of total methanethiol production 15 h after BES addition. The hydrogen sulfide methylation declined after 42 h due to sulfate depletion.

In Figure 4, the effect of molybdate on hydrogen sulfide emissions and the isotope ratio is presented.

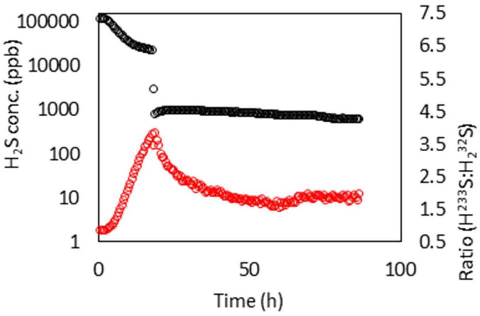

Figure 10. The effect of molybdate on the concentration of H_2S in the effluent gas (○) and the corresponding ratio between $H_2{}^{33}S$ and $H_2{}^{32}S$ (○). Molybdate was added after 18 h.

Figure 4. shows the hydrogen sulfide concentration was reduced 96.5% upon molybdate addition after 18 h. A corresponding decline in the isotope ratio between $H_2{}^{33}S$ and $H_2{}^{32}S$ indicated that the remaining H_2S emissions after molybdate was relatively less sulfate reduction than other sources, such as cysteine degradation.

CONCLUSION: This study demonstrated how the isotope labelling and PTR-MS could be combined to trace the sulfur processes in swine manure. Furthermore, we elucidated the relative activity of sulfide methylation vs methionine degradation, the effect of cysteine and methionine addition and finally the proportion of hydrogen sulfide originating from sulfate reduction.

Acknowledgements. This study was part of the ManUREA project funded by GUDP under the Danish AgriFish Agency, ministry of environment and food Denmark (Grant 34009-15-0934).

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REDUCED DIRECT MEASURING METHODS IN THE RIDGE VENT OF A DAIRY BARN

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INTRODUCTION

Accurate measurement of livestock housing emissions is necessary to assess their environmental impact of the performance of applied mitigation techniques. These emission measurements can be conducted by combining local air velocity and pollutant concentration measurements. However, unsteady wind conditions challenge measuring the air velocities at naturally ventilated buildings. Spatially dense measurements, however, are rarely feasible due to economic and practical constraints. Simplification of measurement methods with limited loss of accuracy is therefore necessary.
The objective of this research was to reduce the amount of air velocity sampling places in order to measure the airflow rate through the ridge vent without exceeding an accuracy loss of ± 20% with respect to detailed measurements.

Keywords: Measuring method, reduced method, accuracy, ridge vent, ultrasonic anemometer

MATERIALS AND METHODS

Velocity measurements were carried out in a naturally ventilated commercial dairy barn situated on a site of the Institute for Agricultural and Fisheries Research in Merelbeke, Belgium (+50° 98’ 48.44” N. +3° 77’86.31” E). The building is sited next to an open grassland (SW and SE of the building), clamp silos for ensilage roughage (North of the building), an stanchion barn (at 15 m distance of the dairy barn to the NE of the building) with an old young stock barn and a beef cattle house next to it.
Velocity measurements in the ridge vent of the dairy barn were conducted during November and December 2016. Every 10s, air velocities were measured using 8 2D ultrasonic anemometers in the 166m ridge vent. Their positions are presented in Figure 1a and 1b. Due to the easy access, the anemometers were installed all above the available bridge (approximately 2/3th of the ridge vent). The resulting airflow rates were compared with values obtained by taking into account 4, 2, and 1 readings, named as RR4, RR2 and RR1, respectively (Figure 1b). The sensor heads measured the velocity over a distance of 0.25 m. Approximately 3/5th of the actual width of the ridge was measured.
Two different curtain configurations (CC) were applied in the side vents: CC1: wind break nets applied at both side vents, CC2: wind stop curtain applied at the SW-side vent (main wind direction) and wind break net on the opposite side vent.
The main wind direction was appointed as 180°, this wind was perpendicular to the SW-side vent opening. The wind directions with airflows parallel to the vent openings were

90° and 270°. Data was collected for all wind directions for the first curtain configuration. Data for the second curtain configuration was mainly measured around 180°, where the SW-vent acted as the main inlet opening.

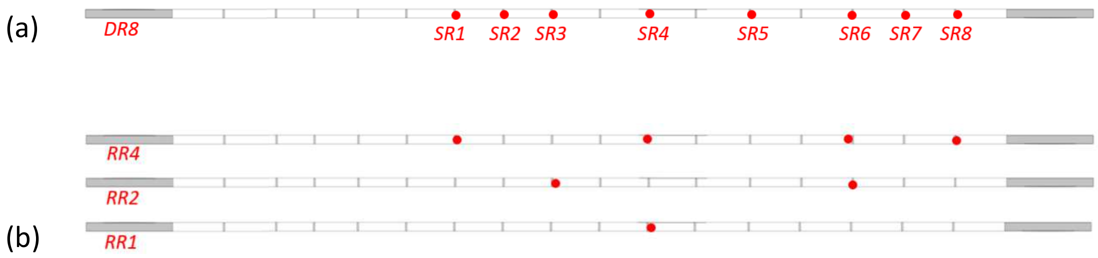

Figure 1: (a) Sampling locations for the detailed measurements ridge vent (DR8), (b) Reduced sampling locations ridge vent with 4, 2 and 1 locations, respectively specified as RR4, RR2 and RR1

2. RESULTS AND DISCUSSION

The results of the experiments in the ridge vent for curtain configurations CC1 and CC2 were plotted in Figure 2: all measurements are plotted in 3 subgraphs for every curtain configuration. The upper graphs show data plots with the mean velocities for RR4, RR2, RR1 and the outside wind velocity v against the wind direction. The middle graphs show the absolute differences between the reduced velocity measurements and the reference horizontal velocity profile in the vent. The lower graphs in the third row show the respective relative differences, with the criterion of 20% in a red line.

In figures a1 and a2, it is seen that the velocities measured in the ridge vent have quite steady values: the velocities range between (0-2) m/s for CC1 and (0-1) m/s for CC2. High wind velocities measured at the meteomast gave a small increase in wind velocity in the ridge vent, although no large effect was measured. The wind direction also did not have a large influence on the velocities measured in the ridge vent resulting in a steady airflow in the ridge vent.

The absolute differences between the mean velocities of the detailed and the reduced sampling location measurements in Figures b1 and b2 show small over- and underestimations of the mean velocities in the ridge vent. These absolute differences range from (+0.1 to -0.4) m/s for CC1 and (+0.1 to -0.3) m/s for CC2. The relative differences shown in c1 and c2.

Results for CC1 showed that 98% of the measured velocities of the reduced sampling location methods remained within the limit of maximum 20% deviation. Results for using only 1 anemometer RR1 for the second curtain configuration (CC2) exceeded the limit of 20% deviation for some wind conditions: high wind velocities coming from the main wind direction (180°).

Results showed that for both curtain configurations, the number of anemometers could be reduced from 8 to 2, remaining within the predefined accuracy limit of ± 20%. The mean relative differences and their standard deviation for the methods for the curtain configurations was (1.2 ± 2.2)% and (-1.4 ± 7.4)%, respectively. Using only 1 anemometer, results were still satisfactory when using the wind break nets (-11.5 ± 3.4)%.

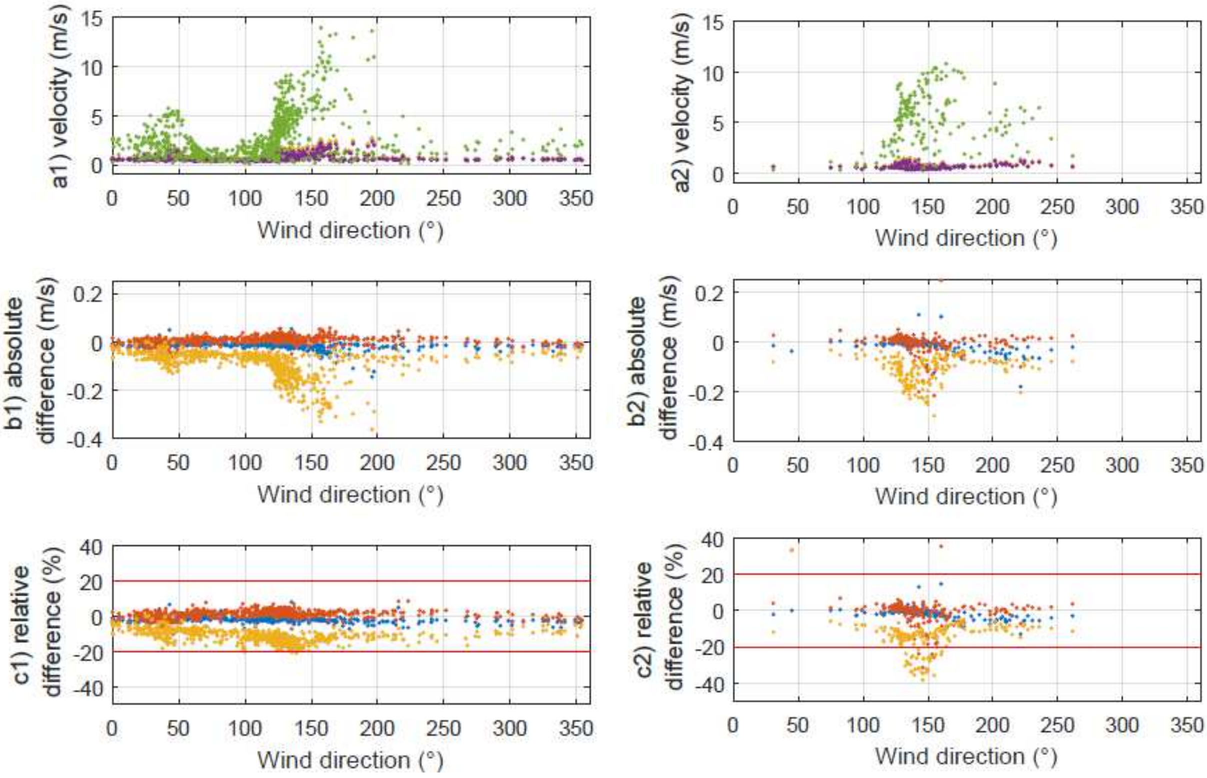

Figure 2: Results for experiments with (reduced) profile measurements in the ridge vent for CC1 (a1-b1-c1) and for CC2 (a2-b2-c2): a) velocity measurements; b) absolute and c) relative differences between the measurements with reduced and detailed method; ● RR4, ●RR2, ●RR1, ●MM,– ±20% criterion

CONCLUSIONS

Although using one sensor gave mostly good results, the relative difference exceeded the criterion of ±20% for some wind conditions. It was concluded that a simplified measuring method using 2 anemometers was possible to measure the velocity in the ridge vent over a length of approximately 80m. Reducing sampling locations to only 2 in the ridge vent was therefore found feasible for 1) constant accurate results and 2) a relative difference within the predefined criterion of 20%.

CONTINUOUS MEASUREMENT OF N_2O EMISSIONS FROM PLOT-SIZE AGRICULTURAL FIELDS.

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ABSTRACT: N_2O emissions vary considerably across even relatively homogeneous terrain in response to variation in the distribution of nitrogen as well as a number of environmental variables. Continuous measurements of nitrous oxide (N_2O) concentration and emission over agricultural fields are difficult due to limited sensitivity of most gas analyzers. N_2O emissions were measured after nitrogen fertilization treatments from multiple adjacent fields of maize in 2013 through 2016 using a micrometeorological approach. To reduce influence of in-field emission heterogeneity, we measured integrated N_2O concentrations along 6-7 optical paths over four adjacent treatment fields with emissions calculated from a simultaneous solution of all path-integrated concentrations within the backward Lagrangian stochastic emissions model (WindTrax®). N_2O emissions generally ranged between 0 and 10 ugm^{-2}s^{-1} N_2O from fields with between 100 kg and 200 kg of nitrogen applied per hectare during the fall and/or spring. The emissions measurements over the 4 years showed diurnal variations as well as trends over days and weeks with peak events that correlate with wind conditions.

INTRODUCTION: Agriculture is recognized as contributing 24% of the greenhouse gas emissions worldwide. Nitrous oxide (N_2O), largely emitted from agriculture, contributes approximately 6% of the world emissions. Although clearly a significant component in the greenhouse gas inventory, fewer emission measurements have been made of this gas than carbon dioxide and methane. The Intergovernmental Panel on Climate Change (IPCC) has consequently estimated these emissions on relatively few actual direct measurements (Mosier et al, 1998). Measurements of N_2O emissions from crop agricultural production that have been reported (Stehfest and Bouwman, 2006) are mostly made using small gas flux chamber measurements made infrequently. Since N_2O emission measurements are notoriously inhomogeneous in space and highly variable in time, continuous measurements are needed (Denmead, 2008). Micrometeorological methods typically provide continuous emissions measurements. This study presents a micrometeorological method that can measure continuously area at scales of 100 m.

1. MATERIALS AND METHODS: Continuous ½ hour emission measurements from 4 fertilizer treatments were made over four years at West Lafayette, IN at two 90m x 240m fields of continuous maize production on tile-drained poorly-drained silty-clay-loam drummer prairie soils. Cultivation changed for one treatment from tilled to no-till in 2015. anhydrous ammonia (AA) fertilizer treatments at 10 cm depth included 200 kg ha^{-1} applied in the prior fall, 200 kg ha^{-1} applied just prior to planting (2015, 2016) or as side dress (2014 at v4 stage), and 100 kg ha^{-1} applied in the prior fall and 100 kg ha^{-1} applied just prior to planting or as side dress (at v4). Measurements began just prior to the spring pre-plant or side dress application.

Measurement methods

The general measurement configuration included an open-path Fourier transform infrared spectrometer (FTIR; MiDAC Monostatic FTIR with 8" telescope) scanning along 6-7 optical paths (OP) of approximately 150 m each across four AA treatments. Each FTIR measurement was an average of 64 spectra collected over approximately one minute. With the scanner dwelling 3 minutes per OP terminating in a retro-reflector array, a complete scan required about 30 minutes. Determining the N_2O concentration from FTIR spectra is highly dependent on method of analysis. Bias in the derived N_2O concentration from the FTIR spectra (Fig. 1) was corrected during each ½ hour averaging period using a high sensitivity (MDL 0.3 ppb) Difference Frequency Generation (DFG) laser-based N_2O analyzer (IRIS 4600, Thermo Fisher Scientific) analyzing air sampled along a line collocated with an FTIR OP. Upwind (background) N_2O concentrations were also measured by the DFG laser from air sampled at points along the edge of the fields.

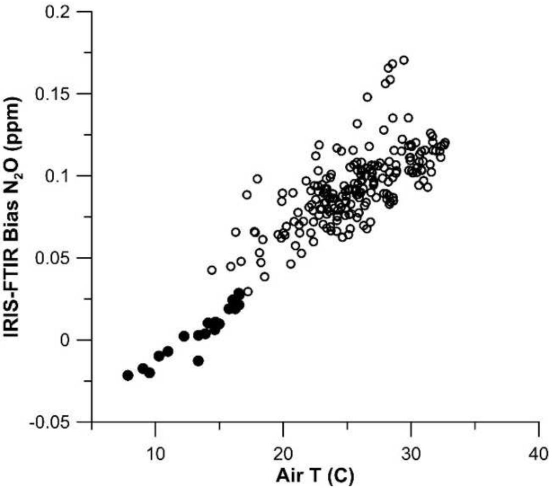

Figure 1- Bias associated with temperature broadening of the absorption features used in determining the N_2O concentration from the FTIR spectra. Measurements from fall of 2014 (filled circles) and spring of 2015 (open circles) are illustrated.

Nitrous oxide emissions for all four treatments were calculated each ½ hour using all concentration measurements and on-site turbulence measurements using a backward Lagrangian Stochastic (bLS) emissions model (WindTrax®) with quality assurance checks on stability, turbulence, and background concentration as reported in Lin et al (2015) and Grant et al (2015). Measurements were limited to the first month after planting due to the height of the corn blocking the optical paths.

Turbulence statistics were determined for ½ hour intervals based on three-component winds measured at 10 Hz using a sonic anemometer (RM Young 81000). Measurements of soil temperature and moisture, atmospheric pressure, air temperature and humidity averaged every five minutes and turbulence were used to determine factors influencing emissions events.

The emissions minimum detection limit (MDL) were estimated by: 1) evaluating the N_2O emissions of fields prior to N application, and 2) evaluating the error in bLS model emissions estimates between pre-defined emission estimates and modeled N_2O

concentrations along each OP given turbulence measurements (the bLS model in 'forward' mode) and the emissions estimated using those modeled concentration values.

2. RESULTS AND DISCUSSION: Emissions from AA treatments were measured over four years. The N_2O emission of fields in which there was no n application in the prior fall (2015) indicated a background level. The measured emissions were -0.33 μ g $m^{-2}s^{-1}$ (standard deviation-SD of 1.14 μ g m^{-2} s^{-1}). Emissions from fields in which 100 kg ha^{-1} were applied in the prior fall averaged 0.77 (SD 1.19). This suggests that there is a -0.33 μ g m^{-2} s^{-1} bias error with a MDL (2SD) of 1.36 μ g $m^{- -1}$. Emissions errors calculated using the bLS model in both forward mode to calculate concentration given specified emission rates and in the backward mode estimating the emissions from the calculated concentrations indicated a 0.11 μ g m^{-2} s^{-1} bias (SD of 0.92 μ g m^{-2} s^{-1}). This suggested a MDL of 1.8 μ g m^{-2} s^{-1}. Negative emissions less than about 2 μ g m^{-2} s^{-1} are believed to be due to interferences of high emission upwind treatments and non-conformance of the array of concentration measurements resulting in a poor solution to the set of simultaneous equations used to estimate the bLS emissions. Emissions less than -4 μ g m^{-2} s^{-1} have been excluded from Figure 2.

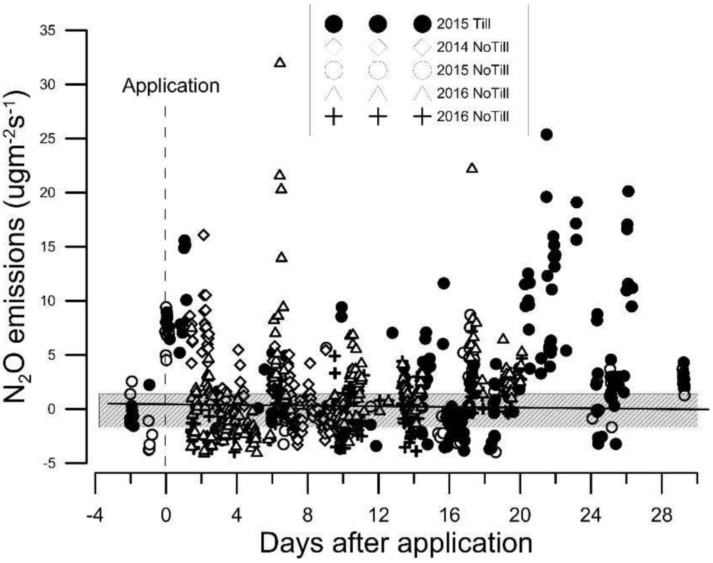

Figure 11- N_2O emissions after spring fertilizer application for field with 100 kg N ha^{-1} applied in both fall and spring. Method measurement error (hatched area) estimated at 1.5 μ g N_2O m^{-2} s^{-1} with a small negative bias.

N_2O emissions generally ranged between 0 and 10 μ g m^{-2} s^{-1} N_2O with peaks up to 30 μ g m^{-2} s^{-1} N_2O from fields with between 100 kg and 200 kg of nitrogen applied per hectare during the fall and spring (Fig. 2). N_2O emissions showed a peak shortly after application, after rain events (events not shown), then generally increased about two weeks after application reaching levels of 20 μ g m^{-2} s^{-1} (Fig. 2). The initial peak in N_2O emissions was thought to be due to nitrification of N residual from the fall 100 kg N ha^{-1}

application. The rising emissions after three weeks was thought to be due to denitrification as soil moisture at 10 cm was weakly but positively correlated with the emissions (Fig. 3). Emissions were not correlated with soil temperature at 10 cm. Unfortunately, there was no conclusive means to check this hypothesis.

The emissions measurements showed diurnal variations as well as trends over days and weeks. These trends were both a result of apparent influences of temperature and wind speeds (turbulence). High emissions were correlated with high winds (friction velocity u_*; Fig. 3) although if overall emissions were low, wind speed had a negligible effect.

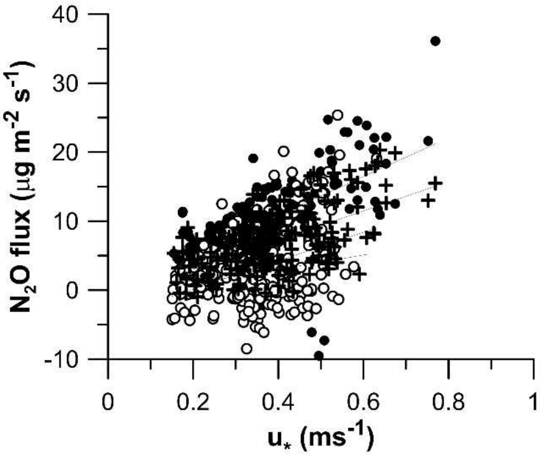

Figure 3- N_2O emissions after spring fertilizer application for field with 100 kg N ha^{-1} applied in both fall and spring in 2014 (cross and filled circle) and 2016 (open circle).

3. CONCLUSION: Results show that there is significant temporal variability in N_2O emissions from fertilized agricultural fields. Such emission variability may not be observed if discrete measurements by soil gas chamber are made every week. This indicates the distinct advantage of such spatially-integrating continuous micrometeorological approaches over more typically conducted soil gas chamber measurements.

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EVALUATION OF BACKWARD LAGRANGIAN STOCHASTIC DISPERSION MODELLING FOR NH_3: INCLUDING A DRY DEPOSITION ALGORITHM

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ABSTRACT: Backward Lagrangian stochastic (bLS) modelling is widely used to assess emission rates from agricultural activities. A large number of investigations using bLS modelling estimates ammonia (NH_3) emissions from confined areas. NH_3 is known to efficiently deposit on surfaces, especially if they are moist. Most bLS models do not include deposition mechanisms. Three release experiments using an artificial source were conducted. A gas mixture of 5% NH_3 and 95% methane (CH_4) was released. Line-integrated measurements of NH_3 and CH_4 downwind of the source were carried out and recovery rates were calculated using bLS dispersion modelling. The recovery rates averaged to 106% for CH_4 and 84% for NH_3, respectively. The comparison between NH_3 and the inert trace gas CH_4 was used to assess the effect of (dry) deposition. The bLS model was extended by a dry deposition algorithm. Modelled concentration reductions due to the inclusion of dry deposition were comparable to the observed differences in the recovery rates of the inert CH_4 and the deposition affected NH_3.

Keywords: GHG, CH_4, NH_3, Method, Measuring method.

INTRODUCTION: Estimating trace gas emission from field measurements using backward Lagrangian stochastic (bLS) dispersion modelling has become a well-established method, especially for investigations of agricultural sources. A large number of such studies include methane (CH_4) and ammonia (NH_3) emission estimations with measurements close to the source or at some distance downwind of the source (Harper et al., 2011). Whereas for CH_4 dry deposition processes can be neglected, NH_3 has a strong affinity to any surface and is efficiently deposited downwind of the source. A standard bLS approach does not include sorption processes. Therefore, estimations based on concentration measurements downwind of a source tend to underestimate the strength of an NH_3 source.

1. MATERIAL AND METHODS: Three release experiments with an artificial source were conducted on november 17th 2016 at a grassland site in Switzerland. the source consisted of 36 individual orifices mimicking a circular area source with a radius of 10 m. a gas mixture consisting of 5% NH_3 and 95% CH_4 was released at a release rate of 20 to 25 nL/min. The duration of each release was approx. 1.5 hours. Line-integrated NH_3 and CH_4 concentrations were measured upwind (C_{in}) and downwind (C_{dwn}) of the source using open-path measuring systems. at 15 m downwind of the source center NH_3 was measured with a minidoas (MD) system (Sintermann et al., 2016) at 1.3 m height and in parallel ch4 was measured at the same height with a GasFinder (GF) system (Boreal Laser, Inc., Edmonton, Alberta, Canada). At 30 m downwind, a parallel measurement of NH_3 and CH_4 was done at 1.3 m with a MD and a GF. additionally, a further md was measuring at 0.6 m height. For all instruments, the path length between the sensor and the reflector was approx. 40 m one way. corresponding recovery rates (*r*) were calculated with a bLS model (Flesch et al., 2004) as:

$$R = \frac{(C_{dwn} - C_{in})}{BQ} \tag{1}$$

where *B* is the modelled ratio of *C/Q*, respectively. The wind statistics that was used as input for the bLS model was measured with a sonic anemometer (Gill Instruments Limited, Lymington, UK) at 1.8 m height. The bLS model was extended by a dry deposition algorithm. The magnitude of the deposition flux (F_{dep}) at each touchdown was approximated via a deposition velocity (v_{dep}) as $F_{dep} = C_{traj} \times v_{dep}$. A resistances analogy was used to quantify v_{dep} at touchdown height (i.e. the roughness height z_0): $v_{dep} = 1/(R_a + R_b + R_c)$ (Sutton et al., 1995), where the aerodynamic resistance R_a, the pseudo-laminar resistance R_b and the canopy resistance R_c are given in s/m. R_a at z_0 equals 0 such that v_{dep} at z_0 can be calculated as:

$$v_{dep} = 1/(R_b + R_c). \tag{2}$$

R_b can be calculated as a function of the friction velocity and z_0 following Flechard et al. (2010). On site measurements of surface temperature and leaf wetness as well as further meteorological parameters provided better insight on the magnitude and trend of a possible NH3 deposition. In the beginning of the release series there was moderate rain that moistened the canopy. The leaf wetness sensors indicated that the canopy stayed moist over the entire release period. Therefore, it was assumed that the canopy resistance is dominated by the cuticular resistance and can be approximated by the temperature dependency given in Flechard et al. (2010). The final R_c values ranged from 50 to 200 s/m, resulting in v_{dep} values between 0.005 to 0.016 m/s (Eq. (2)).

2. RESULTS AND DISCUSSION:

2.1. Recovery Rates: The results from both, GF and MD correspond well to each other, with systematically lower NH_3 recovery rates over all measurements (Figure 1). The average recovery rate was 106% (standard deviation (SD) = 11%, number of results (N) = 48) for CH_4 and 84% (SD = 13%, N = 72). An increase in recovery rate with time occurs. This increase might be caused by changing meteorological conditions (e.g. wind direction etc.).

2.2. Dry Deposition Modelling: Including the dry deposition algorithm lowered the modelled concentration to values between 75% and 95% of the modelled concentration without deposition (Figure 2). The effect of including deposition in the model is similar to the observed ratio between the measured recovery rates of NH_3 and CH_4. The pronounced difference between the prior mentioned modelled ratios and observed ratios at the beginning of the experiment might be due to the moderate rain during release intervals 1 to 5.

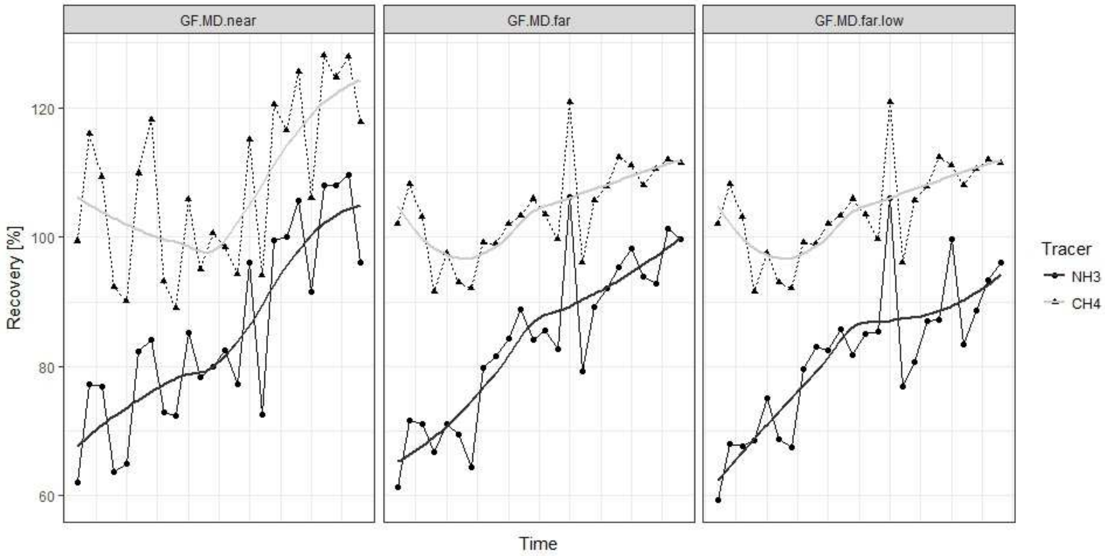

Figure 1. Recovery rates according to Eq. (1) (in %) of CH_4 and NH_3 measurements over individual intervals ordered by the time of the day (Time). The three panels show the results from the GasFinder (GF) and miniDOAS (MD). Left: 15 m downwind. Middle: 30 m downwind at 1.3 m. Right: 30 m downwind at 1.3 m (GF) and 0.6 m (MD), respectively.

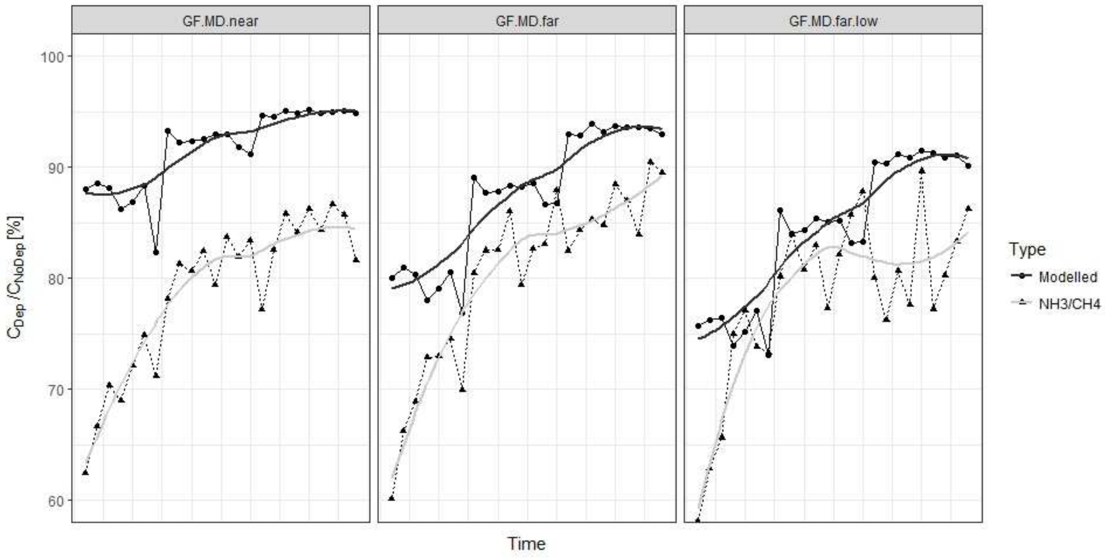

Figure 2. Black solid line: Modelled ratio of concentrations with and without deposition inclusion. Grey dotted: Ratio of the corresponding recovery rates from NH_3 and CH_4 measurements. The three panels show the results from the GasFinder (GF) and miniDOAS (MD). Left: 15 m downwind. Middle: 30 m downwind at 1.3 m. Right: 30 m downwind at 1.3 m (GF) and 0.6 m (MD), respectively.

3. CONCLUSION: Average recovery rates of 106% (CH_4) and 84% (NH_3) have been found. The difference in recovery rates for the two trace gases was attributed to dry deposition. Including a dry deposition algorithm in the bLS model results in a lowering of modelled concentrations that compare well with the observed differences in NH_3 and CH_4 recovery rates.

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ADVANCES IN THE DEVELOPMENT OF PASSIVE FLUX SAMPLING TO ESTIMATE N_2O EMISSIONS FROM LIVESTOCK BUILDINGS

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ABSTRACT: Passive flux sampling (PFS) is a technique with low level of operational requirements and a low capital investment for setting up emissions measurement. This work presents advances related to the development and evaluation of PFS, particularly to estimate N_2O emissions from livestock buildings having mechanical ventilation. The objective of this study is to present advances related to the development and evaluation of PFS, particularly to estimate N_2O emissions from livestock buildings having mechanical ventilation. Results showed that the performance of the PFS depends strongly on the N_2O adsorption capacity of the adsorbent, the air N_2O concentration and the sampling time. The highest accuracies obtained by the current device prototype (88 to 99% versus direct detection), under the evaluated conditions, were obtained when the sampling time was 1.5 hours. In longer sampling times, a reduction of the adsorption rate was observed impacting negatively the accurancy. For the further developpment of the sampler, this sampling time could be increased by the selection of an adsorbent with high adsorption capacity to collect the target gas. It is concluted that, PFS can be adapted to set up a measurement of N_2O emissions from livestock buildings.

Keywords: GHG, N_2O, Passive flux sampling, Livestock buildings, Measuring method

INTRODUCTION: To stimulate cleans economic growth, and builds resilience to the impacts of climate change, Canada established on December 2016, the Plan-Canadian Framework on Clean Growth and Climate Change. In the specific case of agricultural sector, the agricultural greenhouse gases program (AGGP-Canada) promotes the development of technologies, practices and processes that can be adopted by farmers to mitigate GHG emissions. In 2015 agriculture accounted 8% of total GHG emissions for Canada. The 28% and 71% of national CH_4 and N_2O emissions were from this sector (Canada, 2016). However, the estimation of GHG emissions from agricultural sources faces challenges because there are substantial spatial and temporal variations among sources and most of the methodologies available are complex and expensive making difficult to measure a significant number of farms (Larios et al., 2016). In this context, passive flux sampling (PFS) was suggested as an appropriate technique to be developed for GHG. Because is known that PFS requires a low level of operational requirements and a low capital investment for setting up emissions measurement (Godbout et al., 2006). PFS includes the development and evaluation of passive flux samplers. These samplers are based on two principles: (1) Aerodynamic behaviour which requires that air velocity inside the sampler is proportional to the gas flow velocity surrounding the sampler (Scholtens et al., 2003). This behaviour is mainly regulated by an orifice placed in the sampler. (2) Adsorption capacity of the collector medium to capture the gas sample, which is generally dependent on the air flow rate passing through the sampler, the GHG concentration in the inlet air, and the mass of the adsorbent used. The first passive flux sampler prototypes were developed in 2006. This samplers were packed with several adsorbents to capture N_2O and CH_4 being the zeolite 5A the best adsorbent compared to activated carbon Carboxen 1018 and Carboxen 1021. However, the previous samplers presented some limitations such as: air flow restriction due to the adsorbent particle size; low sampling capacity and high cost. Thus, the objective of this work is to present advances related to the development and evaluation of PFS, particularly to estimate N_2O emissions from livestock buildings having mechanical ventilation. This work includes the development and validation of new passive flux sampler prototypes and the performance comparison of the PFS versus direct detection by gas chromatography and versus active sampling at experimental scale.

1. MATERIAL AND METHODS:

1.1. Passive flux sampler and adsorbent material: The new prototype was made up of three consecutive sections which contained cartridges with adsorbents. The central cartridge contained zeolite 5A to adsorb N_2O. The other two cartridges were placed one at each end and contained other adsorbents such as silica gel to dehumidify the inlet air. The cartridges were fabricated from stainless steel tubes. An orifice plate with an orifice size of 0.5, 0.7 or 1 mm of diameter was installed at the end of the PFS by means of a connector to regulate the air flow rate.

1.2. Adsorption tests at laboratory scale to determine breakthrough point: The adsorbent was conditioned by heating at 320 ± 1 °C for 4 h. Thereafter, it was placed in a desiccator for 30 min. Later, the samplers were packed before each corresponding adsorption test. At the end of adsorption tests, the adsorbent was placed back in vials for N_2O desorption. Two N_2O concentrations (0.6 and 2 ppmv) were evaluated in the adsorption tests. The gas was directly injected to the sampler at a flow rate of 40 and 130 ml/min corresponding to a low and a high internal flow rate that sampler prototype will have during field conditions. The outlet gas from sampler was collected each 15 or 30 min in ethyl vinyl acetate (EVA) bags of 2 l (Metrix Co., USA). The gas concentration in EVA bags was determined by using gas chromatography analysis (Clarus 680 GC coupled to Clarus SQ 8T MS, Perkin Elmer, USA).

1.3. Evaluation at experimental scale: The experiments were carried out in rooms of experimental farms: Prairie Swine Centre Inc. (Saskatoon, SK., Canada); Le Centre de recherche en sciences animales de Deschambault (CRSAD, Deschambault, QC., Canada) and the BABE laboratory (IRDA, Deschambault, QC., Canada). During sampling, two passive flux samplers packed with zeolite 5A were placed facing the emission source direction in the ventilation shafts of one or two rooms. The adsorbent in the samplers was replaced with respect to sampling time (from 1.5 to 3.75 h). At the end of each sampling period, the adsorbent used was placed in a glass vial hermetically closed and conserved at 4 ± 1 °C. After each sampling period, the samples were transported to the laboratory. The gas adsorbed on zeolite 5A was then desorbed and quantified by thermal desorption to estimate the mass of N_2O collected during each sampling point. N_2O adsorbed on silica gel was also measured. However, under evaluated conditions, the mass of N_2O adsorbed on silica gel was estimated as negligible in comparison with the N_2O adsorbed on zeolite 5A. The mass flow estimated by PFS was calculated according with (Mosquera Losada, 2003). In parallel, N_2O concentration was directly measured by gas chromatography by pumping the air to a mobile laboratory through Teflon™ tubing. A data logger then recorded the values measured every 180 min. The N_2O concentration was around 0.38 ppmv during all the sampling campaign. Concentration measurements were continuously taken during the entire experiment and were synchronized with the air flow rate. These were used to estimate the mass flow of N_2O from the emissions source by direct detection (Godbout et al., 2012).

1.4. Statistical analyses: A Student's t test was applied to evaluate the difference between the mass of N_2O collected by using different adsorbent beds. Also, a multiple linear regression_analysis was applied to analyze the linear relation among the evaluated parameters and the mass of N_2O collected. R statistical software version 3.1.3 for Windows was used to perform this analysis. Also, Microsoft Excel software was used to compare PFS vs direct detection.

2. RESULTS AND DISCUSSION

2. 1. Validation of PFS at laboratory scale (adsorption behavior of zeolite 5A to collect N2O): The mass of N_2O collected in the passive flux samplers at laboratory scale as a function of the adsorption parameters is presented in Table 1. Results showed that for bed length smaller than 10.9 cm, diffusion and flow rate patterns should interfere with gas-adsorbent interactions decreasing the mass of gas that can be collected when these interferences are eliminated. Also it can be seen that, when the N_2O concentration in the inlet gas changed from 2 to 0.6 ppmv, the breakthrough time decreased significantly from 180 to 115 min. It was because the driving force for the mass transfer is affected at low N_2O concentration decreasing the diffusivity of gas in the adsorbent bed. As consequence, a lower number of molecules were in contact with active sites of the adsorbent causing that a smaller amount of adsorbate mass was retained onto the adsorbent surface area. Thus, among the main parameters to consider in the use of zeolite 5A as collector medium in PFS, the mass of adsorbent presented a critical threshold to eliminate diffusion and interaction interferences to collect N_2O, whereas the effect of the air flow rate was negligible. Zeolite 5A presented a significant relationship with respect to the inlet concentration of N_2O and the mass of the adsorbent. Detailed results are presented in (Larios et al., 2017).

2.2. Evaluation of PFS at experimental scale: Taking into account previous results, the performance of PFS was evaluated at semi-real conditions. The N_2O concentration was close to typical concentration presented in the environment (~0.38). Figure 1 resumes the comparison between PFS and direct detection to estimate the mass flow of N_2O

issued from two room of the BABE laboratory. During these experiments, the air flow rates were from 4 to 4.5 m^3/min (at ~20 °C), and the moisture ranged from 22 to 30%. The experiment was replayed during 4 days, and similar results were found for each sampling time. Results showed an appropriate precision of PFS when zeolite 5A was used as collector medium. It was found that, at around 1.5 h of sampling, the mass flow estimated by using PFS was near to the confidence interval of values from direct detection. In this sampling time (1.5 h), the maximum difference between PFS and direct detection values was around 12%. In longer sampling times, a reduction of the adsorption rate was observed impacting negatively the accuracy. For the further development of the sampler, this sampling time could be increased by the selection of an adsorbent with high adsorption capacity to collect the target gas. Thus, PFS can be adapted to set up a measurement of N_2O emissions from livestock buildings with mechanical ventilation.

Table 1 Mass of N_2O collected on zeolite 5A used as collector medium in PFS

Air flow rate (Q) mL min^{-1}	**[N_2O] in the inlet gas (C_0) ppm$_v$**	***Adsorbent mass used (m_{ad}) g**	**Break-through time ($t_{b5\%}$) min**	**Mass of N_2O collected (m_c) µg**
130	2	4	15	7.02
40	2	4	98	14.11
130	2	13.6	180	84.24
40	2	13.6	570	82.08
130	0.6	13.6	120	16.85

*Length of adsorbent bed was of 1. 9 cm for 4 g and 10.9 for 13.6 g of the adsorbent

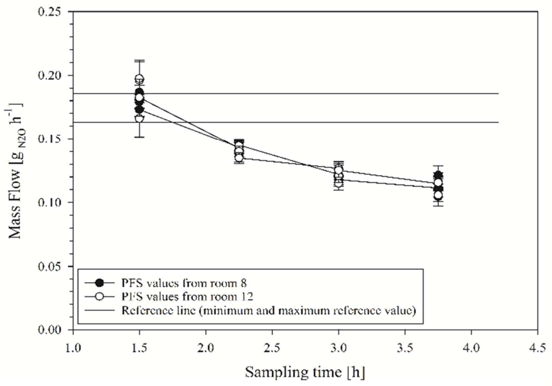

Figure1. Estimation of N_2O mass flow emissions by using passive flux sampling at experimental scale

3. CONCLUSION: The latest passive flux sampler satisfies the requirements to provide a simplified and economical technology to estimate N_2O emissions. Additional works to increase sampling time is required to improve field measurements. The improvement of adsorbent capacity will improve the performance of PFS at lower concentrations (0.3 to 0.6 ppm). The performance of the latest prototype bring new research opportunities as the development of new adsorbents or samplers to collect CO_2, N_2O and CH_4 simultaneously or to estimate the emission of other contaminants from agricultural sources.

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METHANE AND AMMONIA EMISSION MEASUREMENTS IN A NATURALLY VENTILATED DAIRY FREESTALL BARN USING SPECIFIC DATA CLASSIFICATION CRITERIA

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ABSTRACT: Since it is difficult to determine the air exchange rate of naturally ventilated barns, measurements of emissions at herd level which generate reliable and robust results, are a continuous challenge. Therefore, the primary objective of this study was to define a validity range of the measurement variables ‘wind velocity’ and ‘wind direction’ for long-term measurements at barn level and to apply these requirements to a feeding trial in a naturally cross-ventilated dairy freestall barn. Data classification criteria (DCC) for the key variables ‘wind velocity’ and ‘wind direction’ were defined to allow quantification of the ventilation rate. As a result, 18% of the one-hour values of the key variables out of the 169-day measurement period fulfilled the validity range defined by DCC. For methane (CH_4) no differences were observed ($P > 0.05$) but ammonia (NH_3) emissions decreased from 30.0 to 22.3 g NH_3 (livestock unit)$^{-1}$ day^{-1} (-34.5%) by feeding an additive in the ration ($P < 0.01$). The data confirm and support previous findings that greenhouse gas measurements in a naturally ventilated barn on herd level are possible.

Keywords: GHG, CH_4, NH_3, Cattle, Mitigation strategy

INTRODUCTION: Livestock production systems in agriculture are one of the major emitters of climate-related trace gases. As livestock densities will increase regionally, mitigation strategies are required to reduce ammonia (NH_3) emissions which affect surrounding ecosystems as well as emissions of the greenhouse gases (GHG) methane (CH_4) and nitrous oxide (N_2O). Extensive animal experimentation on individual animals in respiration chambers has already been carried out to evaluate the potential of dietary changes and opportunities to mitigate CH_4 emissions from ruminants. The efficiency of mitigation measures of emissions, such as feeding strategies, from naturally ventilated animal buildings is difficult to quantify (Samer et al., 2011). Measurements under practical conditions in the barn environment are necessary and of great interest. However, the determination of the ventilation rate in naturally ventilated barns is a big challenge and necessary to quantify emission rates (Samer et al., 2012).

The main focus of this study was to quantify the emission rates of CH_4 and NH_3 at herd level using defined minimum criteria for the CO_2 balance method to quantify the ventilation rate of the barn.

1. MATERIAL AND METHODS: The influence of different feeding strategies on emission rates of these trace gases were investigated in a cross-ventilated experimental dairy barn with 96 cows on slatted floors in North Rhine-Westphalia, Germany. Trace gas concentrations in the exhaust air of the building were measured by using a photo acoustic multi-gas analyser (1412 and multiplexer 1303; LumaSense Technologies SA, Ballerup, Denmark) (Schmithausen et al., 2016). To estimate emission rates, the ventilation rates of the barn were calculated by using the CO_2 balance method. Wind velocity and direction were measured and used as criteria for exclusion of data. Due to the natural ventilation of the barn, location- and building-specific characteristics as well as current weather conditions had to be considered to allow quantification of the air exchange rate. Data of gas concentrations were only used for calculating emission rates if wind velocity and wind direction guaranteed that no cross contamination from neighbouring sectors within the barn or surrounding buildings of the experimental station could have occurred (Schmithausen et al., submitted).

During experimental time (169 days), 1% and 3% (of ration dry matter) of an extract rich in condensed tannins (CT) (from *Acacia mearnsii*) were added during four different periods to daily fodder rations of 48 dairy cows, whereas the control group received the regular diet (Gerlach et al., submitted). Variables such as individual values per cow (e.g., dry matter intake) as well as real-time and simultaneous detection of the gas concentrations for two feeding groups (section 1 ≙ control group; section 2 ≙ experimental group) each with 48 lactating German Holstein cows within one experimental barn (case-control) were considered.

2. RESULTS AND DISCUSSION: For calculation of the ventilation rate only values with defined data classification criteria (DCC) were used to obtain representative data. Minimum criteria e.g. were a wind velocity of ≥ 0.7 m s^{-1} and an hourly mean wind direction from an angle of 210° to 300° (Figure 1). The hourly values were summarised to weekly means because of several days in which no measured data fulfilled the minimum criteria. Furthermore, management interventions such as milking time and homogenisation of slurry underneath the slatted floors were excluded from calculation.

Figure 1 shows the measurement frequencies in weeks with also irregularly distributed data over the timeline. Over the period of 24 weeks only 18% of the overall one-hour values fulfilled the named criteria of wind direction and wind velocity. Even long-term measurements showed periods when measured data were unsuitable for a naturally ventilated barn with a prevailing wind direction. The predefined DCC provided reliable results when applied to a feeding trial that was conducted with the aim to mitigate emissions of NH_3 and the GHG CH_4.

Figure 2 shows the air exchange rates of section 1 and section 2 depending on the measured wind velocity at the barn. The measured wind velocity was highly correlated with the calculated air exchange rates ($R^2 > 0.85$) as a function of the opening position of the curtains at the side wall of the barn. The logarithmised values show an air exchange rate even during windless conditions. However, these thermic effects were not taken into consideration in this investigation because of methodical reasons such as the minimum wind velocity of 0.7 m s^{-1} (Figure 2).

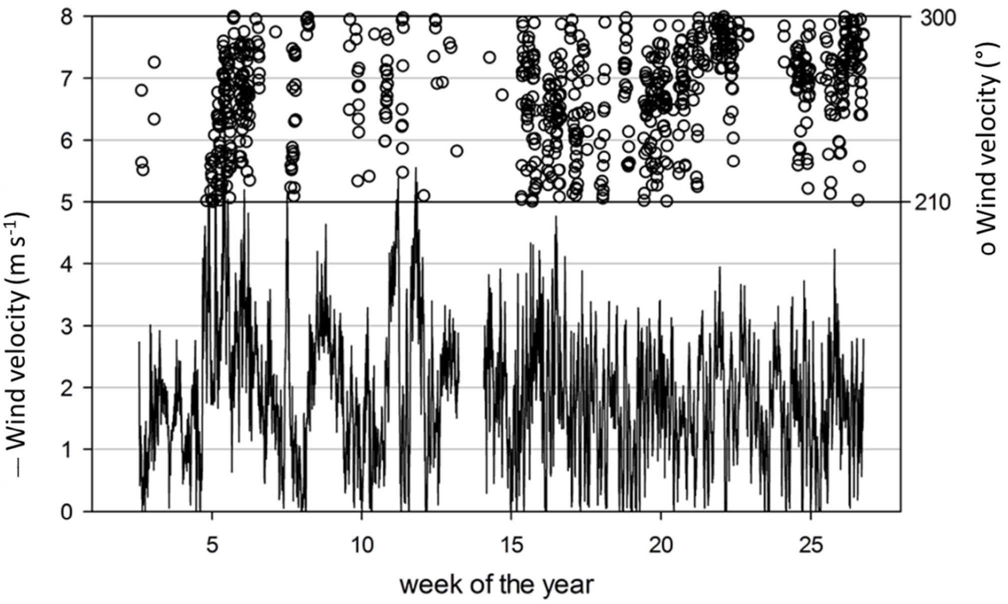

Figure 1. Time axis over 24 weeks with hourly mean values of wind velocity (solid line) in the lower part and wind direction (open circle) between 210° and 300° in the upper part of the figure.

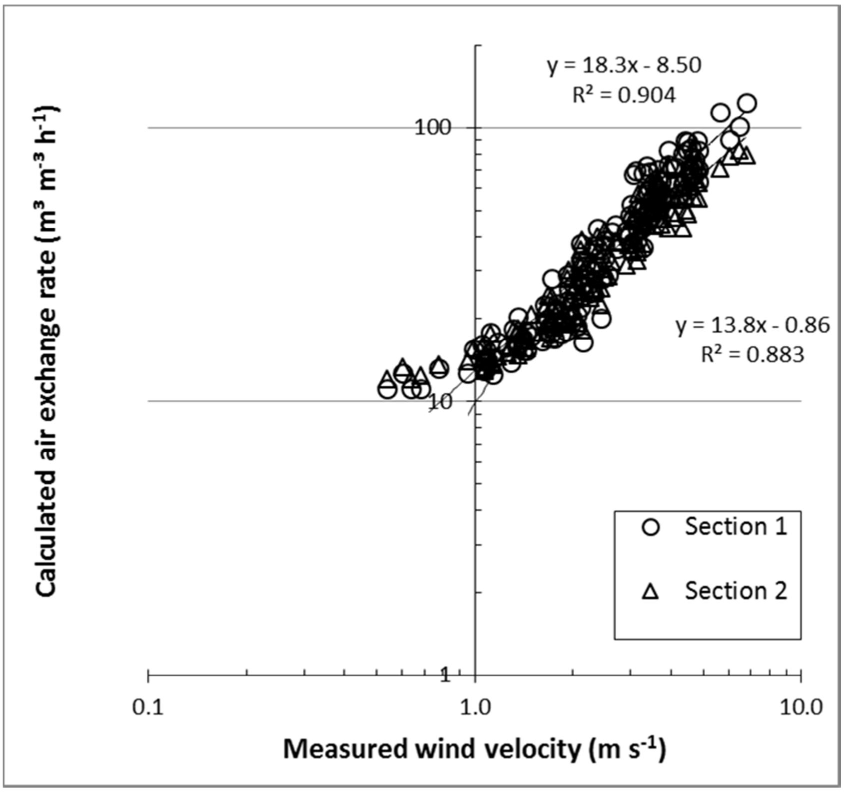

Figure 2. Relationship between the wind velocity (m s^{-1}) and the air exchange rate (m³ m^{-3} h^{-1}) in the control (section 1: SE = 0.232) and experimental group (section 2: SE = 0.176) in the winter (n = 149) calculated with the CO_2 balance method. The point of intersection was set through zero, and the wind velocity on the x-axis starts at 0.7 m s^{-1}.

Consequently, measurements of trace gas emissions from naturally ventilated dairy barns should be carried out as long as necessary to generate reliable values. Average emission rates of CH_4 per livestock unit showed no difference between experimental- and control group ($P > 0.05$). When feeding 1% CT in ration dry matter no differences in NH_3 emissions were detected ($P > 0.05$). However, during feeding 3% of CT NH_3 emissions of the experimental group decreased by 34.5% in comparison to the control group. Differences between both groups were quantifiable on herd level. Furthermore, additional long-term measurements are needed considering defined characteristics and sufficient frequency of data acquisition to get reliable data.

3. CONCLUSION: The present study showed long-term measurements of CH_4 and NH_3 emissions in a naturally ventilated dairy barn. It was possible to quantify emission rates on barn level and to examine feed-related mitigation strategies. It was recognised that determination of the ventilation rate by using defined criteria of wind velocity and wind direction generates more reliable data for naturally ventilated buildings. However, it requires further long-term measurements implemented as long as necessary.

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AMMONIA EMISSION MEASUREMENTS OF AN INTENSIVELY GRAZED PASTURE

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ABSTRACT: The quantification of ammonia (NH_3) emissions at ambient air conditions is still a challenge and emission factors for ammonia have therefore a large uncertainty. We present first results of a pasture experiment carried out in western Switzerland in 2016. During the measurement campaign, the pasture was grazed by 24 dairy cows in an intensive rotational management. NH_3 concentrations were measured with line-integrating open-path instruments. The NH_3 emission fluxes were calculated by applying a backward Lagrangian Stochastic dispersion model (bLS) to the difference of paired concentration measurements upwind and downwind of a grazed sub-plot. The instruments were able to retrieve small horizontal concentration differences (as small as 0.5 µg NH_3 m^{-3}) and the resulting fluxes were within a range of 0 to 3 µg N-NH_3 m^{-2} s^{-1}. We found, that the fluxes decreased to values below 0.5 µg N-NH_3 m^{-2} s^{-1} typically within 48 hours. First flux evaluation showed, that rain events during the grazing period had a major effect on the cumulative emissions.

Keywords: NH_3, emission, flux measurements, pasture, grazing, bLS, micrometeorological methods

INTRODUCTION: Agricultural livestock production is the main source of air pollution by ammonia. Grazing is one efficient mitigation option to reduce NH_3. However NH_3 emission experiments over grazed pastures are rare and the available studies reported a large range of emissions factors (2.7 to 25.7% of excreted urine nitrogen (N); Bussink, 1992, Laubach et al., 2013). Many of the studies used manual applied urine and measured the emissions with chamber or wind tunnel methods. These techniques might lead to questionable results due to the altering of the environment and the high heterogeneity of the emissions. Sintermann et al. (2016) showed that line integrated ammonia concentrations can be quantified using open-path MiniDOAS systems. They also suggested that paired systems together with a dispersion model can be used to estimate emissions of a grazed system. This might lead to a better characterization of the emissions compared to previous methods. Häni et al. (this issue) already estimated successfully the emissions of an artificial source. In the present experiment we examined the ability of the MiniDOAS systems to measure NH_3 concentrations and estimate the emissions of a rotational grazing system over a full grazing season.

1. MATERIAL AND METHODS:

1.1. Experimental site: The study site was located in the Pre-Alps of Switzerland at the research farm Agroscope Posieux in the canton of Fribourg. The experiment was conducted at a 5.5-ha-pasture and the cows were managed in a rotational grazing system. Usually twice a day the cows were brought to the nearby barn for milking. The whole pasture was divided into two separate systems (north and south) where each system was divided into 11 paddocks resulting in a rotation period of about 20 days, depending on the grass condition. The herd for each system consisted of 12 dairy cows. The rotation was managed synchronously on both systems and the main measurement campaign took place between May 2016 and October 2016. Monitoring of dung and urine patches on the paddock allowed for the quantification of excreted nitrogen (see also Ammann et al. (this issue).

1.2. Meteorological measurements: For the characterization of turbulent mixing the 3-dimensional wind velocity (u,v,w) and air temperature was measured at 10 Hz using an ultra-sonic anemometer-thermometer (HS-50, Gill Instruments Ltd., UK) mounted at 2 m above ground. Each system (north and south) was equipped with one of those anemometers. Further weather parameters (e.g. global radiation, precipitation) were measured with a standard automated weather station (Campell Scientific Ltd., UK) installed at the northern field.

1.3. Ammonia measurements: Line-integrated ammonia concentrations were measured using four MiniDOAS systems as specified in Sintermann et al. (2016). These open-path instruments make use of the differential optical absorption in the UV range. Two MiniDOAS systems (namely S5 and S2) were installed at the northern field and two instruments (S1 and S6) on the southern field, respectively. All instruments were installed at a height of about 1.3 m. Each MiniDOAS pair (e.g. S5 and S2) was separated by a horizontal distance of about 30 m which allowed for concentration measurements upwind and downwind of the paddock in between. The single light path between the sensor and the reflector for the individual devices had a length of 30 to 35 m. The instruments reported NH_3 concentration at a temporal resolution of one minute. The one minute data were averaged to 30-minute values for further processing.

1. 4. Emission calculation: We used an open source R-version of the bLS dispersion model (bLSmodelR, Häni, 2016; based on Flesch et al., 2004) to relate the measured 30-minute concentration difference to the unknown source strength E of the emitting paddocks (see Eq. 1). The dispersion coefficient D was determined based on the simulated movement of many thousand fluid particles released at the sensor line positions and tracked backwards in time till their eventual touchdown on the specified source area.

(1)
$$E = \frac{C_{Downwind} - C_{Upwind}}{D} \qquad (1)$$

The bLS program uses wind and turbulence information measured by the sonic anemometer. In order to calculate a concentration footprint for each 30-minute period, we used averaged data of the wind direction, the standard deviations of the wind components, the friction velocity and values representing the surface roughness.

2. RESULTS AND DISCUSSION:

2.1. Concentration results: Due to different problems (power supply, software issues…) the MiniDOAS systems were not running continuously during the grazing period. At the northern field, simultaneous concentration measurements of both systems could be achieved for five management rotations, at the southern field for four management rotations. Figure 1 shows an example of concentration measurements at the northern field during grazing (grey shaded area) and a few days afterwards of the sub-plot in between the MiniDOAS instruments. The concentration measurements yielded values between close to zero and more than 80 µg NH_3 m^{-3}. Depending on wind and atmospheric stability, the concentrations showed a strong temporal variation. The highest concentrations were usually observed during low wind conditions, which prevented an efficient mixing of the boundary layer. During periods with well-developed turbulence and favorable wind direction (no advection from the farm buildings) the horizontal concentration difference between paired MiniDOAS instruments was generally highest shortly after the cows left the monitored paddock with values up to 10 µg NH_3 m^{-3}. Typically the concentration difference decreased significantly within the first 48 hours to values less than 10-20 % in relation to the maximum measured concentration difference. Throughout the measurement campaign, the MiniDOAS instruments showed a high accuracy in the measurements. Concentration differences down to values of about 0.5 µg NH_3 m^{-3} could be detected with sufficient precision.

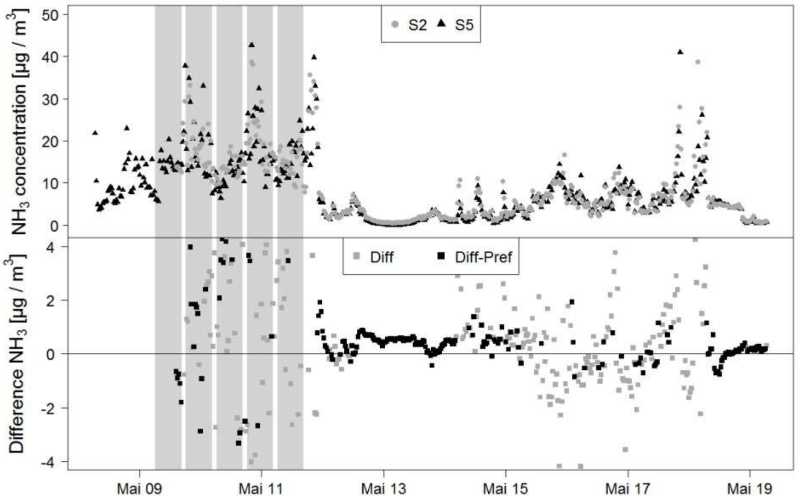

Figure 12. Measured ammonia concentration (top panel) of the MiniDOAS systems S2 and S5. The black dots of the bottom panel show the concentration differences during favorable wind conditions whereas the grey dots show all other differences. Favorable wind conditions exclude the wind sectors with potential advection from farm buildings as well as cases with no or only very little turbulence. The grey shaded areas indicate the time period when cows were grazing on the monitored paddock and the short interrupts indicate the milking periods.

2.2. Emission results: Ammonia advection from nearby farm buildings can lead to severe errors regarding the quantified emissions. Therefore we excluded time periods from further processing with potential advection from the farm buildings. Based on the derived concentration differences and the simulated dispersion coefficients (see Eq. 1) the emissions for the individual 30-minute periods were calculated. Cumulative emissions were estimated by applying a combination of polynomial and linear regressions to the measured data points in order to account for missing or excluded data. Depending on the weather and turbulence conditions the highest emissions were observed at the end of the grazing period. The maximum fluxes observed during the grazing periods were in the range of 1.0 to 3.5 µg $N\text{-}NH_3$ m^{-2} s^{-1}. Rain events during the grazing period significantly reduced the emissions and subsequently resulted in less cumulative emissions. Typical accumulated emissions after 5 days were in the order of 200 to 350 µg $N\text{-}NH_3$, depending on weather conditions and the time the cows spend on the paddock.

3. CONCLUSION: During a field campaign in western Switzerland in 2016 we tested the performance of the open–path MiniDOAS instruments to estimate NH_3 emissions of a grazing system. We found that the instruments worked very well and that they reported stable and plausible NH_3 concentration measurements throughout the field campaign. The emissions were calculated using the measured concentration differences upwind and downwind of the emitting paddock and the dispersion coefficient modeled by bLS. As expected, the highest emissions were observed at the end of the grazing period. These emissions dropped to very low values usually within the first 48 hours after. Rain events during the grazing period resulted in decreased cumulative emissions after 5 days.

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Measurement methods

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Part.5 Inventories and environmental assessment

Inventories and environmental assessment

SULPHUR HEXAFLUORIDE TRACER TECHNIQUE FOR MEASURING METHANE DIRECTLY FROM RUMEN OF DAIRY COWS VALIDATED WITH RESPIRATION CHAMBERS

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ABSTRACT: Traditionally respiration chambers are used to measure methane (CH_4) emissions from individual animals but due to limitations, alternative techniques must be developed and validated. Sulphur hexafluoride (SF_6) tracer technique was used to estimate CH_4 emissions directly from the rumen of cannulated animals fed different diets. Ten cannulated dairy cows were used for 3-5 days to compare SF_6 technique and respiration chambers simultaneously in an incomplete change-over design with three periods and four different diets resulting in 29 cow/period comparisons. The diet and period did not influence the ratio of CH_4 measured by both techniques. The average CH_4 emissions were 485 and 510 g/d for SF_6 and chamber techniques, respectively. Repeatability of daily CH_4 measurement was 0.52 and 0.90 for SF_6 and chamber techniques, respectively. Residual coefficient of variation was 11.2 and 3.24%, for daily CH_4 emissions and 5.79 and 3.25 for cow/period averages for SF_6 and chamber techniques, respectively. Lin's concordance correlation coefficient between two techniques was 0.62 and 0.76 for daily or cow/period average CH_4 emissions, respectively. It is concluded that SF_6 technique can be used as an alternative method to estimate CH_4 emissions using rumen gas sampling from cannulated cows.

Keywords: Dairy cow, CH_4, Measuring method, Sulphur hexafluoride, Respiration chambers

INTRODUCTION: Generally respiration chambers are considered as gold standard due to the accuracy for measuring CH_4 emissions from individual animals. However, they cannot be exploited under grazing conditions, are expensive and laborious, and can measure a limited number of animals over time. Therefore alternative methods must be developed and validated. Sulphur hexafluoride (SF_6) tracer technique was first used by Johnson et al. (1994) using breath samples in ruminants. The technique has been used mainly under grazing conditions but a variant of the technique is used in animals fitted with rumen cannulae allowing collection of gas samples directly and continuously from the rumen (Boadi et al., 2002; Bayat et al., 2015). The objective of this study was to compare CH_4 emissions measured directly from rumen using SF_6 tracer technique and those measured using respiration chambers simultaneously.

1. MATERIAL AND METHODS: ten dairy cows in mid-lactation fitted with rumen cannulae (#1c, i.d. 100 mm; bar diamond, inc., parma, id) were used. the study was conducted as incomplete change-over design with three periods resulting in 29 cow/period comparisons. the cows received four diets including low, medium and high forage diets based on grass (forage to concentrate ratio 30:70, 50:50 and 70:30 on dm basis, respectively) or red clover (50:50 on a dm basis) silages for 14 days before sampling (overall 6, 8, 8 and 7 cows per diet, respectively). milk yield, dry matter (dm) intake and ch_4 emissions were measured over 3-5 days from day 15 of each experimental period. the ch_4 measurements were conducted for both techniques simultaneously inside the chambers. ruminal ch_4 emissions were measured using the sf_6 tracer technique (boadi et al., 2002). gases in the rumen headspace were drawn continuously (1.7 ml/min) over every 24-h period into evacuated 5.5 l air-tight canisters (-0.9 and -0.4 bar in the beginning and end of sampling, respectively) through sampling tubes (4-mm i.d.) and 100 cm of capillary tubing (peek 1.6 mm × 0.13 mm i.d., vici valco instruments co, houston, tx, usa). a filter with 0.2 µM was used to prevent rumen liquor entering the capillary tube. a t-shape connection was used for the tip of the sampling tube to ensure a better flow of the rumen gas to the sampling line and the open heads were covered with nylon cloth (17-µM pore size) to prevent the entrance of and blockage by rumen particulates. tubes used to collect the ruminal gas were anchored securely to the neck of the rumen cannula allowing gas to be collected at approximately 5 cm above the rumen mat. the sf_6 releasing tubes (measured rate of release 1.11±0.31 mg/d) were suspended in the rumen via cannulae. sub-samples of ruminal gases were analysed in triplicate for ch_4 and sf_6 concentrations by gas chromatography (agilent 6890n, agilent technologies, santa clara, ca, usa). daily ruminal ch_4 emissions were calculated based on the measured sf_6 release rate in the rumen over the course of experiment and concentrations of CH_4 and SF_6 in analysed rumen gases.

Four open-circuit respiration chambers, located in the Minkiö dairy barn, Jokioinen, Finland, were used to measure CH_4 within each period for 3-5 consecutive days. Concentrations of CH_4 in the inlet and exhaust airflow were measured using dedicated analysers (Columbus Instruments., Columbus, OH, USA) with 3.5 min interval for each chamber and the reference air. Gas analysers were calibrated using the standard gases in the beginning of each measurement. Air flow was measured for every chamber using mass flow meter (HFM-200, Teledyne Hastings Instruments, Hampton, VA, USA) while corrected for temperature and pressure. An adjustable air conditioning system (Flow 500-2000 L/min; cooling capacity 2.9 kW; heating capacity 3.2 kW) allowed mixing the air inside the chambers and environmental control of temperature across a range of 12-22°C and a relative humidity of 50-70% monitored using electronic sensors. For cow welfare and safety, an emergency door sensitive to electricity failure or high CO_2 concentration was installed. Cows were restrained within the chambers by a neck yoke on a dedicated platform (180 × 126 cm) covered with a rubber mat and free access to fresh water and salt block. Experimental feeds were offered ad libitum four times daily at 6:00, 9:00, 16:00 and 19:00 as total mixed ration.

The residual coefficient of variation (CV) was calculated using Proc GLM of SAS (Version 9.4) using a model including animal, treatment, period and period by treatment interaction. Repeatability was calculated by dividing between-animal variation to the sum of between-animal and residual variation. The diet or period did not influence ($P\geq0.28$) the ratio of CH_4 measured by both techniques, therefore, they were excluded from further calculations. Lin's concordance coefficient (LCC) for continuous variables was calculated to evaluate the equivalence between the techniques (http://services.niwa.co.nz/services/statistical/concordance). Linear regression analysis was used to find the best equation fitting to the data.

2. RESULTS AND DISCUSSION: feed intake, milk yield and ch_4 emissions measured by SF_6 or respiration chamber techniques across all periods, are presented in table 1. The overall average of CH_4 emission (g d^{-1}) and intensity (g kg^{-1} milk) were lower (p<0.01 482 vs. 510 and 12.5 vs. 13.2, respectively) and CH_4 yield (g kg^{-1} dm intake) tended to be lower (p=0.07; 20.8 vs. 22.0) for SF_6 compared with chambers. lower CH_4 emissions from SF_6 compared with chambers (5.5%) can be expected as the SF_6 technique measures only the emissions from rumen. it was estimated that about 3% of total enteric CH_4 is excreted via rectum of cattle (grainger et al., 2007; muñoz et al., 2012). repeatability of daily CH_4 measurements was 0.52 and 0.90 for SF_6 tracer and chamber techniques, respectively.

The CV of daily CH_4 emissions for SF_6 and chamber techniques were 11.2 and 3.24%, and the respective values were 5.79 and 3.25% for cow/period average CH_4 emissions, respectively. These results confirm the previous findings of CH_4 emissions measured by SF_6 tracer technique having greater CV compared with respiration chambers (Grainger et al., 2007; Muñoz et al., 2012). The LCC between two techniques was 0.62 and 0.76 for daily or cow/period average CH_4 emissions, respectively. The LCC improved for CH_4 yield and intensity (0.87 and 0.85, respectively for cow/period average CH_4 emissions). These findings based on ruminal gas analysis are consistent with those from breath sampling of animals (Muñoz et al., 2012; Deighton et al., 2013).

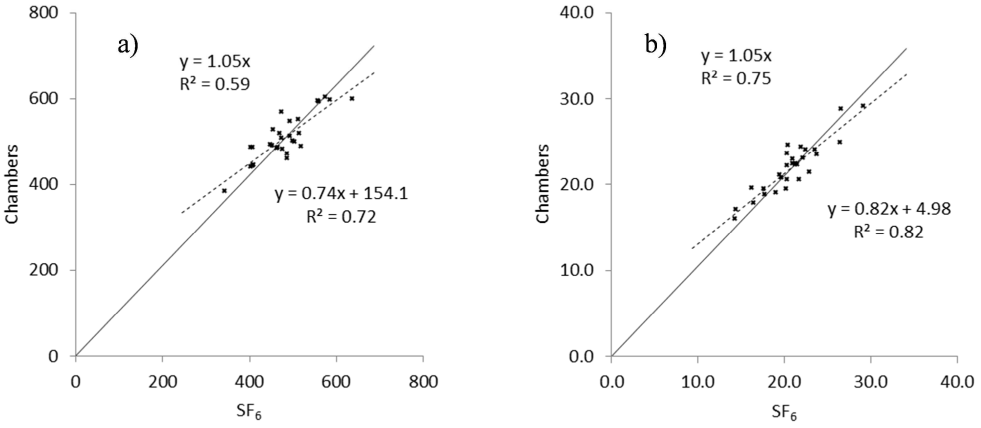

Figure 1. The relationship between cow/period averages of a) methane emissions (g d^{-1}) and b) methane yield (g kg^{-1}DM intake) measured simultaneously by SF_6 and respiration chamber techniques for individual cows. The solid line depicts the line with 1:1 fit and the dotted line depicts the best linear line fitting to the data.

Table 1. Summary statistics of feed intake, milk yield, and methane emissions during the sulphur hexafluoride (SF_6) technique and chamber measurements (n=29).

Item	Mean	SD	Minimum	Maximum
DM intake (kg d^{-1})	23.5	3.17	17.1	31.6
Milk yield (kg d^{-1})	39.1	5.28	31.6	50.3
Methane (g d^{-1})				
SF_6 technique	482	63.2	343	637
Chamber	510	54.8	384	605
Methane yield (g kg^{-1} DM intake)				
SF_6 technique	20.8	3.34	14.3	29.1
Chamber	22.0	3.01	16.0	29.1
Methane intensity (g kg^{-1} milk)				
SF_6 technique	12.5	2.13	8.84	17.2
Chamber	13.2	2.04	9.71	16.6

3. CONCLUSION: The SF_6 tracer technique can be used as an alternative method to estimate CH_4 emissions using rumen gas sampling from cannulated cows even though the technique has more variability compared with the respiration chambers.

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AGRICULTURAL EMISSION FACTORS OF PARTICULATE MATTER AND NON-METHANE VOLATILE ORGANIC COMPOUNDS FOR SWITZERLAND

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ABSTRACT: Within the framework of the Gothenburg Protocol of the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP), Switzerland is committed to report the current emissions. The EMEP/EEA air pollutant emission inventory Guidebook 2016 provides a basis for the calculation. For the section 3.B (Manure Management), we conducted a literature study on emissions of particulate matter (PM) and non-methane volatile organic compounds (NMVOC). Based on the results, we present an overview on recently published PM emission factors (EFs) for dairy cattle and a procedure for deriving EFs for total suspended particles (TSP), PM_{10} and $PM_{2.5}$ which includes gap filling where the data basis is incomplete. The suggested EFs for the PM fractions are up to eleven times smaller than the values listed in the Guidebook. Furthermore, we discuss questions arising with currently used EFs for PM and NMVOC.

Keywords: Emission Factors, Particulate Matter, NMVOC, Dairy Cattle, Inventory

INTRODUCTION: European countries are committed to report their current emissions within the framework of the Gothenburg Protocol of the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). In the scope of the review 2016, the EMEP emission centre CEIP made miscellaneous suggestions to improve Switzerland's inventory, especially in the agricultural sector. Therefore, we were commissioned to suggest appropriate emission factors (EFs) for the inventory section 3.B Manure Management. The parameters to be included are non-methane volatile organic compounds (NMVOC) and particulate matter (PM) with the fractions total suspended particles (TSP), PM_{10} and $PM_{2.5}$. Here, we suggest updated EFs for dairy cows based on a literature review and a method to derive EFs based on published data in case of gaps therein. Further, we shortly list open questions related to the EFs of NMVOC.

2. RESULTS AND DISCUSSION: Based on a review of selected peer review papers and reports, we present current experimental data with a focus on PM and suggest a procedure on the determination of (TSP, $PM_{10,}$ $PM_{2.5}$) where the data basis exhibits gaps. It cannot be considered as an exhaustive review which includes all publications potentially contributing to the topic.

Particulate Matter: An overview of studies providing EFs from seven different countries categorised according to housing systems is given in Table 1. We discovered limits, gaps or inconsistencies in most of the studies. For example, Takai et al. (1998) simply measured TSP and respirable dust and some measurements were conducted during winter only. Moreover, the results were not background corrected and might therefore be too high. Schrade et al. (2017) produced the unique measurements results for Switzerland. This study included six different houses where diurnal and seasonal variations were assessed. However, only PM_{10} was measured. Mosquera et al. (2010)

measured all size fractions of interest but the TSP values were not background corrected. The findings from Winkel et al. (2015) are based on the measurements of Mosquera et al. (2010) but for unknown reason the emission factors differ by a factor of up to four. Due to time issues, no quality assignment was done for Hinz et al. (2007) and Heidenreich et al. (2008). The findings from Schmidt et al. (2002), Goodrich et al. (2002, 2003), Henseler-Passmann (2010) and Joo et al. (2013) were excluded since they were conducted in housing systems or under climatic conditions which were not comparable to Switzerland.

Table 1. Overview of the literature reporting emission factors (EFs) for particulate matter (PM). TSP (Total Suspended Particle), TH (Tied-housings), LH (Loose-housings), CS (Cubicles with a production of slurry), CSSM (Cubicles with a production of slurry and solid manure), DL (Deep litter).

Housing System	**Source**	**EF TSP** *[kg head^{-1} a^{-}*	**EF PM_{10}** *[kg head^{-1} a^{-}*	**EF $PM_{2.5}$** *[kg head^{-1} a^{-}*
TH/LH	EMEP/EEA Guidebook, 2016	1.38	0.63	0.41
TH/LH	This study	0.53	0.16	0.04
TH	Vonk et al., 2016	-	0.081	0.022
	Hinz et al., 2007 in Schrade et al., 2017	0.184[‡]	0.070	-
	Takai et al., 1998	1.016[*]	-	-
LH CS	Winkel et al., 2015	2.321	0.075	0.014[†]
	Joo et al., 2013	18.469[‡]	4.909	1.022[†]
	Mosquera et al., 2010	3.900	0.148	0.041[†]
	Henseler-Passmann 2010 cited in Schrade et al.,	-	0.076[*]	-
	Schrade et al., 2017	-	0.234	-
	Heidenreich et al., 2008 cited in Schrade et al.,	0.630‡	0.210	-
	Goodrich et al., 2003	3.960	-	-
	Goodrich et al., 2002	2.957[‡]	0.730	-
	Schmidt et al., 2002	4.515[*]	0.379[*]	2.033[*]
	Takai et al., 1998	1.964[*]	-	-
LH CSSM	Heidenreich et al., 2008 cited in Schrade et al.,	1.340[‡]	0.360	-
LH DL	Henseler-Passmann 2010 cited in Schrade et al.,	-	0.702[*]	-

[*] *EFs were provided as per livestock unit (500 kg life weight). For the conversion to animal head 650 kg life weight per dairy cow was used.*

[†] *Used to calculate transformation factor for $PM_{2.5}$ from PM_{10}.*

[‡] *Used to calculate transformation factor for TSP from PM_{10}.*

The EFs listed in the Guidebook are the average of the two EFs from Takai et al. (1998) and for the conversion from livestock unit to animal head an average weight of 600 *kg* per dairy cow was used. As described above, Takai et al. 1998 provided TSP values only and therefore the Guidebook used transformation factors to determine the EFs of PM_{10} and $PM_{2.5}$.

In case of gaps for PM size fractions in a published dataset it is possible to calculate the different PM fractions by extrapolation from a study providing all or a part of the PM fractions. Such transformation factors can be obtained from the literature. As for the EFs, the pattern of the individual PM fractions differs widely between countries and studies. Not all of the transformation factors are recommended to use. For example the Guidebook uses the conversions provided by Seedorf and Hartung (2001) which are at the very high end of reported values. These are based on a single 24-hour measurement in a loose-housing and conflict with the measurements of Takai et al. (1998). The share provided by Seedorf and Hartung (2001) of 30% of $PM_{2.5}$ relative to TSP is equal to the respirable dust (PM_5) share of TSP measured in Takai et al. (1998), which is implausible. Other conversions should not be used as they contain EFs that are not background corrected (e.g. Mosquera et al., 2010, Winkel et al., 2015).

As we were commissioned to do derive a set of EFs for dairy cattle in Switzerland, we present a possible solution: we used the average of selected shares (see footnote † and ‡ in Table 1) which resulted in a transformation factor of 3.34 from PM_{10} to TSP and of 0.23 from PM_{10} to $PM_{2.5}$. Our derived EFs for loose-housings based on the PM_{10} value from Schrade et al. (2017) were used to generate EFs for tied-housings. This was done using a transformation factor of 0.43 which is based on the measurements of Takai et al. (1998) and a conversion given in Vonk et al. (2016). The EFs for loose-housings and tied-housings were then aggregated according to their occurrence for dairy cattle in Switzerland in the year 2010. Our calculations resulted in an EF of 0.53, 0.16 and 0.04 $kg\ head^{-1}\ a^{-1}$ for TSP, PM_{10} and $PM_{2.5}$, respectively. The derived EFs are four to eleven times smaller than those listed in the EMEP/EEA Guidebook 2016. The question arises which option is more adequate for the calculation national emission inventories: (i) adoption of EFs as given in the Guidebook or (ii) determination of country specific EFs as shown here.

Non-methane volatile organic compounds: Data from our literature study suggest that the data basis on EFs for NMVOC is scarcer than for PM. Individual compounds investigated in the studies varied widely. This is due to the complexity of analytical issues which required for a selection of compounds according to the availability of analytical methods applicable at the investigating institutes. Most of the studies were carried out at a laboratory scale instead of investigations at a field scale. Also, the focus of most studies was rather on odour and odorous emissions than on total NMVOC emissions. Therefore, we see at the moment no other option than to adopt the EFs listed in the Guidebook for the calculation of a national emission inventory.

3. CONCLUSION: Our literature study revealed that the data basis for EFs of PM and NMVOC is scarce in general. It includes gaps and inconsistencies and the reported EFs differ widely between studies and countries. We derived EFs based on data for PM_{10} measured in Switzerland being at 0.53, 0.16 and 0.04 $kg\ head^{-1}a^{-1}$ for TSP, PM_{10} and $PM_{2.5}$, respectively. These EFs are lower by a factor of four to eleven than those listed in the Guidebook. We think that the numbers in the Guidebook are at the high end of reported values. It can be discussed, whether it is best practise to use country specific EFs as shown here or to apply the EFs listed in the Guidebook in spite of the identified inconsistencies

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INVESTIGATION ON THE AMOUNT OF ODOUR NUISANCE CAUSED BY PIG FARMS IN THE NETHERLANDS

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ABSTRACT: In the past very different values of pig odour nuisance were reported in the Netherlands. In order to get a better idea of the actual nuisance, an independent research was ordered by a Dutch pig-farmers association. In this project, on the one hand, odour emissions were determined using sniffing team measurements according to EN16841-2. Dispersion models were used to calculate the odour load for receptors in the surroundings. On the other hand, the odour nuisance was determined at the different receptor points, by means of a telephonic enquiry. Combining the output of these two methods, a coupling could be made between the degree of nuisance and the perceived odour concentration. One of the purposes of this study was to derive a proposal for a new odour standard. This however could not be done, since only very low percentages of nuisance were communicated in the residential areas. This could indicate that the existing regulatory system in the Netherlands, together with an efficient rural planning, led to an acceptable situation around the investigated farms. The difference between these results and a former study could probably be explained by the difference in approach of questioning people during the respective surveys.

Keywords: Odour nuisance, Pig Housing, Dispersion Modelling, Sniffing Team Measurement, EN16841-2

INTRODUCTION: A study conducted in 2015 in the Netherlands (GGD, 2015)) indicated that the amount of nuisance caused by pig farms could be higher compared to previous studies (PRA, 2001). Instead, according to NVV (a Dutch pig-farmers organisation), the amount of nuisance was thought to be lower instead of higher. Therefore, NVV ordered an independent research that was executed in 2015-2016.

1. MATERIAL AND METHODS: In this research project, the methodology was followed as used to build the Flemish odour regulation (Universiteit Gent, 2000). In the Netherlands, a subdivision is made between so called ‘concentration zones’ and ‘non-concentration zones’. In the concentration zones, cumulative effects can be expected due to the ubiquitous presence of intensive husbandry. For this research project, five representative and for the Netherlands typical pig farms were selected, three in ‘concentration zone’ and two in a ‘non-concentration’ zone. During selection of the cases, special attention was given to the presence of enough houses downwind the farms to perform the measurement of odour nuisance by means of telephonic enquiries.

During summer and winter period, ten sniffing team measurement cycles according to EN16841-2 (CEN, 2016) were executed around the farms to determine their global odour emission strength. In this method, at least two experienced panel members, who fulfil the criteria of being a EN13725 panel member, traverse independently the plume, while conducting single measurements (observations during one inhalation) at frequent intervals.

The plume direction is traversed at different distances from the source; the crossings can be started far away from the source and heading to it, or vice versa (see Figure 1). These crossings include traverses at distances where no recognizable odour is detected. A transition point is defined as the point halfway between an adjacent odour absence point and odour presence point for the odour type under study. In order to prevent possible adaptation effects causing incorrect observations, the transition points in the dynamic plume method are only determined while entering the plume, and not while exiting.

The maximum plume reach estimate is determined as the distance along the plume direction between the source and the point halfway from the furthest crossing where odour presence points were recorded and the first crossing where only odour absence points were recorded.

Figure 1 shows schematically the two possible routes to determine the odour plume extent. This extent is defined as the smoothed interpolation polyline through the transition points, the source location and the location determined by the maximum plume reach estimate.

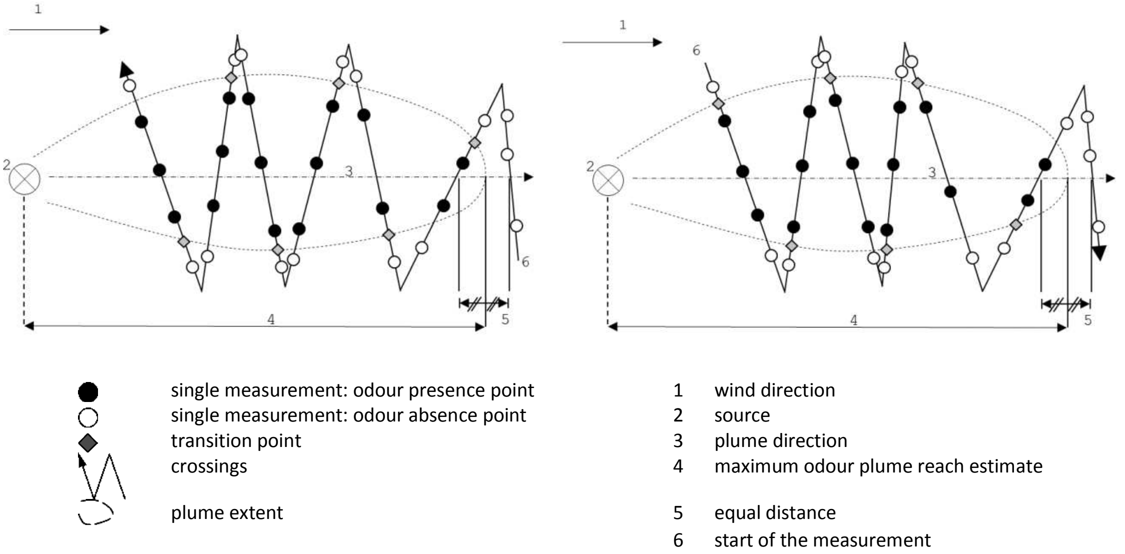

Figure 1. Schematic drawing of the execution of the dynamic plume method (EN16841-2)

The odour emission rate of the pig farm under study is calculated on the basis of the recorded plume extent, the source characteristics and the local meteorological conditions during the plume measurement.

To underline the differences between the field measurement and the olfactometric measurement, the odour emissions calculated on the basis of the plume measurement are expressed as sniffing units per second ($su.s^{-1}$) instead of odour units per second ($ou_E.s^{-1}$). A very important difference between su and ou_E is the fact that the odour observation during sniffing team measurements concerns the identification of a recognizable odour, while in the olfactometric laboratory measurements detectable odours are observed. Typically 1 $su.m^{-3}$ corresponds with a concentration between 1 $ou_E.m^{-3}$ and 5 $ou_E.m^{-3}$. One sniffing unit per cubic meter can be defined as the odour concentration at the border of the plume. This means that in every transition point the odour concentration can be defined as 1 $su.m^{-3}$.

The mean odour emission values of the ten measurements cycles were used to calculate the odour load for each receptor (house) in the surroundings, comparing Dutch and Flemish dispersion models.

On the other hand, the odour nuisance was determined at the different receptor points, by means of a telephonic enquiry. In order to obtain unbiased answers in this enquiry, odour was not the main focus during the questioning: people were asked about their general satisfaction with their living environment during the last year; odour was one of the many aspects that were considered.

2. RESULTS: The sniffing team measurements and the back-calculation to obtain the total odour strength of the source resulted in different values when different models were compared. Emission factors per animal were calculated and compared with existing factors determined with dynamic olfactometry (EN13725). Some values were comparable, others differed importantly. The emission factor derived from the sniffing team measurements however either coincides with the other factors or is an average of the other ones.

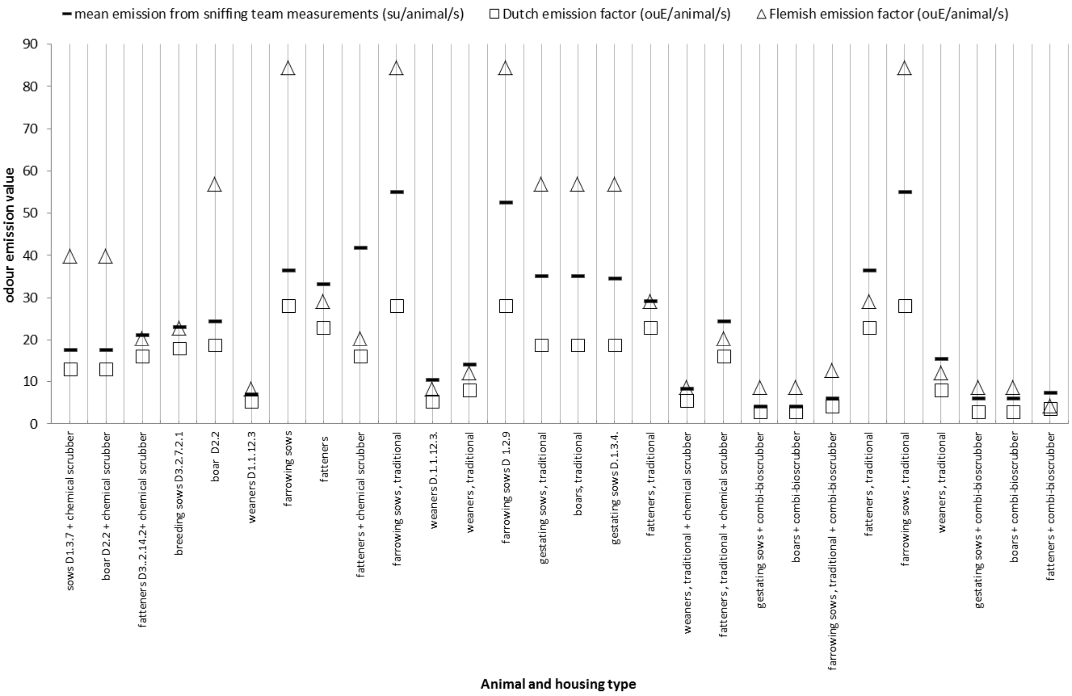

Figure 2. Comparison of emission factors per animal per s

Around the five pig stables, in total 784 valid questionnaires were obtained. Only 0,3% indicated the observed pig smell as being very annoying; 2,9% judged the situation as annoying. 96,8% of the receptors observes no smell at all or judged the odour climate as not annoying.

Applying this methodology in Flanders, the combination of the degree of nuisance and the perceived odour concentration resulted in a relationship able to predict nuisance based on the odour concentration present. In this study, no such coupling could be made due to the very low nuisance percentages. This could indicate that the existing regulatory system in the Netherlands, together with an efficient rural planning, led to an acceptable situation around the investigated farms.

The difference between these results and the former study (GGD, 2015), where much higher percentages of observed nuisance were reported, can probably be explained by the difference in approach of questioning people during the respective surveys: in the former study, a written questionnaire was sent by the general medical practitioner with 15 questions related to lung diseases, asthma and respiratory problems, followed immediately by two questions on the nuisance of odour caused by agricultural activities. It could be expected that this way of questioning led to a bias.

3. CONCLUSION: A new approach was used to determine the odour nuisance around pig stables in the Netherlands. Combining the measured odour load (using sniffing team measurements) with the determined degree of nuisance (using hidden telephonic enquiries), a coupling could be made between these two parameters. However, our research showed only very low nuisance percentages, indicating that the existing regulatory system in the Netherlands, together with an efficient rural planning, led to an acceptable situation around the investigated farms.

The use of sniffing team measurements instead of dynamic olfactometry appeared to be a valid alternative. Consensus however is necessary on the use of models, since different models result in different conclusions. European harmonisation in dispersion modelling would be a very valuable next step.

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ENVIRONMENTAL AND ECONOMIC EVALUATION OF SLAGHTERHOUSE WASTE USED AS A SOURCE OF BIOMASS FOR ENERGY PRODUCTION.

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ABSTRACT: This work aims to valorise the residue of anaerobic digestion of slaughterhouse waste using an alternative approach. A demonstrative-scale plant for the drying and combustion of digestate was evaluated in order to understand its capability in terms of environmental and economic performance. The solution appears feasible when the lower heating value of digestate is 17000-18000 kJ kg_{TS}^{-1}, the digestate production is more than 10 t d^{-1} or the cost of digestate disposal is higher than 50 € t^{-1}.

Keywords: Digestate, Waste Combustion, Environmental evaluation.

INTRODUCTION: The amount of organic waste related to meat industries is increasing worldwide (Pagés-Díaz et al., 2014). A suitable solution for its treatment is the anaerobic digestion (AD), that enables to recover energy through biogas production (Palatsi et al., 2011). Nevertheless, the AD produces relevant amount of a solid residue, that contains compounds that cannot be converted into biogas. For its high content of nutrients and stabilized organic matter, digestate can be used for agricultural purposes as organic fertilizer. However, its application on soil is controversial when the AD involves mixtures containing organic waste. This kind of digestate is often considered as waste and disposed in landfills or used as fuel in solid waste incinerators. Otherwise, post-treatments are required with subsequent further investments. This work suggests an alternative solution considering the in-situ combustion of digestate (Kratzeisen et al., 2010), evaluating its environmental and economic performance. A demonstrative-scale plant was installed and operated for two years in an important slaughterhouse, enabling the recovery of energy and of a fraction of the nitrogen for agricultural purposes.

1. MATERIAL AND METHODS:

1.1. Demonstrative scale plant: A demonstrative-scale plant for the in-situ combustion of digestate was installed downstream of an anaerobic digester serving an important cattle slaughterhouse of northern Italy. Figure 13 shows the scheme of the whole process.

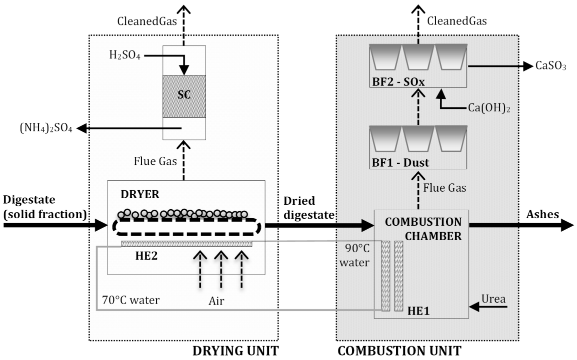

Figure 13. Scheme of the scale plant.SC=scrubber, HE1 and HE2=heat exchangers, BF1 and BF2=baghouse filters.

1.1.1. Drying unit: A third (4.2±0.2 t d^{-1}) of the overall daily production of the solid fraction of digestate (obtained with a centrifugal separator) was treated in a moving conveyor dryer, operated at mid-low range of air temperature (70°C) and with a thermal power consumption of 150 Kw. Digestate humidity was continuously measured in order to set consequently the time duration of the process (approximately assumed around 40-50 min, maximum humidity of 15%). The optimal air flow rate was empirically established at 6,400 Nm^3 h^{-1}, which assure a maximum water evaporation of 130 kg h^{-1}. The ammonia and dust particles removal in the output gas was achieved with a vertical scrubber, using a solution of sulphuric acid. The pH of the resulting ammonium sulphate solution ($(NH_4)_2SO_4$) is maintained at a value below 4, adding acid to the recirculation water. The empty bed contact time of the reactor was 2 seconds, with a gas velocity of 2 m s^{-1}. The overall electric power consumption of the drying unit was 11.5 kW (for the movement of digestate and the ventilation system).

1.1.2. Combustion unit: The combustion unit was designed in order to obtain a self-sufficient process, producing 150 kW of thermal energy from the dried digestate combustion. The burner was externally constituted of a triple-layer steel chassis and, internally, of a monolithic ring of refractory concrete (internal Ø 60 cm, external Ø 80 cm, depth 50 cm) with a high content of alumina (>50%) in order to assure corrosion resistance. The energy transfer from the combustion chamber to the dryer was obtained through a countercurrent heat exchanger with an efficiency of 70% and an electric power consumption of 2 kW. The water temperature in the heating circuit ranged between 70-90°C. An aqueous solution of urea (32.5%) was directly injected in the combustion chamber to perform a non-catalytic NOx abatement. The temperature in the combustion chamber was maintained around 950-1,100°C by modifying the amount of excess air using a thermocouple. The flue gas was treated in a two-step baghouse filtering process. The former filter removes dust particles, while the second filter allows the abatement of $CaSO_3$ obtained by the addiction of $Ca(OH)_2$ reacting with SOx in the “dust-free” gas. Both filters have a total surface of 11 m^2 and a filtration velocity of 1.5 cm s^{-1}. During the abatement of SOx, temperature did not exceed 170°C.

1.2. Physical-chemical characteristics: Total Solids (TS) and Volatile Solids (VS) were determined for each sample of raw digestate, dried digestate and ash, according to

Standard Methods [15]. Lower heating value (LHV) was measured according to UNI EN 15400:2011. Total nitrogen was measured according to UNI 10780:1998 method. Analyses were carried out in duplicate, two-three times per month. Gases characteristics were determined according to UNI 10169/01, UNI EN 13284-1/03 and EPA CTM-34, at least one times per month.

2. RESULTS AND DISCUSSION: The main characteristics of digestate entering the scale plant, of the dried digestate and of ashes are shown in Table 3.

Table 4 reports the measured parameters of the flue gases coming from the drying and combustion processes.

Table 3. Characteristics of digestate (solid fraction), dried digestate and ashes.

Parameters	U.M.	Digestate (solid fraction)	Dried digestate	Ashes
TS	%	25.6±1.5	92.8±2.8	98.9±0.2
VS	% TS	71.5±7.8	71.7±10.4	0.4±0.1
LHV	kJ kg$_{TS}^{-1}$	-	17 398±1 751	-
Nitrogen (total)	g kg^{-1}	9.6±2.0	9.7±1.8	0.50±0.7

Table 4. Characteristics of the flue gases from drying and combustion processes and their emissions limits (dry gas, reference O2=5%).

		Drying unit			Combustion unit		
		Pre-scrubbing	Post-scrubbing	Limit [mg Nm^{-3}]	Pre-filters	Post-filters	Limit [mg Nm^{-3}]
Gas flow rate	Nm^{3} h^{-1}	-	6 465±314	-	-	566±32	-
Temperature	°C	68±4	47±5	-	223±26	148±24	-
CO	mg$_{CO}$ Nm^{-3}	-	-	-	-	248±63	500
NH_3	mg$_{NH3}$ Nm^{-3}	227.3±18.7	7.0±0.5	150	-	<0.5	150
NOx (as NO_2)	mg$_{NO2}$ Nm^{-3}	-	-	-	-	415±28	450
SOx (as SO_2)	mg$_{SO2}$ Nm^{-3}	-	udl*	350	1 630±269	297±41	350
TPM**	mg Nm^{-3}	-	1.0±0.5	10	-	7.2±2.1	10

* Under detection limit, ** Total Particulate Matter

2.1. Mass balance: It can be observed that, after the drying process, the digestate lost 72% of its weight (as a consequence of water evaporation, 125-130 kg h^{-1}). At the same time, the 70% of the nitrogen initially present in the digestate was stripped as ammonia. In fact almost all the nitrogen present into the dried digestate was in the organic form (92%). Finally the consumption of sulfuric acid for the ammonia abatement was measured at 130 kg d^{-1} (3.65 kg$_{H2SO4}$ kg$_{NH3,removed}^{-1}$, +27% with respect to stoichiometric ratio) and the removal efficiency of the acid scrubber reached 97%. The vertical scrubber produced about 140 kg d^{-1} of $(NH_4)_2SO_4$. Thereafter, the combustion process significantly reduced the initial mass of digestate (about 93%) producing ashes and oxidation gases. At the same time, nitrogen was almost completely converted to NOx. The non-catalytic process for the abatement of NOx requests the dosage of urea. The consumption of urea was estimated at 47.3 kg d^{-1} (1.58 kg$_{CO(NH2)2}$ kg$_{NO2,removed}^{-1}$, +102%

with respect to stoichiometric ratio). The removal of SOx implied an average consumption of $Ca(OH)_2$ of 43.8 kg d^{-1} (2.41 $kg_{Ca(OH)2}$ $kg_{SO2,removed}^{-1}$, +117% with respect to stoichiometric ratio) and the process efficiency reached 80%. The plant produced about 72 kg d^{-1} of $CaSO_3$.

2.2. Energy balance: The LHV of dried digestate was measured equal to 17,398±1,751 kJ kg_{TS}^{-1}. This value is equivalent to other common low-value fuels (such as lignite or wood pellets). The combustion generated a thermal power of about 778±80 MJ h^{-1}. The hot combustion flue gases flux represents a heat loss and a thermal flux of 171±39 MJ h^{-1} with the flue gases can be estimated. The dryer requests a thermal power of 150 kW, which corresponds to 540 MJ h^{-1}. Therefore, the overall average energy balance appears to be positive but this value is overestimated, since the thermal flux through the surfaces was not considered. Nevertheless, the plant was self-sufficient for at least the 85% of the operation time. In winter, when the external air temperature was below 5°C, the heat exchanger was no able to reach the correct water temperature. Thus, for about 45 days per year, it was necessary to integrate the dried digestate with wood pellets in order to compensate the heat losses (2.5 kg h^{-1}, which assured an additional heat flux of about 50 MJ h^{-1}). A better thermal insulation of the structure, or a more efficient heat exchanger, could avoid the need of additional fuel.

2.3. Economic balance: The cost analyses refer to Italian prices and conditions and are reported in Table 5 (the monitored demonstration-scale plant, treating a third of the digestate production and a designed full-scale plant). A life-span of 15 years, with a replacement of the baghouse filters after 7.5 years and a 5% discount rate for the capital costs were assumed. The studied demonstrative-scale plant treats a third of the overall production of digestate at a cost of 85,980 € y^{-1}. Currently, the slaughterhouse spends 270,000 € y^{-1} for the digestate in agriculture (90,000 € y^{-1} considering the same quantity of digestate treated in the scale plant). Thus, the drying-combustion solution appears to be not particularly interesting. On the contrary, the designed full-scale plant would allow an estimated saving of 60,000 € y^{-1}, with a specific treatment cost of about 45-50 € t^{-1}. In this balance are not included the products of the process, $(NH_4)_2SO_4$ and $CaSO_3$. These products could have a destination in, respectively, fertilizers and cements production. However, due to the presence of impurities, it is much more plausible that these materials will have no economic value on the market.

Table 5. Economic evaluation of the demonstrative plant (real data) and of the full scale plant (data extrapolated from the results of the demonstrative plant).

	Demonstrative plant (real)		**Full plant (designed)**	
	Equipment cost, €	***Yearly cost, € y^{-1}***	***Equipment cost, €***	***Yearly cost, € y^{-1}***
Dryer	105 000	10 115	250 000	24 085
Scrubber	60 000	5 780	120 000	11 560
Combustion	75 000	7 225	160 000	15 415
Other devices*	20 000	1 930	35 000	3 370
Plant costs	260 000	**25 550**	565 000	**54 430**
	Unit cost	*Yearly cost, € y^{-1}*	*Unit cost*	*Yearly cost, € y^{-1}*
Reagents**	-	13 590	-	40 770
Electric energy	0.15 € kWh^{-1}	17 750	0.15 € kWh^{-1}	55 000
Wood pellet	195 € t^{-1}	550	195 € t^{-1}	-
Maintenance	5% of the plant cost	13 000	3% of the plant cost	16 950
Personnel	13 € d^{-1}	4 680	26 € d^{-1}	9 360
Ash disposal	100 € t^{-1}	10 860	100 € t^{-1}	32 600
Running costs	-	**60 430**		**154 680**
Total costs	-	**85 980**		**209 110**

* Electric connections, storage of chemicals, etc., ** Urea (300 € t^{-1}), $Ca(OH)_2$ (120 € t^{-1}), Sulphuric acid (137 € t^{-1}).

3. CONCLUSION: The production of solid waste from the anaerobic digestion process can be reduced recovering, at the same time, a fraction of nitrogen under a chemically stable form (ammonium sulfate). The process can be self-sufficient and avoid the need of additional fuel, if the LHV of dried digestate is higher than 17,000-18,000 kJ kg^{-1}. An efficient thermal insulation is also required in order to minimize any heat loss. Nevertheless, this solution appears feasible only for large anaerobic plants and/or when digestate cannot be used for agronomic purposes and has to be disposed as waste, since the system is expensive. From the economical evaluation of the present study it was observed that the drying-combustion process is affordable for a digestate production higher than 10 t d^{-1} and for a conventional digestate disposal cost higher than 50 € t^{-1}.

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EVALUATION AND COMPARISON OF TWO TECHNIQUES FOR ESTIMATING ENTERIC METHANE EMISSION IN YOUNG BULLS

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ABSTRACT Enteric methane emission by ruminants is mainly measured using the SF_6 or the Greenfeed technique when they are not tied. The objective of this trial is to compare these two methods in fattening bulls, and to provide additional information on the reliability of the Greenfeed technique. Sixteen young bulls weighing 348 kg at the beginning of the experiment were used for 3 months. Reliability of the Greenfeed technique was determined from continuous measurement for 90 days; comparison between methods was made from measurements during the last 15 days and the last 4 days of the experiment for Greenfeed and SF_6, respectively. A repeatability higher than 0.70 was achieved for methane emission and yield with a 15-day period of measurement; a total of 16 animals is necessary to test the mitigating effect of a treatment when two groups of animals are compared. Greenfeed resulted in higher methane emission than SF_6 (192 vs 170 g/day, respectively) but inter-animal correlation between methods is low. These results show that Greenfeed method can be used for comparing the effect of feeding treatments on methane emission, but additional work is necessary to better understand differences in emission and yield between Greenfeed and SF_6.

Keywords: enteric methane, ruminants, measuring method, Greenfeed, repeatability

INTRODUCTION Enteric methane (CH_4) represents about 37% of greenhouse gases emission due to livestock activities, when expressed as carbon dioxide (CO_2)-equivalents (Gerber et al., 2013). Among the methods available to quantify the emission of enteric CH_4 emission in ruminants housed in free-stalls or on pasture, the sulphur hexafluoride (SF_6) tracer method, used since two decades, and the Greenfeed technique (GF) (C-lock, Rapid City, SD, USA) which appeared recently are the most popular. The SF_6 technique is based on the release of a tracer gas (SF_6) from a bolus placed in the rumen and continuous sampling of gases produced by the animal, by eructation and exhalation; CH_4 and CO_2 emission are determined from SF_6 release rate and from SF_6, CH_4 and CO_2 concentration in air samples (Johnson et al., 2007). The GF technique is based on the spot sampling of gases produced by the animal when eating concentrate at an automatic feeder, then measuring air flow out of the feeder, and CH_4 and CO_2 concentration in this flow (Huhtanen et al., 2015). However, few comparisons between them have been made, as stated by Hammond et al. (2016), and there is limited information on the reliability of the GF technique. The objective of this trial was to evaluate in young bulls at fattening the repeatability of the GF technique and to compare results obtained by the GF and the SF_6 technique, for the average emission and the individual variability.

1. MATERIAL AND METHODS: The experiment lasted 3 months. Sixteen Charolais young bulls aged 305 ± 6 days and weighing 348 ± 27 kg at the beginning of the experiment were housed in the same pen of a semi-open barn. They received a fattening diet of constant composition offered ad libitum made of 67% baled haylage of permanent grassland and 33% concentrate. Haylage was offered at 0900 h. A fraction of concentrate (ca. 2.1 kg) was introduced in the GF system and the rest was top-dressed on haylage at trough in equal amounts at 0900 and 1600 h. Methane estimation using the SF_6 technique was performed at the end of the experiment on 4 successive days according to Martin et al. (2016). Methane estimation using the GF system (C-lock, Rapid City, SD, USA) was made according to Arbre et al. (2016a). The GF was calibrated for a maximum of 6 daily visits per animal. Methane estimation for the analysis of repeatability of GF technique was achieved for 90 successive days; for the comparison with SF_6 technique, only data of the last 15 days were taken. Animals were accustomed to the diet and to the GF system for 1 month before the beginning of the experiment. Outliers were eliminated before statistical analysis by calculating the distance of each daily data to axis from the joint distribution of CO_2 vs CH_4 emission according to Arbre et al. (2016a). In order to evaluate repeatability, average data per cow were calculated for periods defined as sequences of consecutive days. From means per cow and per period, variances of animal (varA), of period, and residual error (varR) were calculated, and repeatability (R) was defined as R = varA/(varA+varR). The number of animals to be used for comparing two treatments was calculated as specified in Arbre et al. (2016a) with a level of significance of difference taken as 5% and a statistical power taken as 80%. Comparison between SF_6 and GF techniques was made from average data for each animal (mean of 15 days for GF and of 4 days for SF_6) by analysis of variance using a mixed model (SAS 9.1 release, SAS Inst. Inc., Cary, NC, USA) with method as fixed effect and animal as random effect.

RESULTS AND DISCUSSION Dry matter intake regularly increased from 7.48 ± 0.93 to 9.81 ± 0.69 kg/day between the beginning and the end of the experiment. Liveweight gain during the experiment was 1.67 ± 0.17 kg/day. For GF individual daily data, 11.0% were missing due to not enough daily visits of animals to the system and 3.9% were outliers. Due to increase in dry matter intake (DMI) throughout the experiment, gas emission (g/day) increased with time, but gas yield (g/kg DMI) did not. Repeatability (Table 1) was higher than 0.70 from 15-day period for CH_4 emission, from 5-day period for CH_4 yield, and from 10-day period for CO_2 emission and yield and for CO_2/CH_4 ratio. Repeatability was close or higher than 80% for any variable from a 30-day period.

Table 1. Repeatability of GF technique according to duration of measurement period in bulls.

	Duration of the measurement period							
	1-day	**2-day**	**4-day**	**5-day**	**10-day**	**15-day**	**30-day**	**45-day**
Dry matter intake (DMI, kg/d)	0.62	0.68	0.72	0.75	0.79	0.82	0.88	0.86
Methane (CH_4)								
g/day	0.21	0.32	0.41	0.52	0.63	0.72	0.79	0.81
g/kg DMI	0.48	0.57	0.65	0.72	0.77	0.81	0.86	0.88
Carbon dioxide (CO_2)								
g/day	0.38	0.50	0.59	0.66	0.74	0.77	0.83	0.86
g/kg DMI	0.45	0.52	0.60	0.65	0.71	0.75	0.80	0.82
CO_2/CH_4 ratio	0.31	0.43	0.55	0.61	0.74	0.79	0.85	0.89

The number of animals to be used in experiments is specified in Table 2. When the objective is to detect a 10%-difference between experimental treatments, the required number of animals is very high, but for a 20%-difference the total number of animals is equal to 16 or 20, i.e. 8 or 10 per group, according to the objective of the study. Comparison of techniques is presented in Table 3. Methane emission and yield was significantly lower for SF_6 than for GF (P=0.01 and 0.04, respectively) although numerical differences were moderate (-11 and -8% for SF_6 compared to GF). Neither CO_2 emission and yield nor the CO_2/CH_4 ratio varied between methods (-7, -2 and +5%, respectively, for SF_6 compared to GF).

Table 2. Total number of animals required for determining CH4 emission with GF according to the significant difference (Δ,%) to be detected between treatments and duration of measurement.

Days of measurement	Mean ± standard deviation	Δ = 10%		Δ = 20%	
		1-sided test	2-sided test	1-sided test	2-sided test
15	263 ± 40	60	76	16	20
30	262 ± 40	58	74	16	20
45	253 ± 39	58	74	16	20
90	235 ± 39	70	88	18	22

1-sided test is used when the mitigating effect of treatment on CH_4 emission is known; 2-sided test is used when the direction of the difference between treatments is not known.

Table 3. Comparison between SF_6 and GF techniques in bulls.

	Technique		SEM	P-value
	SF_6	GF		
Methane (CH_4)				
g/day	170	192	6.2	0.01
g/kg DMI	23.7	25.8	0.98	0.04
Carbon dioxide (CO_2)				
g/day	5592	6042	198.5	0.09
g/kg DMI	776.9	796.4	25.85	0.51
CO_2/CH_4 ratio	33.1	31.6	0.98	0.23

Individual correlations between the two methods (n = 16) are shown in Table 4. Correlation coefficient was low and non-significant for CH_4 emission, and higher and significant for CH_4 yield. Difference in correlation coefficients for CO_2 emission and yield is of low extent.

Table 4. Correlation between SF_6 and GF techniques for CH_4 and CO_2 emission and yield.

	CH_4 (g/day)	CH_4 (g/kg DMI)	CO_2 (g/day)	CO_2 (g/kg DMI)	CO_2/CH_4 ratio
Correlation coefficient	0.27	0.52	0.48	0.42	0.38
***P*-value**	0.31	0.03	0.06	0.10	0.15

DISCUSSION: Repeatability of GF measurements is confirmed to be high, as already stated in a previous study in dairy cows (0.65 and 0.84 for 10-day and 30-day periods for CH_4 yield, respectively; Arbre et al., 2016) and in heifers (0.65 and 0.69 for 7-day and 30-day periods for CH_4 yield, respectively; Renand and Maupetit, 2016). In another study, Manafiazar et al. (2017)

conclude that the average of 7 to 14 days is enough for repeatable data when a minimum of 20 spot samples is reached. In practical conditions, GF measurements are easy to implement in a 30-day period; a longer period of measurement improves measurement accuracy to a low extent. Experiments with GF require 8 or 10 animals per group according the type of comparison between treatments. This number of animals is compatible with most facilities in experimental stations or in commercial farms when a difference of 20% between treatments is expected, whereas a difference of 10% between treatments can be evidenced with a very large number of animals, as previously found in dairy cows (Arbre et al., 2016a). Increasing the number of days of measurement from 15 to 90 days does not result in a decrease in the number of animals required for a comparison. This allows moving from a study to another when animals are available for several months. The higher mean emission for GF is surprising because both methods measure emissions from mouth and do not account for flatulence. Arbre et al. (2016b) using the same techniques found the similar CH_4 emissions for GF and SF_6 whereas measurements in open chambers gave higher emissions. Hammond et al. (2016) who summarized the available literature found 4 comparisons between SF_6 and GF in dairy cows or heifers, with contrasted results, SF_6 being higher, similar or lower than GF according to the study. However in all studies the difference in CH_4 emissions between methods is lower than 15%. The low correlations between methods for individual CH_4 emissions show that at least one of the two methods may not give an accurate estimate of emissions. In dairy cows Arbre et al. (2016b) found a good correlation between open chambers and SF_6 and a lower correlation between GF and the other two techniques; in heifers Hammond et al. (2015) found a significant correlation between SF_6 and GF. In the present experiment, the low correlations may be due to limited differences in CH_4 emissions between animals.

3. CONCLUSION: This study confirmed that the GF technique, which appeared a few years ago, is reliable for CH_4 estimation of enteric emissions. There may be a small difference in emissions measured by SF_6 and GF techniques which remained to be confirmed, but the main issue is the low correlation between techniques for individual emissions; additional progress in the implementation of these methods is necessary..

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ENTERIC METHANE EMISSIONS FROM RUMINANTS FED FORAGES: A META-ANALYSIS ON THE ROLE OF TANNINS CONTENT

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ABSTRACT: Enteric methane emission by ruminants fed forages is highly variable and depends on forage composition, intake and digestibility. In addition, plant secondary compounds such as tannins have antimethanogenic properties; however, the mitigating effect of tannins on CH_4 is inconsistent. A meta-analysis approach was used to compare the effects of different forages, supplemented or not with tannins, fed to ruminants on CH_4 emission. Tannin content (TAN, condensed or hydrolysable), averaged 35.6 (sd =53.0) g/kg DM and varied from 0 to 199 g/kg DM, for 19 experiments and 53 treatments. Methane production, expressed per kg of digestible OMI (g/kg DOMI) significantly decreased when feeding level (FL, calculated as DM intake % liveweight) increased and when NDF content of the forage decreased. Moreover, tannins content (g/kg DM) decreasing effect on methane emission was significant. The effect of tannins for mitigating CH_4 emission is in agreement with previous studies, but in the present study the impact of tannins was lower, probably due to accounting for decreasing effect of FL and increasing effect of NDF effects in the equation and to small relations between these factors.

Keywords: enteric methane, forage, meta-analysis, tannins, emission factor

INTRODUCTION: Feeding forages, especially those rich in protein (legume), could represent an interesting strategy to both provide N to the animal and decrease methane emissions, thus enhancing animal productivity and reducing climate change. Forages rich in plant secondary compounds, such as tannins have been studied both for their nutritional effects (positive or negative) on animal productivity (Reed, 1995) and also for their antimethanogenic properties (Doreau et al., 2011; Jayanegara et al., 2012). However, the mitigating effect of tannins on CH4 is inconsistent (Beauchemin et al., 2008; Makkar, 2003). The objectives of this study were first to estimate CH4 emission of ruminants fed forages based on intake level, crude protein (CP) and neutral detergent fibre (NDF) forage content, then to go further and evaluate the effect of tannins content. A meta-analysis approach (Sauvant et al., 2008) was used to compare the effects of different forages, supplemented or not with tannins, fed to ruminants on CH4 emissions.

1. MATERIAL AND METHODS:

1.1. Data collection: We collected published data (Web of Science, CAB) that reported, on the same treatment, dry matter intake (DMI), CH_4 emissions, digestibility parameters, and forage chemical composition. The whole database contained 103 publications, 205 experiments and 554 data on CH_4 emission. Tannins contents (condensed or hydrolysable), was reported only in 19 experiments (sub dataset) and averaged 35.6 (sd=53.0) g/kg DM and varied from 0 to 199 g/kg DM. There was different forage species containing either condensed tannins or hydrolysable tannins in the dataset.

1.2. Data statistical analysis: We applied a meta-analysis based on Sauvant et al. (2008) on the sub dataset to estimate CH_4 emission. The main factors tested (Proc GLM, Minitab 16) were CP, NDF, acid detergent fibre (ADF) contents of the forage, digestibility of OM (DOM), feeding level is DMI expressed as % of live weight (DMI%LW) and $\log_{10}$ 1+ tannins content ($\log_{10}$ (1+TAN)) as covariates and animal species (cattle, sheep, goat) and experiment as qualitative factors. Qualitative factors were considered as fixed effects tested on inter-experiment-intra-factor variance. Log transformation of (1+ TAN) was required to achieve normal distribution of data and to include data where TAN=0. Outlier treatments were removed when their normalized residues were >3.

2. RESULTS:

Effects of tannins on CH_4 emission:

As previously observed (Eugène et al., 2014), methane production, expressed per kg of digestible OMI (g/kg DOMI) was significantly related to DMI%LW and NDF content of the diets. Moreover, this study indicates that TAN (g/kg DM) content of the diet can be taken into account:

$$CH_4/DOMI = 33.83 - 3.18\ FL + 0.018\ NDF - 3.21\ Log10\ (1+TAN) \quad (1)$$

(nt = 53 treatments, nexp = 17 experiments, RMSE = 3.3 g/kg, R^2 adj = 68%, P <0.001)

Where CH_4/DOMI (32.1 ± 8.6, min = 11.0, max = 48.8 g CH_4/kg DOMI) is the methane production per kg of digestible OMI, FL is the feeding level (DMI expressed as %LW), NDF the dietary NDF content (g/kg DM, limit of significance, p<0.10) and TAN is the dietary tannin content (g/kg DM).

Table 1. Main descriptive parameters (number of observations (n), mean, sd, min, max) of chemical composition of the diets, feeding levels (DMI%LW), OM digestibility (DOM) and CH_4 emission factors, in the sub dataset (19 experiments).

	n	mean	sd	min	max
Chemical composition[1]					
CP (g/kg DM)	66	180.0	60.4	93	300
NDF (g/kg DM)	65	472	148	147	764
ADF (g/kg DM)	45	336	87	145	490
Tannins (g/kg DM)	69	36	53	0	199
DMI/LW (%)	69	2.3	0.9	0.5	4.9
DOM (%)	61	64.0	10.8	42.3	81.6
Methane emission factors					
CH_4 (g/kg DMI)	69	19.04	5.51	6.67	33.70
CH_4 (g/kg DOMI)	61	32.11	8.65	10.97	48.78

[1] Chemical composition content of the diet (g/kgDM): CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, Tannins: tannins contents.

3. DISCUSSION AND CONCLUSION: Similarly to a previous study (Sauvant et al., 2011) we observed that DMI%LW decreased CH_4 emissions. It's the main factor that explain CH_4 variations, but moreover, we observed that NDF contents in forages increased significantly CH_4 emissions, whereas tannins contents decreased it. The decreasing effect of tannins on CH_4 emission was in agreement with Jayanegara et al. (2012). But in the present study the impacts of tannins were lower presumably because of the significant decreasing effect of FL and increasing effect of NDF effects. Indeed, increased NDF content of forages induced increased fermentation and thus lead to increased CH4 production (Eugène et al., 2014). Further analysis and studies are needed in order to test the effect of the source of tannins because there are too few direct comparisons within a same study in the literature.

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COMPARISON OF AMMONIA EMITTED BY SYSTEMS FOR LAYING HENS, WITH STORAGE OF MANURE AND WITHOUT STORAGE OF MANURE.

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ABSTRACT: Global production of eggs for human consumption is increasing. In 2003 it was around 1.022 trillion units or approximately 61.3 million tons, and by 2015, it had grown to an estimated 71.5 million tons, an average annual growth of 1.5%. This is best attributed to industry consolidation and scale-up, with new housing such as vertical aviary systems where it is possible to house hundreds of thousands of hens in just one building. With increased production, there is concomitantly concerns about animal welfare and environmental issues. Ammonia concentrations from laying hens manure in vertical systems, and, conventional systems, in hot weather conditions, were compared in this research. Ammonia sensors were used inside the facilities to measure the concentration at the height of the animals. In the vertical caged systems we chose the average height of the cage batteries, while in conventional aviaries the chosen height was the first line of cages. It was observed that the vertical system presented lower mean concentrations of NH_3 in their interior (average of 3 ppm) when compared to the conventional housing (average of 10 ppm). Thus, it is concluded that frequent withdrawal of the manure material contributes to reduce the potential for the generation and emission of ammonia into the atmosphere.

Keywords: NH_3, Eggs production, Hot weather conditions.

INTRODUCTION: Brazil is one of largest producers of animal food in the world and the largest egg producer in Latin America. It produced 39.51 billion units in 2015, up 6.1% from 2014 (ABPA, 2016). This increase in Brazilian production is possible due to changes in production systems. For example, the space beneath cages in the conventional system gives place to automated manure belt, allowing a vertical structuring of cages as depicted in Figures 1 and 2 (Augusto, 2007). Vertical cage production systems are typically fully automated, have a greater efficiency in laying hens per area unit and better manure management. This fact is due to the disposition of the manure in automated belts that carries them out of the facility, in counterpoint to the deposition of manure on the ground under the conventional cage systems.

Vertical systems have much higher bird density per unit area of building, and thusgenerate a higher volume of manure per area, highlighting concerns about environmental issues. In this sense, the ammonia gas (NH_3) stands out among the gaseous emissions associated to manure. The volatilization of NH_3, besides presenting high pollution potential, constitutes a mechanism of nitrogen loss, which causes Depletion of manure, which has the most indicated use, according to Ndegwa et al. (2008), the incorporation to the soil as fertilizer.

Baek et al. (2004) reported that the formation of some inorganic aerosols in the atmosphere may be related to the release of NH_3 from laying hens farms. Reactions between gases naturally present in the atmosphere with NH_3 volatilized can lead to the creation of these aerosols, which are potentiates of the greenhouse effect, and are directly related to climate change.

The Brazilian facilities used for egg production are predominantly open-sided, presenting permanent closure only at the ends. The fact of following this typology facilitates the removal of toxic gases generated to environment, through the natural ventilation (Tinôco, 2001).

This work aimed to carry out a field study, in a commercial egg farm, representative of the constructive pattern of vertical and conventional cage systems, to diagnose the conditions of the air environment in terms of NH_3 concentrations.

MATERIAL AND METHODS: a commercial facility was used as base, with automated production system in batteries of vertical cages. This system operates with 370 cm^2 ave^{-1} of density and 10 cm linear feed feeder for each hen. The building has dimensions of 12.5m wide by 138m long, with 100,000 laying hens housed in it, distributed in four rows of cages each with six levels. Manure and eggs are collected automatically with separate belts. The corridors were numbered from 1 to 5 (1l, 2l, 3l, 4l and 5l), in addition, cross profiles were also established in the shed also from 1 to 5 (1t, 2t, 3t, 4t and 5t) for the demarcation of points of data collection (Figure 1).
The second commercial facility evaluated has barns with a conventional cage system for laying hens. Six thousand laying hens are housed in pyramidal shaped cages, two rows of cages, with four sets of cages in each row (Figure 2). Feeding and withdrawal of eggs is done manually, the manure is stored under the cages until the end of the productive cycle. The dimensions are 7m wide by 75m long. The corridors were numbered from 1 to 3 (1C, 2C and 3C), in addition, cross profiles were also established from 1 to 3 (1T, 2T and 3T).

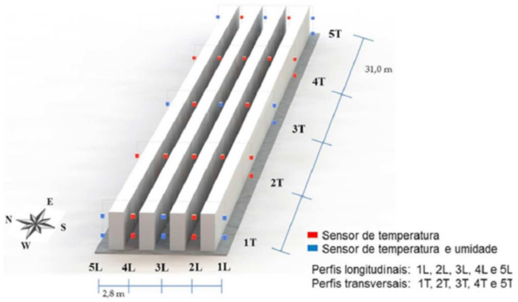

Figure 1: Measurement points of ammonia concentration. Source: COELHO et al., (2015)

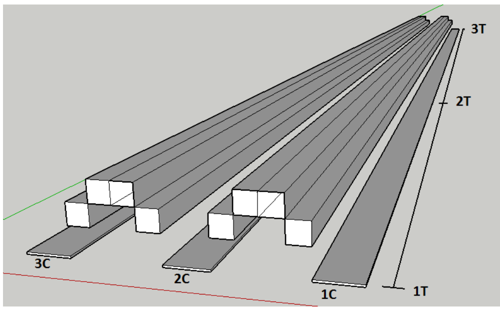

Figure 2: Measurement points of ammonia concentration.

The laying hens were Hy Line W36 breed, all in their maximum egg production period at the same age (36 weeks).

1.1. Air ammonia concentration: The NH_3 concentration inside the facility was obtained with GasAlert Extreme sensors from BW Technologies model GAXT-A-DL. Measurements commenced at six in the morning and repeated every three hours. The total collection time was 48 consecutive hours.

The gas sampling points in the vertical cage system were distributed along the lines 2T, 3T and 4T (Figure 1), and a sensor was fixed in each of the five passageways for employees (1L, 2L, 3L, 4L and 5L). The ammonia concentrations were measured simultaneously and at 1.80 m from the ground level at the mean height of the rows of cages. Measurements were initiated at 6 o'clock in the morning of the day after the activation of manure belt, and it was extended for 48 hours after a new cleaning was performed. For the conventional system the gas sampling points were distributed in lines 1C, 2C and 3C.

1.2. Manure characterization: Samples were collected from the manure to determine total nitrogen levels. For this, a plastic screen was used between the cage and the belt, avoiding that the exits had contact with the manure belt, thus not altering its physical properties. The collection points were distributed following the 2T, 3T and 4T cross profiles, totaling 12 points, detailed in Figure 1. Being used 3 repetitions.

2. RESULTS AND DISCUSSION:

1.1. Air ammonia concentration: No NH_3 concentrations were detected in corridors 1L and 5L of the vertical cage system, which was attributed to completely open sides of the facility. The NH_3 concentrations in the other lines (2L, 3L and 4L) are represented in Figure 3.

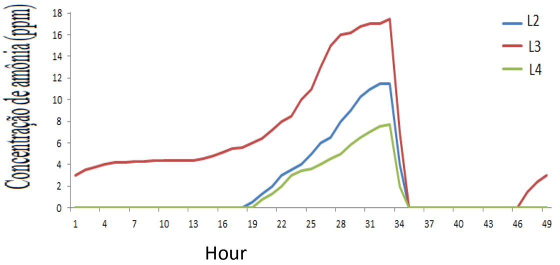

Figure 3: Concentration of NH_3 over time. Vertical System

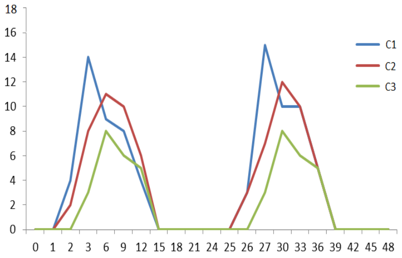

Figure 4: Concentration of NH_3 over time. Conventional System

At Figure 3, the presence of NH_3 in 3L and its reduction in the others lines (peak of 18 ppm vs 6 to 12 ppm maximum at about 34 h post-manure removal), can be explained, possibly, by insufficient natural ventilation, which was serves to dilute and eliminate ammonia in the proportion in which it was generated. Since fresh air delivery is impaired by the successive batteries of cages, it's not possible to eliminate the NH_3 generated in the center of the aviary (3L).

In Figure 4, two peaks of ammonia concentration are observed, each corresponding to the daytime period, reaching their extreme values (8-14 ppm) when the sun reaches the manure. In the night period, when there is a reduction of the ambient temperature, the natural ventilation is sufficient to dilute the gases generated. Thus, besides the time of accumulation, the temperature of manure has a direct influence on the generation and emission of ammonia. The average value of 3 ppm for ammonia concentration in the vertical system was observed while in the conventional system this value was 10 ppm.

1.2. Manure total nitrogen: The average concentration of total nitrogen (N) found in the manure was 4.98%, and no significant difference was detected between the collected samples (t-test). Considering the results of mean N concentration in laying hens, described by several authors cited in Table 1, it can be seen that the values obtained in this research are in accordance with the literature data.

Table 1: Average levels of nitrogen found in laying hens manure

Author	**Averages of N concentration in laying hens (%)**
LEESON and SUMMERS (2000)	5.00
PROCHNOW et al. (1995)	5.45
AUGUSTO (2007)	7.40

The previous results were for the vertical system, already in the conventional system the mean content of total nitrogen found in manure was of 2.8% (six points of sample collection and three replicates). Recalling the laying hens were 36 weeks old and the manure was being stored since the beginning of the production cycle.

3. CONCLUSION: The time in which manure remains stored in facilities has a direct influence on generation and emission of ammonia by hens. As in the vertical system, if manure removal is carried out frequently, the concentration of NH_3 is lower than in the conventional system, even, these having a lodging capacity, of laying hens, much smaller. Besides the storage time, it is concluded the temperature of the manure also has a direct influence on the emission of ammonia. The longer the storage time, the greater the total mass generated and emitted ; .Given that the natural ventilation is not enough to remove all this pollutant from internal environment, its concentration at the interior of the facilities can be greater.

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EFFECTS OF LINSEED LIPIDS ON METHANE EMISSION OF YOUNG ON A COMMERCIAL FARM

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ABSTRACT: To spread linseed feed on the market as a commercial solution to reduce methane, trials on commercial farms need to be carried out. A commercial feed has been tested in a young bulls fattening farm in Western France. Growing performance and methane production of 2 groups of 10 Charolais young bulls were evaluated during 3 months at the finishing period. Methane emissions were assessed at the same time with 2 Greenfeed Systems. Average Daily Gain (ADG) for the "test group" was not significantly different from the ADG of the "control group": 1692 (±604) g/day vs. 1630 (±213) g/day (p=0.77, t-test). Only 8 young bulls from the "control group" and 4 from the "test group" had enough visits in Greenfeed to ensure a good repeatability in methane measurements: 64 visits in average for "control group" and 44 visits on average for "test group". No significant differences were shown in methane production: 248 g/day vs. 244 g/day (p=0.23) but with the poor attendance in the Greenfeed unit, no conclusions can be drawn at the moment.

Keywords: CH_4, Cattle, Measuring, Commercial farm

INTRODUCTION: Methane is one of the major end products of rumen fermentation and linseed fatty acids have been shown to decrease enteric methane production (Martin et al., 2010). Most of the studies concerning linseed fatty acids effects on methane production have been done in experimental farm with a controlled environment. A commercial feed has been tested on a young bulls fattening farm in Western France.

1. MATERIAL AND METHODS: growing performance and methane production of two groups of 10 charolais young bulls (482 days) were evaluated during 3 months at the finishing period. "control group" with an average body weight of 601±34kg was fed with maize silage, triticale and commercial feed (canola cake, sunflower cake and coproducts). "test group" with an average bodyweight of 603±35kg was fed with maize silage and a commercial feed enriched with 1.8% linseed lipids. methane emissions were assessed at the same time with 2 greenfeed systems (huhtanen et al. 2015) during 12 weeks.

2. RESULTS AND DISCUSSION: average daily gain (adg) for the "test group" was not significantly different from the adg of the "control group": 1692 (±604) g/day vs. 1630 (±213) g/day (p=0.77, t-test). only 8 young bulls from the "control group" and 4 from the "test group" had enough visits in greenfeed to ensure a good repeatability in methane measurements: 64 visits in average for "control group" and 44 visits on average for "test group". no significant differences were shown in methane production: 248 g/day vs. 244 g/day (p=0.23).

Table 1. Performance results for the 2 groups of young bulls

Performance	**Test group n=10**	**Control group n=10**	**Prob**
Initial age (days)	492	474	< 0,05
Initial weigh (kg)	603	601	NS
ADG (g/d)	1692	1630	NS

Table 2. Methane emission results for the 2 groups of young bulls

Methane emission	**Test group n=10**	**Control group n=10**	**Prob**
Number of animals visiting the Greenfeed (GF)	4	8	/
Average number of visits per visiting animal in GF	44	64	NS
Methane (g/d)	244	248	NS

3. CONCLUSION: Due to the poor attendance of animals from the test group, no conclusions can be drawn at the moment about the impact of this commercial feed on methane emissions. Others trials on the same programme will be completed in the months to come to enlarge the numbers of young bulls and develop strategies to enhance attendance. With this experiment, Terrena Innovation confirms its skills in managing Greenfeed trials on commercial farms.

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LONG TERM MEASUREMENTS OF AMMONIA EMISSIONS FROM NATURALLY VENTILATED DAIRY BARN

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ABSTRACT: Tracer gas balancing methods are commonly used to estimate air exchange rates (AER) and emission factors (EF) of naturally ventilated barns (NVB). These methods highly depend on the choice of position for gas sampling. In most cases, NVB are equipped only for measuring AER and EF from one wind direction, which means that all values that where measured for flow regimes deviant from the main wind direction are skipped. We present our new measurement concept, which is designed to measure AER and EF for any kind of wind direction in temporal and spatial high resolution, taking into account adjacent pollutant sources. The objective of the concept was to increase the number of usable samples in a given time period and so to increase the quality of measurements. Two FTIR gas analysers in parallel operation, about 1000m of sampling tubes and more than 100 capillary traps were installed to ensure a representative sampling of NH_3 and CO_2 in high temporal and spatial resolution. Measurements in a NVB in northern Germany were carried out over a period of 7 months with hourly AER derived by CO_2 balance and EF for NH_3. The results suggest that taking into account all wind directions significantly increases the number of usable samples and so the quality of the measurements, which could compensate the increased effort in the measurement design.

Keywords: measuring method, air exchange rate, NH_3, CO_2, wind direction

INTRODUCTION: An experimental barn located in Dummerstorf, Germany, was equipped with an extensive measurement program to investigate air exchange rates (AER) and ammonia emission factors (EF) with a high accuracy. The main focus, besides accurcy, was the increase of data usability. That means, independent of pollutant sources like neighboring barns or manure storage, the AER and EF should be measurable for any approaching flow direction.

Figure 1: Left: Investigated barn. Right: Overview of the barn and its surroundings. The barn is outlined yellow; potential external pollutant sources are outlined red.

1. MATERIAL AND METHODS: The Barn Is 96m Long, 34m Wide And Has A Gable Peak Height Of 11m And Has An Internal Volume Of 25,500m^3. It Houses 375 Dairy Cows, Divided In 4 Groups That Leave The Barn Twice A Day For Milking. The Main Wind

Direction Is South West, With Fluctuating Wind Directions. In The Vicinity Of The Barn, Several Obstacles Are Positioned That Could Act As Possible Pollutant Inflow Sources And Bias The Measurements For Co_2 And Nh_3 Concentrations (See Figure 1). Further Details About The Barn, The Operational Management And The Animals Can Be Found In (Fiedler Et Al., 2014).

1.1. Devices: Gaseous concentrations were measured using two high resolution Fourier-Transform-Infrared- (FTIR-) Spectrometer measurement devices (Gasmet CX4000). Sample air was sucked through PTFE tubes with an inner diameter of 6mm. Every 10m, the tubes had an orifice with a capillary trap, which ensured uniform volumetric flow at every orifice. At the roof of the barn, an ultra-sonic anemometer (USA, Windmaster Pro ultrasonic anemometer, Gill Instruments Limited, Lymington, Hampshire, UK) was installed to measure the wind velocity and direction.

1.2. Setup and Sampling: Inside the barn, six sample lines were installed, so that each side or opening was equipped and two lines were placed in the middle. All lines were positioned at a height of 3m except the second middle line, which was at a height of 5m. Outside the barn, six sampling lines were installed, one on each side or opening of the barn and two for additional measurements of potential hot spots. The duration of measurement per line was 10 minutes and each FTIR was connected to six lines, so that one cycle per hour was measured.

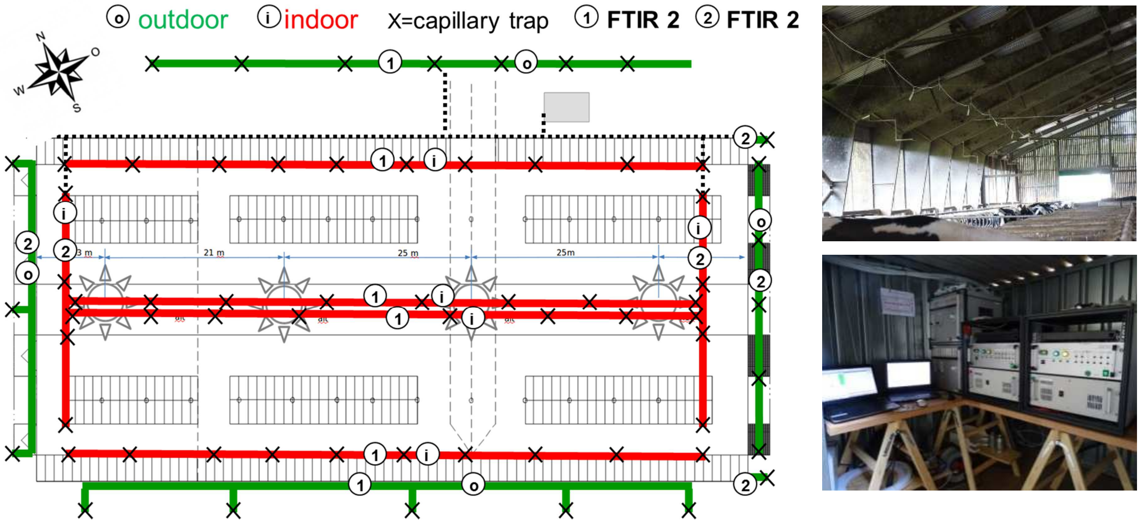

Figure 2. Left: Sketch of the installed sampling lines. Right up: Installed southern sample line in the barn. Right down: FTIR in parallel operation.

Table 1: 1-hour cycle for both FTIR in parallel operation. Suffixes –o and –i indicate outdoor or indoor sample lines, respectively. Extra1 and extra2 are additional lines for future investigations of hot spots.

Time [min]		10	20	30	40	50	60
FTIR 1	**line location**	west-o	north-i	east-o	west-i	extra1	extra2
FTIR 2	**line location**	south-o	north-i	middle1	middle2	north-o	south-i

The FTIR were set to measure pairing sequences of sample lines, i.e. first an outdoor line and directly after that, the corresponding indoor sampling line was measured. Figure 3 depicts the pairing of these sample lines and table 1 shows one cycle of measurement.

1.3. Data processing: The AER and EF where hourly estimated by CO_2 balancing according to the guidelines of (CIGR, 2002). For that, the sampling lines for outside and inside gas concentrations of CO_2 and NH_3 that would be used for the estimations had to be chosen. Hence, the wind data from the USA were analysed and for every hour it was determined whether the main flow was coming from north, east, south or west. With that information, the respective corresponding sample line pair was taken from the database to estimate the AER and EF for every hour.

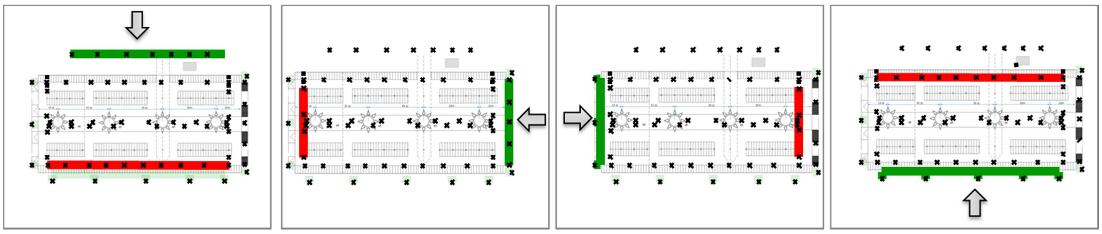

Figure 3: Sampling strategy: The choice of sampling lines as in- or outlet depends on the approaching flow conditions. From left to right: approaching flow from north, east, west or south.

2. RESULTS AND DISCUSSION: The devices measured in the period October 2016 until April 2017. This corresponds to 4165 hours, which is the theoretical maximum number of datasets that could be generated for hourly AER and EF.

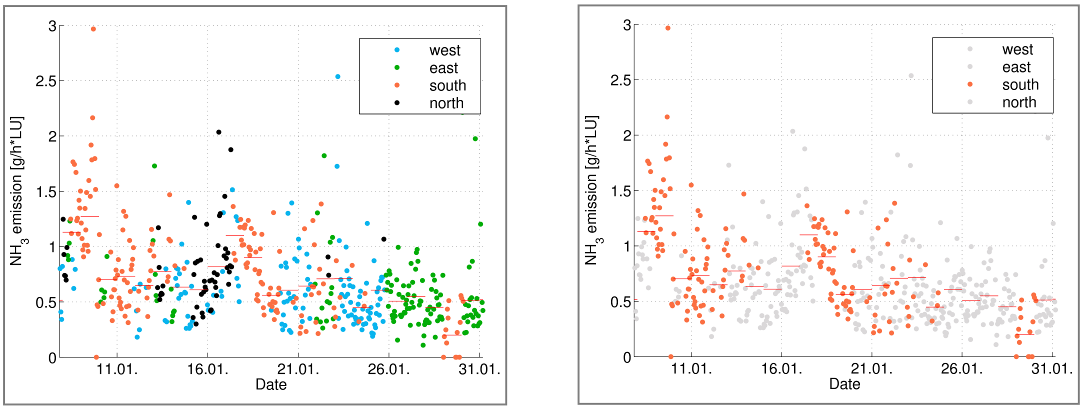

Figure 4: Detail view for a short period. Coloured dots represent the according wind direction, to which the EF was estimated. Left: Taking into account every wind direction. Right: Using only values for the main wind direction.

Data were skipped, if the total difference between inside and outside CO_2-concentration $\Delta c = CO_{2\text{-}i} - CO_{2\text{-}o}$ was less than 20 ppm, if Δc was negative and in periods where the curtains of the barn were closed. Due to a power failure, the devices did not measure for several days. Hence, all in all a number of 1850 hourly measured values for AER and EF were available for the whole period, When taking into account every wind direction. When operating the system only for the main wind direction, these values were reduced to 626 available values, which is a decrease of 66.2%. Figure 4 shows a detailed view of cut out values for non-main direction values. In figure 5, the mean values of all hourly data are sorted by wind direction. The AER is the highest for western winds, which is flow from longitudinal direction. This is surprising, we had expected the highest AER would occur for directions through the largest openings, i.e. northern or soutern. On the other hand, as seen in figure 1, west is the direction, where the flow is not disturbed at all by any obstacles. We will study this phenomena further by analyzing the flow velocity distribution inside the barn.

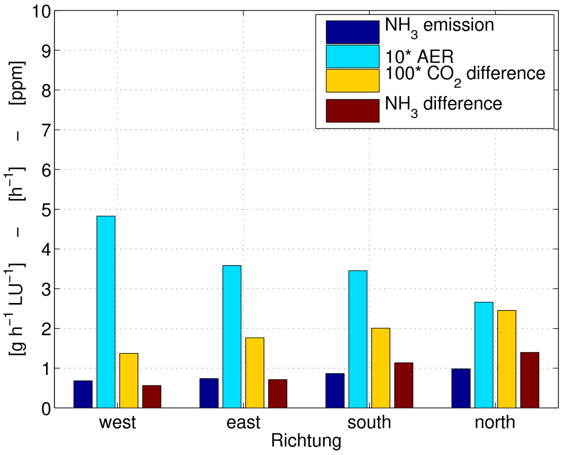

Figure 5: Mean values for NH_3 emissions, AER, CO_2 and NH_3 differences between inside and outside concentrations. Derived by the whole dataset, clustered in respective wind directions.

3. CONCLUSION: Designing the measuring concept to measure any wind direction significantly increases the number of usable measurement values. The increased effort for installing additional sampling lines and measuring devices can be compensated by shorter measurement periods and more accurate estimations of AER and EF due to the increase in the number of measurement values. AER were highest from a longitudinal approaching flow. More invastigations on the dynamical behavior of the flow field need to be done to explain the found dependency of the AER and NH_3 emissions on the wind direction.

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EVALUATION OF AMMONIA RELEASES IN FREE RANGE BROILER PRODUCTION IN THE PAYS DE LA LOIRE

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ABSTRACT: The negative impact of ammonia on environment and human health has led to a strengthening of regulations with the Göteborg protocol. This one imposes a reduction of nitrogen by 4% between 2005 and 2020. To meet these environmental commitments the technical center for studies on atmospheric pollution conduct an inventory of emissions and pollutants annually. However, uncertainties remain concerning the calculation of ammonia emissions for free range productions. The study on the "Evaluation of Ammonia releases in free range broiler production" aims to acquire, a value of ammonia emission taking into account the particularities of free range broiler production. A simplified protocol to measure the ammonia for free range broiler was set. The average of ammonia emission for free range broiler is 23.70 ± 11.53 g NH_3/animal/rearing period. This result is similar to the CORPEN 2006 and ITAVI 2013: 27.90 ± 14.00 g/animal/rearing period.

Keywords: NH_3, Poultry, Measuring method, Inventory.

INTRODUCTION: The Göteborg protocol sets a commitment to reduce nitrogen emissions by 4% by 2020 compared to 2005, and targets of 13% reduction by 2020 are expected under the NEC Directive (2001/81/CE). In order to meet these international commitments made by France, the interprofessional technical center for studies on air pollution (CITEPA) is responsible for carrying out annually an inventory of emissions and polluting substances. It is based on calculations methodologies recognized by international experts (EMEP/CORINAIR, IPCC, etc.) and technical data specific to national agricultural practices (standard value ITAVI 2013) to obtain representative calculations. The CORPEN 2006 (Poultry Group) indicates that an ammonia emission factor of 30% (±15%) is representative of the different poultry production. Applied to the standard value of specific nitrogen excreted by production (ITAVI, 2013), it allows the calculation of the corresponding emission value of ammonia (NH_3 *emission* $_{(g)}$ *= emission factor*standard value*). Based on these indications and the average level of nitrogen excreted (standard value) for free range broiler (ITAVI, 2013), the average ammoniac emissions into the barn are estimated at 27,90 g/animal/rearing period. Given the regulatory context and the limited information available on the methodology used to define the CORPEN 2006 (30% ± 15%), it becomes important to have reliable information on ammonia emissions for the free range broiler production.

In order to meet this demand, a measurement campaign was carried out in the « Pays de la Loire region » which is the first region for the production of « Label rouge ». The practices are representative of free range broiler production. The study was carried out on two stages: development of a protocol of measures adapted to outdoor production (with exit to a range) and easy to use (practically and equipment cost). This protocol adapted to the production of outdoor broiler, made it possible to carry out measurements, and thus to obtain an emission value of ammonia specific to this production.

1. MATERIAL AND METHODS

1.1 Development of a simplified protocol to measure the concentration of ammonia into the barn: The protocol used for measurements in conventional farms is based on the realization of a mass balance and on the method of concentration gradients: indoor and outdoor air samplings at different periods of the rearing period are carried out and the air is then analyzed by infrared spectrometry (analyzer INNOVA®) (Ponchant et al., 2009). In our study, by economical choice and ease of the use, the portable Kimo ToxiRAE2® ammonia detector was chosen. It was necessary to ensure that the ammonia concentrations measured with the detector are similar to the one with the gas analyzer used in the simplified method. This phase was carried out in a pilot farm with two identical buildings. In order to obtain representative measurements of the whole barn (width and length, with and without exit traps, entrance and bottom), the portable ammonia detector was used to make 8 measurements inside and 3 measurements outside the barn (one per sprocket and one at the level of a long side), i.e. one measure per accessible side. The measurements were made about 1 meter above the ground. At the same time, sampling were carried out according to the reference method (Ponchant et al., 2009). Therefore, 2 round trips were carried out in the barn, using SKC FlexFoil® PLUS sample bag and an aquarium pump to collect air in the bag. A round trip outside the barn, along the long side was also carried out. The air samples were then analyzed by the gas analyzer INNOVA® Airtech Instrument 1412 Photoacoustic Field Gas Monitor giving an ammonia concentration (converted in ppm) every minute. The average concentration of ammonia obtained by the analyzer in each barn (10 analyzes/barn) was compared with the average concentration obtained with the ToxiRAE2® detector in the building (8 measurement points/barn).

In the case of free range farms, it was necessary to determine the number of follow ups required during the rearing period. To obtain the kinetics of evolution during this period, daily measurements were carried out in the 2 pilot barns, with the portable ammonia detector. The measurements were taken 1 time per day. In order to obtain an estimate of the average ammonia concentration in the barn, the 8 measurements were carried out, distributed throughout the building. These series of measurements made possible to identify the evolution of the concentrations of ammonia in the building and thus to identify the number of follow-ups needed during the rearing period to obtain a representative ammonia concentration.

1.2. Calculation of the emission of ammonia in broiler production in the Pays de la Loire: The study took place in 2015 and 2016 in Pays de la Loire. A total of 22 broiler barn « Label rouge » were monitored during the summer period and 13 of them during the winter period (it was not possible to carry out a second follow up of the 9 others). 4 productions organizations were represented. The farms monitored were characterized by buildings of 400 m^2 in static ventilation (transversal or high extraction) with clay floors.

To calculate an emission of ammonia in g/animal/rearing period it was needful to determine the ventilation rate in the barn. For the calculation, it is necessary to collect: the broiler weight, temperature and hygrometry inside and outside the barn. These parameters make possible to calculate the energy inputs and losses in the form of heat in the barn according to the following formula (Hassouna et al, 2005): Heat inputs (in W) = Heat losses (in W): AI + HI + LF + SI = WL + VL + EV with : AI : inputs from animals ; HI : Inputs by heating ; LF : Fermentation of litter; SI : solar inputs (negligible) ; WL : Losses by the walls ; VL : Ventilation losses ; EV : Evaporation losses of water (negligible). VL corresponds to the enthalpy in W/animal lost by ventilation. The ventilation rate (m^3/h/animal) corresponds to the ratio VL/energy difference (J/kg dry air) calculated at the different temperatures and hygrometries between the indoor and outdoor air, multiplied by its density, per hour. Emissions of ammonia can then be calculated using the following formula: Emission = Ammonia concentration x Ventilation rate.

In our study, the weight of the animals was obtained from the animal weighing by the breeder. The temperature and humidity measurements were carried out inside and outside the barn using a KIMO AMI 301® probe, according to the same measurements of ammonia. In order to obtain the cumulative emission over the total duration of the rearing period, it was necessary to estimate the emission for the days between the visits. For this purpose, a linear estimate was made before the first measurement day, and from the first visit to the end, a polynomial estimate allowed us to approximate the daily emission. Thus, the total ammonia emission in g/animal/rearing period corresponds to the sum of the emissions estimated daily. The ammonia emission value calculated in free range broiler was then compared to the one calculated from the excreted nitrogen emission factor of 30 % (±15%) (CORPEN, 2006) and the average level of nitrogen excreted in the barn (standard value) by free range broiler (ITAVI, 2013).

1.3. Season and ammonia: To evaluate the season effect on ammonia emission, a Wilcoxon comparison test was carried out at α=5% risk on summer and winter data.

2. RESULTS AND DISCUSSION

2.1. Development of a simplified protocol: There was no significant difference in ammonia concentration measurements using the portable ammonia detector (1,61 mg NH_3/m^3) or the gas analyzer (1,63mg NH_3/m^3) (P=0,98). The portable ammonia detector can replace the gas analyzer in the simplified protocol.

Regarding the location of measurement points in the building, the concentration of ammonia differs according to the place of sampling. Indeed, a measurement near the long side with the exit trap is on average 0,90 ± 0,07 ppm against 1,40 ± 0,11 ppm on the opposite long side. In addition, a difference was found between a measurements close to the airlock (0,72 ± 0,11 ppm), a mid-barn measurement (1,40 ± 1,12 ppm) and a measurement at the end of the barn (1,34 ± 0,11 ppm). The results are similar in both pilot barns. It is therefore important to retain these 8 measurements points as they are representative of the average transverse and longitudinal ammonia concentration in a free range barn. This step validated the location and the number of measurements.

To obtain a concentration value of ammonia corresponding to daily measurements, one measure must be taken before the opening of the traps, around 35 days of age, and another after the opening of the traps towards 50 days. To take into account the concentration of ammonia at start up, a measurement must be carried out around 20 days since the emission of ammonia from litter begins around 15 days (CORPEN, 2006). A last measurement will be carried out around 65 days to estimate the concentration of ammonia at the end of the rearing period. This represents a total of 4 measures (20-35-50 and 65 days). Results were similar between the two measurement protocol ($p=0.76$) thus, it is possible to obtain a concentration value of ammonia close to that obtained with daily measurements.

2.2. Ammonia emissions inside the barn from free range broiler: The average concentration of ammonia (ppm) into the barn of free range broiler is 5,80 ± 4,47 ppm (min : 1,60 ; max : 21,20) with an uncertainty of calculation of 1,16 ppm due to the 20% uncertainty of the portable ammonia detector. The average ammonia emission was 23,70 ± 11,53 g of NH_3/animal/rearing period (min : 9 ; max : 52) with a calculation uncertainty of 7,11 g/animal/rearing period corresponding to an error of 30 % due to the possible approximation of the heat generated by the animals in the barn, equivalent to 10,36 ± 3,11 g of NH_3/kg body weight/rearing period. Considering the variability encountered on livestock emissions, this result is close to the value obtained from the information from the CORPEN 2006 and ITAVI 2013 : 27,90 g of NH_3/animal/rearing period with an uncertainty of 14 g/animal/rearing period because the excreted ammonia is within a range of 15 and 45 % of the outdoor excreted nitrogen that is 88 g/animal.

2.2. Season effect: In summer period, the ammonia emission value is 27,30 ± 12,53 g/animal/rearing period (min : 12,90 ; max : 51,90) with a calculation uncertainty of 8,19 g/animal/rearing period. The winter ammonia emission is 20,00 ± 10,26 g/animal/rearing period (min : 9,30 ; max : 50,10) with a calculation uncertainty of 6 g/animal/rearing period. Summer and winter emissions are significantly different ($p < 0{,}01$). This can be explained by a greater activity of the animals during the summer period.

3. CONCLUSION: This study resulted in a simplified measurement protocol for ammonia concentration in free range broiler barn using an easy equipment (portable ammonia detector) and responding to specificity of free rang production. This protocol can be easily used by everyone to mesure ammonia concentration and then calculate ammonia emissions. An average ammonia emission value in the barn for free range broiler of 23,70 ± 11,53 g of NH_3/animal/rearing period calculated from measurements in « Pays de la Loire ». These results are consistent with the calculated data from the CORPEN, 2006 and ITAVI, 2013.

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DATABASE CONSTRUCTION FOR META-ANALYSIS OF METHANE EMISSIONS BY RUMINANTS RELATED TO FEED

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ABSTRACT: As part of the global network project (anr-13-jfac-0003-01), led by a. n. hristov (the pennsylvania state university, usa), a database containing more than 6000 individual animal (including dairy cattle, beef cattle, sheep and goat) data from 11 international research teams on methane (ch_4) and ammonia (nh_3) emissions, and other metadata (intake, diet composition, animal parameters) was built. within this database, a sub-dataset specific of french data, with 597 observations in 13 studies from inra theix herbivores research centre will be used to evaluate the performances of extant predictive models of ch_4 emission (built with different statistical approaches). in the present paper, we report first the features of the sub-dataset, then the procedures of recoding and completing the noisy, inconsistent and incomplete data. different dietary treatments were classified into five ch_4 mitigating strategies: increased concentrate proportion, enhancing forage quality, lipid supplementation, plant extract supplementation and other additives. ipcc (2006) model of ch_4 emission was evaluated with the french sub-dataset. overall, ipcc model presents a large random error, when applied to this french dataset. furthermore, 33% of ch_4 variation is not explained by gei used by ipcc model (2006). further work will focus on the comparison of extant predictive models, considering the different mitigating strategies tested in our sub-dataset.

Keywords: CH_4, emission factor, mitigating strategy, ruminant

INTRODUCTION: In the context of the global network project, a large database was built with individual data on ch_4 emission of ruminants from 11 international research teams. one of the aims of the project is to model ch_4 emission by ruminants according to their feed characteristics using a meta-analytical approach and to compare different extant models. these research teams used different experimental protocols, animal categories, diets, ch_4 measurement methods and other analytical methods. they were asked to fill the same database template in order to compile all the data together. however, the database presents structural heterogeneity and contained missing values. consequently, recoding and completing the database are mandatory in order to properly define the meta-design of the database prior to statistical analyzes. in this paper, we illustrate database pre-processing methodology on the data from inra umr1213 herbivores research centre**,** to prepare a sub-dataset for comparing the performances of extant predictive models of ch_4 emission built with different statistical approaches. the first model evaluated is the ipcc (2006) tier 2 model.

1. MATERIAL AND METHODS

1.1. Data collection: INRA's data were collected from 13 studies (597 observations) using 3 experimental designs (randomized block: 4 studies, 52.8% of data; Latin square: 8 studies, 43.4% of data and crossover design: 1 study, 3.8% of data), 3 animal categories (beef cattle: 4 studies, 40.4% of data; dairy cattle: 4 study, 29.3% of data and sheep: 5 studies, 30.3% of data), 50 different dietary treatments, 2 methane measurement techniques (open-circuit chamber: 2 studies with sheep and dairy cattle (10.7% of data) and SF6: 11 studies, (89.3%).

1.2. Data processing: Selection, completing and coding: Data were discarded when CH_4 or dry matter intake (DMI) values were missing. Missing values of metadata (with respect to dietary chemical composition) were not estimated with the help of the respective national feed tables in this study. Heterogeneous names or unit values were recoded homogeneously. Then, the 50 dietary treatments were classified based on their forage and concentrate content and into 5 CH_4 mitigating strategies (A to E) according to reviews of literature (Doreau et al., 2011; Hristov et al., 2013). There were: (A) increased concentrate, (B) enhancing forage quality, (C) lipid supplementation, (D) plant extract supplementation, and (E) other additives.

1.3. Model evaluation: Statistical analyses were performed with R (3.3.2, (R Core Team, 2016)), and graphical descriptive figures with Minitab (Minitab Inc. 2013).

The IPCC (2006) model was applied to the sub-dataset (with no lab effect tested) indicating the gross energy intake (GEI, MJ/d) of animals to estimate CH_4 values, based on the following equation:

$$CH_4 \text{ (Kg/d)} = \left((Ym/100) * GEI \text{ (MJ/d)}\right)/55.65$$

With Ym=3% for feedlot cattle, Ym=4.5% for lambs<1 year, Ym=6.5% for other animal categories. The factor 55.65 (MJ/kg CH_4) is the energy content of methane.

Determination of model performances based on the following 3 criteria was performed: with y_i and $\hat{y}_i$ are respectively observed and predicted values of CH_4 emission for animal *i*; SS_{res} is the regression sum of squares; SS_{res} is the total sum of squares proportional to the variance of the data; s is the least squares regression coefficient.

1) Coefficient of determination (R^2)

$$R^2 = 1 - \frac{\sum_1^n (y_i - \hat{y}_i)^2}{\sum_1^n (y_i - \bar{y}_i)^2} = 1 - \frac{SS_{res}}{SS_{tot}}$$

2) Root Mean Squared Prediction Error% (RMSPE%)

$$RMSPE = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^n (y_i - \hat{y}_i)^2}}{\frac{1}{n}\sum_{i=1}^n y_i}$$

3) Decomposition of Prediction Error (Bibby, 1978)

1. ECT:squared mean bias of the prediction: $(\bar{y} - \bar{\hat{y}})^2$
2. ER:line bias (slope): $var(\hat{y}_i) \times (1 - s)^2$
3. ED:random variation: $var(y_i) \times (1 - R^2)$

2. RESULTS AND DISCUSSION:

2.1. Descriptive analysis: The distribution of descriptive values for chemical contents, DMI and CH_4 by animal category is given in figure 1. We can observed that, for each animal category, the values for DMI and CH_4 were normally distributed; the values for chemical contents were in general normally distributed except for some diet rich in protein, lipid, fibre or starch, reflecting the different dietary strategies used in the studies.

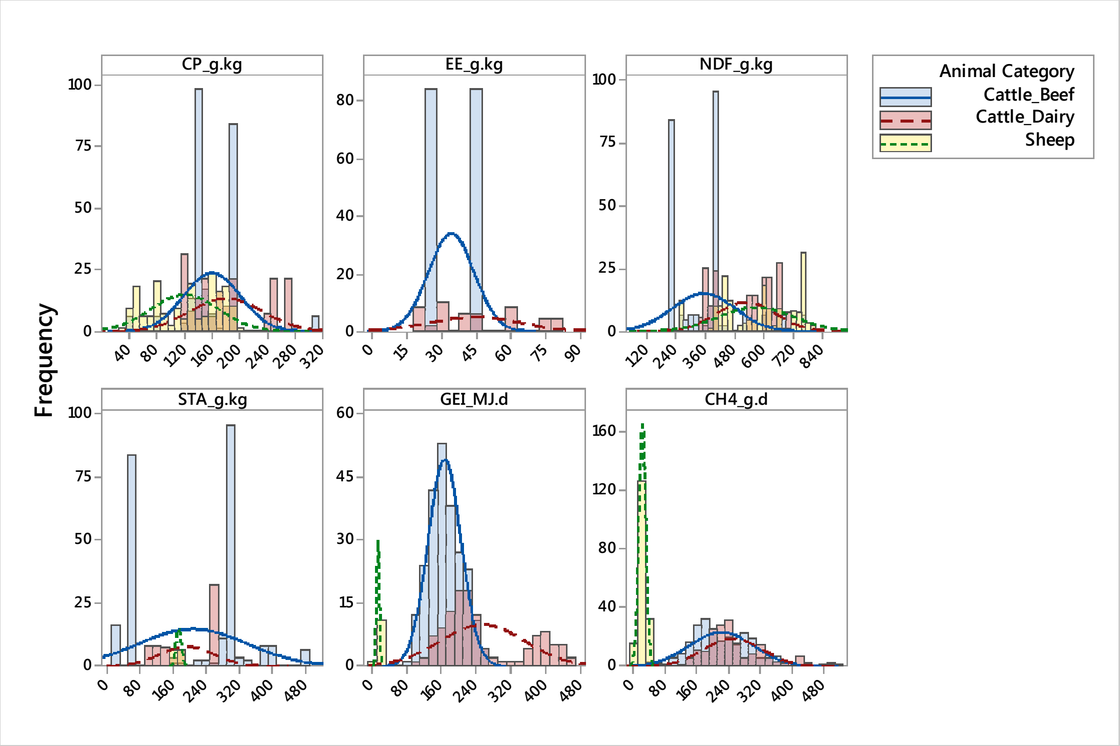

Figure 1. Distributions of descriptive values for chemical contents and CH_4 by animal category.

The descriptive values (mean, standard deviation (S.D.)) of the dataset are presented for each animal category and dietary strategy (Table 1). Those values are in the range observed in the study of Sauvant and Nozière (2016) and present some discrepancies linked to the feeding practises for the different animal category of the studies.

Table 1. Main descriptive parameters of the database by CH_4 mitigating strategies [mean (S.D.)].

Strategy	**Control**			**A**		**B**			**C**	**D**		**E**
Animal category	**Beef Cattle**	**Dairy Cattle**	**Sheep**	**Beef Cattle**	**Sheep**	**Beef Cattle**	**Dairy Cattle**	**Sheep**	**Dairy Cattle**	**Dairy Cattle**	**Sheep**	**Dairy Cattle**
N of stu.	3	4	4	2	1	2	1	3	2	1	1	2
N of obs.	27	24	47	180	12	34	103	99	32	8	23	8
CP (g/kg)	179.6 (73.70)	145.6 (24.02)	114.9 (35.91)	167 (24.17)	53.2 (0.47)	110.9 (39.54)	206.1 (51.43)	121.3 (50.98)	156.3 (22.30)	120 (4.28)	167.8 (14.38)	122 (0.00)
EE (g/kg)	-	25.4 (3.40)	-	34.3 (9.88)	-	-	-	-	54.6 (16.04)	-	-	19 (0.00)
NDF (g/kg)	425.5 (57.20)	443.2 (98.00)	634.6 (122.46)	316.3 (90.47)	263.7 (3.29)	501.0 (197.40)	619.9 (46.10)	567.2 (145.49)	366.2 (14.45)	401 (1.07)	605.6 (23.43)	402 (0.00)
STA (g/kg)	135.2 (135.20)	214.1 (41.50)	-	199.2 (125.48)	174.4 (6.37)	323.3 (71.07)	-	-	152.6 (61.90)	263.5 (0.53)	-	257 (0.00)
DMI (kg/d)	8.5 (1.84)	15.3 (4.82)	1 (0.35)	8.7 (1.92)	0.8 (0.18)	9.6 (2.20)	9.8 (2.69)	1.1 (0.39)	18.3 (3.89)	11.8 (0.74)	1.2 (0.29)	12.1 (0.99)
GEI (MJ/d)	159.4 (40.87)	308.2 (97.2)	-	167.7 (36.29)	13.82 (3.22)	177.7 (43.75)	195.7 (47.11)	-	358.5 (86.10)	200.3 (15.19)	-	201.1 (16.38)
CH_4 (g/d)	165.0 (41.59)	321.4 (92.80)	24.7 (9.16)	234.1 (84.83)	10.5 (4.56)	209.9 (48.43)	216.9 (40.76)	22.4 (7.61)	315.6 (70.20)	250.2 (64.13)	25.2 (6.55)	228.6 (23.95)
CH_4/DMI (g/ kg DMI)	19.8 (5.17)	21.4 (3.32)	27 (12.67)	27 (8.65)	13.6 (3.47)	22 .4 (5.07)	23.3 (6.16)	20.4 (6.84)	17.4 (2.11)	21.2 (5.17)	22.6 (6.8)	18.9 (1.96)
CH_4/GEI (% GEI)	5.9 (1.60)	7.0 (1.24)	-	7.8 (2.47)	4.2 (1.08)	6.7 (1.50)	6.9 (1.59)	-	5.0 (0.72)	6.9 (1.56)	-	6.3 (0.66)

CP, Crude Protein; EE, Ether Extract; NDF, Neutral Detergent Fiber; STA, Starch ; DMI, dry matter intake in kilogram per day; CH_4, methane emission in gram per kilogram of DMI; Mitigating strategies: (A) increased concentrate, (B) enhancing forage quality, (C) lipid supplementation, (D) plant extract supplementation, and (E) other additives.

2.2. Model evaluation

The IPCC (2006) model was applied to the sub-dataset (n= 367 data) where GE content of the diet (g/kg DM) was indicated (38.5% of missing values). The CH_4 (g/d) predicted values were plot against the CH_4 g/d observed values (Figure 2). For lower CH_4 range (<270 g/d) IPCC underestimated CH_4 emission, whereas for higher CH_4 range IPCC overestimated it.

Furthermore, the performance of the IPCC model was estimated based on the decomposition of the variance (Table 2). The main error is due to the random variation of the model, indicating that CH_4 variations is not fully explained by GEI factor of the IPCC model (2006). CH_4 variations could be further explained by other variables, like the dietary content of the diets rich in lipids or concentrate for example.

Table 2. Evaluation of the prediction performance of the IPCC model (2006).

	RMSPE	**RMSPE%**	**ECT**	**ER**	**ED**	**R^2**
CH_4 g/d	72.91	31.4%	1.97	16.67	54.28	0.35

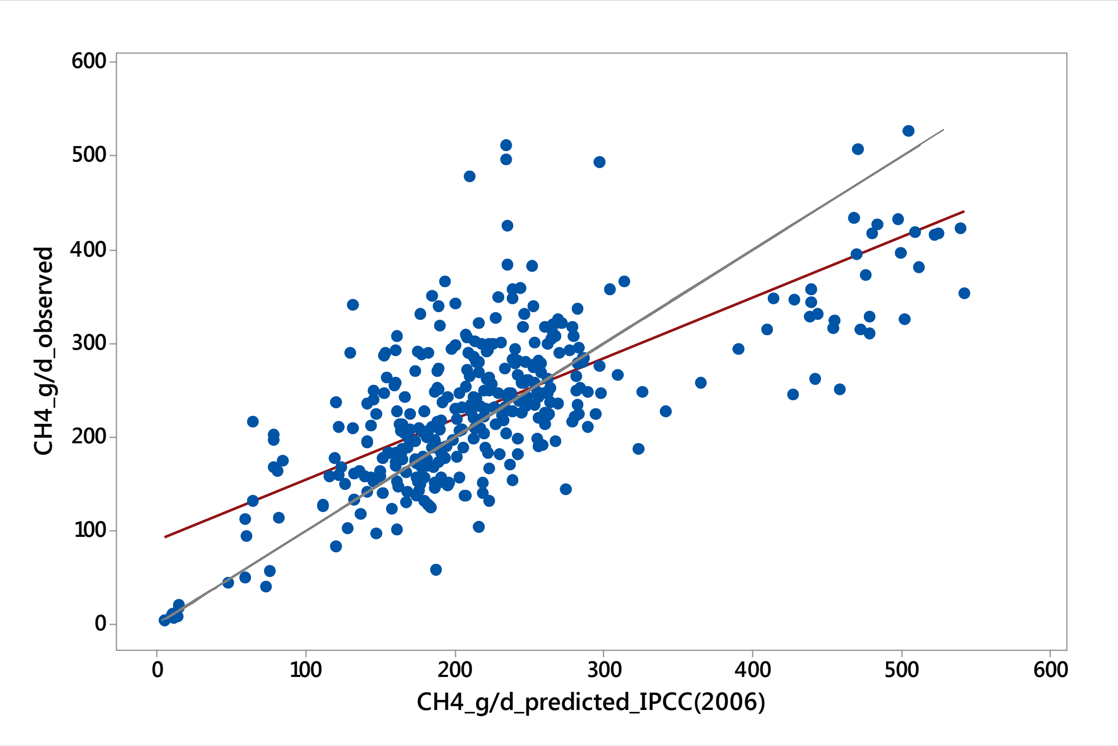

Figure 2. Predicted vs. observed value plots based on IPCC (kg/d per cow) prediction equations using GEI level. Red line represents the regression equation: CH_4_observed g/d = 89.20 + 0.650*CH_4_kg/d_predicted_IPCC (2006) N. studies = 9, N. treatment = 29, N=367, adjusted R2=0.51, P value =0.001. Black line represents y=x.

3. CONCLUSION: It was possible to collect individual CH_4 data from 13 french studies conducted at inra umrh since 2004. The descriptive statistics showed that the meta-design was unbalanced. Indeed, most of the data concerned beef and sheep animals fed very different diets with mitigating strategies. IPCC (2006) tier 2 model was evaluated on this sub dataset, and large random variation was observed. Furthermore, GEI did not fully explain all CH_4 variations. This indicates that further work and models evaluation are required and other variables must be included to fully account for all CH_4 variation of this dataset, especially the dietary composition.

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EMISSIONS OF GASES IN THE PROCESS OF ACCELERATED COMPOSTING IN TREATMENT OF DEAD PIG CARCASS

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ABSTRACT: This work aimed to measure the gaseous emissions from the process of composting dead pigs in rotary drums reactors. Three reactors of 4 m^3 were used, in which pig carcasses and sawdust were arranged. The study comprised 3 treatments, regarding the time which reactor remained in pause between the rotation movements: 1 hour (reactor A), 2 hours (reactor B) and 4 hours (reactor C). To evaluate the gaseous emissions, a photoacoustic analyzer (INNOVA 1412) was used. CO_2 emission was responsible for the greatest carbon loss in all treatments. Most of the nitrogen gas loss was from N_2 emission for all treatments.

Keywords: rotating drums reactors, gaseous emissions, GHG, ammonia, pig carcasses.

INTRODUCTION: Proper disposal of carcasses of animals that die in production cycles is necessary to avoid environmental damage, or even to human health (BASS *et al.*, 2012). Among the alternatives, composting emerges as a suitable method for the treatment of organic wastes (HUANG *et al.*, 2006; TROY *et al.*, 2012). The objective of this study was to evaluate the gaseous emissions (GHG and NH_3) in the composting process, in rotary drum reactors, as a technology for the treatment of dead pig carcasses.

1. MATERIAL AND METHODS: For the experiments, three reactors, each with a volume of $4m^3$ and a continuous ventilation system, were used, and all the reactors were programmed for a period of 24 minutes cylindrical body movement (aeration). The time of stopping of the reactors, between each movement time, originated the three treatments: in the first one (reactor a) the pause time was 1 hour; in the second (reactor b), 2 hours; and in the third treatment (reactor c) the reactor remained in pause for 4 hours between each time of movement. In each reactor, a mass of 188 kg of pig carcasses and 300 kg of sawdust (1:1.6) was used, filling 50% of the reactor volume. The composting process occurred over a period of 19 days, with ibutton type temperature meters being allocated within each reactor. Throughout the study, samples of decomposable material were collected for analysis of carbon, nitrogen, dry matter and phosphorus. The concentrations of CH_4, CO_2, N_2O AND NH_3 in the air at the input and output of the reactor were determined using a photoacoustic equipment (innova 1412). The emissions determined from the calculation principle of the concentration relations method (Paillat, 2005; Robin et al., 2010), which assumes that all carbon loss in the material during the composting process occurred through the emission of CO_2 and CH_4 (equation 1). In order to calculate the emission, the concentration gradient of each gas between the output air and the reactor input air (equation 2) must be known. This gradient correlates with the CO_2 emission (equation 3), which is determined by the loss of carbon in the material (equation 4).

$$\mathrm{Loss_C} = \mathrm{Emission_{C-CO_2}} + \mathrm{Emission_{C-CH_4}} \tag{1}$$

$$\mathrm{G_{gas}} = \mathrm{M_{output}} - \mathrm{M_{input}} \tag{2}$$

$$\mathrm{Emission_{gas}} = \mathrm{Emission_{C-CO_2}}.\left(\frac{\mathrm{G_{gas}}}{\mathrm{G_{C-CO_2}}}\right) \tag{3}$$

$$\mathrm{Emission_{C-CO_2}} = \mathrm{Loss_C}/[1 + \left(\frac{\mathrm{G_{C-CH_4}}}{\mathrm{G_{C-CO_2}}}\right)] \tag{4}$$

Being, $Loss_C$: materi loss of carbon in the mass of the material (kg); $Emission_{C-CO_2}$: C-CO_2 emission (kg); $Emission_{C-CH_4}$: C-CH_4 emission (kg); G_{gas}: concentration gradient for each of the gases (N-NH_3 ou N-N_2O) (mg/m^3); M_{output} : median of the concentrations observed in the reactor output air (mg/m^3); M_{input}: median of the concentrations observed in the reactor input air (mg/m^3); G_{C-CH_4}: C-CH_4 concentration gradient (mg/m^3), G_{C-CO_2}: C-CO_2 concentration gradient (mg/m^3). The emission of N_2 was determined by the difference between the amount of nitrogen lost in the mass of the material during the composting process and the sum of the emissions of N-NH_3 and N-N_2O.

2.**RESULTS AND DISCUSSION:** For the nitrogen emissions, it was observed that the greatest loss of this element occurred through the emission of N_2, verifying a complete nitrification/denitrification process. The N_2 emission represented 63.20, 83.22 and 90.91% of the total nitrogen loss in the mass of the material, respectively, for the reactors a, b and c (figure 1-a). The high nitrogen emission was caused by the low C/N ratio of the mixture prepared in the reactors (Huang, 2004). In terms of n-nh3 emissions, it was observed that reactor a was responsible for the largest emission of this gas, emitting a total of 0.61 kg (36.26% of total n emitted), followed by reactor b and c, 0.35 kg (16.54%) and 0.19 kg (8.8%), respectively. For the N-N_2O emissions, it was found that they were quite low: 0.54%, 0.24% and 0.29% of the total n lost for reactors a, b and c, respectively, which can be justified by their conversion to n2 in the denitrification process.

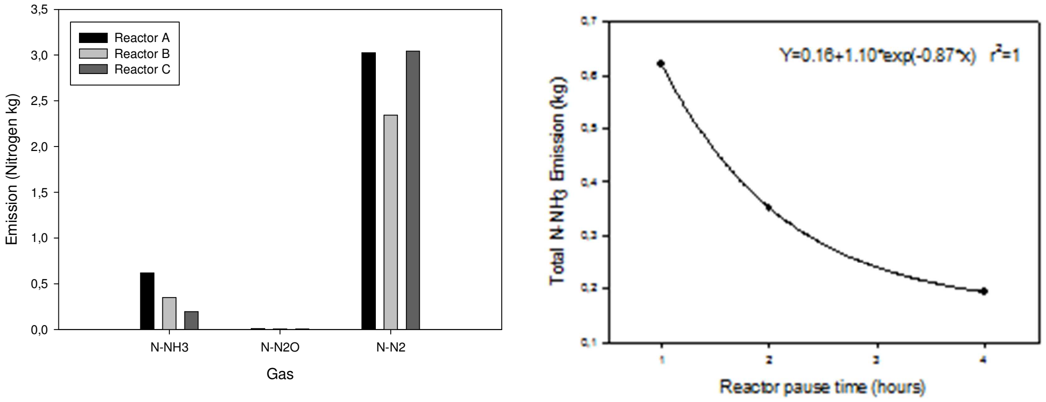

Figure 1. a) Total emission of nitrogenous gases; b) Correlation between N-NH_3 emission and reactor pause time.

For the N-NH_3 emissions, it was verified that with the increase of the pause time between the rotations of the reactor, the reduction of the emission of this gas occurred. By constructing a correlation on this effect, we obtained a decreasing exponential curve, with $r^2 = 1$ (Figure 1-b). This relationship is probably caused by the fact that Reactor A, because of a shorter pause time, has a greater number of material stirring, which facilitates the release of this gas, while the other reactors have the same effect. For C-CO_2 emissions, it was found that Reactor C presented the highest emission, totaling 15.54 kg of this gas during the whole process, followed by reactors B and A, which totaled an emission of 11.99 and 10.02 kg, respectively (Figure 2-a).

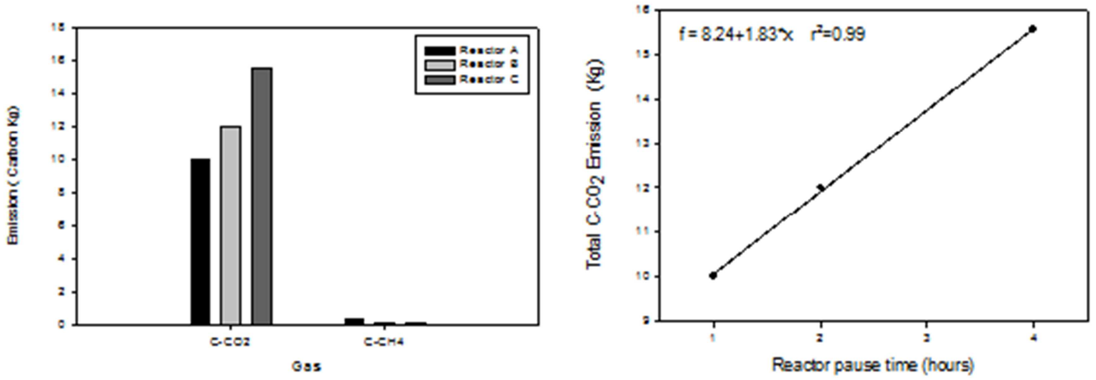

Figure 2. a) Total emission of carbon; b) Correlation between C-CO_2 emission and reactor pause time.

Correlating the emission of C-CO_2 with the rest time of the reactor, a positive linear adjustment was obtained, with $r^2 = 0.99$ (Figure 2-b). This behavior of the emission of C-CO_2 with the time of pause of the reactor, is in agreement with the temperatures measured in the material in compost. The reactors with the highest C-CO_2 emissions were the ones that obtained the highest temperature values and remained longer with high temperatures, indicating a greater biological action, and consequently a higher C-CO_2 generation. For C-CO_2, it was found that Reactor C presented the highest emission, totaling 15.54 kg of this gas during the whole process, followed by reactors B and A, which totaled an emission of 11.99 and 10.02 kg, respectively (Figure 2-a). The total nitrogen loss in the mass of the material was 1.71, 2.13 and 2.20 kg, whereas for the carbon a loss of

10.39, 12.09 and 16.58 kg was observed for the reactors A, B and C, respectively (Table 1). There was a reduction of 5, 8 and 11% in the dry matter disposed in reactors A, B and C (Table 2). Already, the water reduction reached 84%, 79% and 78% for the same sequence of reactors, which is expected, because in reactor A, the rotation of the reactor was more frequent (1 hour), which favors Evaporation of water. The process was validated using the mass of phosphorus as a testimony, since this element cannot be volatilized or lost by other means. The difference between the mass of phosphorus in the material placed and removed from the reactor was 4%, -2% and 11% for the reactors A, B and C, respectively, and these values were close to the maximum, stipulated by Paillat et al. (2005), 10%.

Table 1: Material balance in the reactor for carbon and nitrogen.

Parameter	**Carbon**			**Nitrogen**		
Treatment	**A**	**B**	**C**	**A**	**B**	**C**
Input (kg)	111,05	111,05	111,05	5,71	5,71	5,71
Output (kg)	100,66	98,96	94,47	4,00	3,58	3,51
Loss (kg)	10,39	12,09	16,58	1,71	2,13	2,20
Loss (%)	9%	11%	15%	30%	37%	39%

Table 2: Material balance in the reactor for water, dry matter and phosphorus.

Parameter	**Water**			**Dry matter**			**Phosphorus**		
Treatment	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Input (kg)	262,81	262,81	262,81	225,19	225,19	225,19	0,78	0,78	0,78
Output (kg)	43,14	54,47	56,52	212,88	206,39	199,94	0,74	0,79	0,86
Loss (kg)	219,67	208,34	206,28	12,31	18,80	25,25	0,03	-0,01	-0,08
Loss (%)	84%	79%	78%	5%	8%	11%	4%	-2%	-11%

3. CONCLUSION: the process of composting in biological reactors proved to be adequate as a technology for the destination of pig carcasses. it was concluded that there is a relation between c-co_2 and n-nh_3 emissions and the pause time of the reactors, the longer the pause time, the greater the emission of C-CO_2 and the lower emissions of N-NH_3.

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THE EMISSIONS OF GREENHOUSE GASES FROM EWE FARMING IN THE REGION OF SLOVAKIA IN 2015

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ABSTRACT: The aim of this study was to determine the emissions of greenhouse gases from ewe farming in the territory of Slovakia. We calculated methane emissions from enteric fermentation and manure management as well as the nitrous oxide emissions from manure management and grazing. The average values of methane emission factors from enteric fermentation and manure management amounted to 10.21 kg and 0.29 kg per ewe and year, respectively. The emission factors of nitrous oxide from housing and grazing were 0.005 kg and 0.01 kg per ewe and year. The total emission amounts of methane from ewes' enteric fermentation and manure management achieved 1,633.22 t and 46.64 t per year in the territory of Slovakia. The total emission amounts of nitrous oxide from their housing and grazing reached 11.600 t and 23.584 t per year. The ewes produced 1,679.86 t of methane and 35.184 t of nitrous oxide in the territory of Slovakia in 2015.

Keywords: ewe, enteric fermentation, manure management, housing and grazing, emission factors, methane, nitrous oxide

INTRODUCTION: Sheep farming is typical for Slovak agriculture mainly in the region of Central and Eastern Slovakia. Currently, extensive farming with pasture from spring to autumn dominates. Like other farm animals, the sheep produce the greenhouse gases (GHG) which are subject to national inventory of GHG. The emission of methane (CH_4) from enteric fermentation and also emissions of methane and nitrous oxide (N_2O) from manure management are monitored.

Methane is the second most important greenhouse gas after carbon oxide (Hindrichsen et al., 2006). It is formed by anaerobic digestion and digestion of organic material (Dustan, 2002). The enteric fermentation in ruminants and rice fields are the main sources of methane. Anaerobic fermentation of animal wastes accounts for only 8 % (Olesen et al., 2006). Nitrous oxide is produced by the microbial transformation of crude proteins in the excrements during their storage and application (Oenema et al., 2005). Agriculture represents its main source in the region of Slovakia (59 % of agricultural lands, 12 % of animal wastes). Both of these gases have a high global warming potential (CH_4 - 21 times, N_2O - 310 times higher than carbon oxide) (Hardy, 2003) which influences the increase of greenhouse effect and therefore it is necessary to reduce them.

1. MATERIAL AND METHODS: For determination of methane and nitrous oxide emissions from ewe farming, we used tier 2 methodology of 2006 ippc guidelines for national greenhouse gas inventories (Dong et al., 2006). We divided the territory of slovakia into 8 regions in which we calculated CH_4 and N_2O emissions. for calculation of emissions, we had to find out the number of animals and CH_4 and N_2O emission factors in individual regions.

In the case of CH_4 emissions from enteric fermentation, we determine CH_4 emission factors in each region from need of gross energy (GE) and methane conversion factor (Ym). For calculation of GE, we needed to identify the amount of net energies for maintenance, activity, milk and wool production, pregnancy, as well as digestibility (DE) of feed ration. For calculation of net energies, we used some information from farmers (live weight, walk up meters per day, annual milk and wool production, duration of grazing, number of lambs per sheep). The Ym value was default. We multiplied detected CH_4 emission factor by the number of ewes in the region. We obtained CH_4 emission from enteric fermentation in region. We repeated the same in each region. Then we summed the emissions from all regions. We determined the total CH_4 emission from enteric fermentation in the territory of Slovakia.

In the case of CH_4 emissions from manure management, we used for calculation of emission factor the values of DE, GE, methane conversion factor (MCF - solid storage) and fraction of solid manure storage on total manure management. Detected emission factor we multiplied by the number of ewes in region. We identified CH_4 emission from manure management in region. Then, we repeated all steps as in the case of CH_4 emission from enteric fermentation.

We determined emissions of N_2O from housing and grazing. For calculation of N_2O emission from housing in region, we needed to find the number of ewes, annual nitrogen excretion per ewe and fraction of solid storage manure (housing) on total manure management. Emission factor for solid storage of manure was default. Then we summed emissions from all regions. We obtained N_2O emission from housing in the territory of Slovakia. We also repeated these steps in the case of N_2O emission calculation from grazing. However, we used for calculation emission factor for grazing (default) and fraction of grazing on total manure management. Then N_2O emission were obtained from grazing in the territory of Slovakia. At the end, we summed N_2O emission from housing and grazing in the territory of Slovakia. So we identified total N_2O emission from ewe farming in territory of Slovakia.

2. RESULTS AND DISCUSSION: The course of CH_4 emissions from enteric fermentation is showed in table 1. Emission differences among individual regions were related to differences in number of animals and emission factors. The differences in the emission factors were tied to the amount of milk and wool produced, because the other parameters entering to the calculations were equal. Higher milk production required higher net energy intake for its production. The same was true in the case of wool production (higher wool production - higher net energy intake for its production). The largest CH_4 emission from enteric fermentation was found in region of Žilina in which the largest number of animals was detected.

Table 1. CH_4 emissions from enteric fermentation in individual regions of Slovakia and within Slovakia

Region	**Ba**	**TT**	**TR**	**NR**	**ZA**	**BB**	**PO**	**KE**	**SK***
Ewe (number)	**221**	**429**	**16,085**	**3,799**	**45,908**	**43,060**	**36,471**	**13,962**	**159,935**
Live weight (kg)	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Milk yield (kg day^{-1})	0.34	0.40	0.48	0.29	0.41	0.38	0.36	0.33	0.39
DE (%)	65.04	65.04	65.04	65.04	65.04	65.04	65.04	65.04	65.04
Ym/100	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
Wool (kg ewe^{-1} year^{-1})	1.88	3.09	1.52	2.92	1.57	1.93	1.71	2.11	1.78
NEm (MJ day^{-1})	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68
NEa (MJ day^{-1})	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
NEl (MJ day^{-1})	1.56	1.83	2.21	1.35	1.90	1.73	1.65	1.50	1.78
NEp (MJ day^{-1})	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
NEwool (MJ day^{-1})	0.12	0.20	0.10	0.19	0.10	0.13	0.11	0.14	0.12
REM	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
REG	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
GE (MJ ewe^{-1} day^{-1})	23.59	24.81	25.41	23.31	24.52	24.14	23.81	20.36	23.95
EF (kg CH_4 ewe^{-1} year^{-1})	**10.06**	**10.58**	**10.83**	**9.94**	**10.45**	**10.29**	**10.15**	**8.68**	**10.21**
Emission CH_4 (Gg year^{-1})	0.002	0.005	0.174	0.038	0.480	0.443	0.370	0.121	1,633
Emission CH_4 (t year^{-1})	**2.223**	**4.537**	**174.276**	**37.746**	**479.945**	**443.115**	**370.175**	**121.204**	**1,633.221**

BA - Bratislava TT - Trnava TR - Trenčín NR - Nitra ZA - Žilina BB - Banská Bystrica PO - Prešov KE - Košice DE - digestibility of feed ratio Ym - methane conversion factor NEm - net energy for maintenance NEa - net energy for activity NEl - net energy for lactation NEp - net energy for pregnancy NEwool - net energy for wool production GE - gross energy EF - emission factor REM - ratio of net energy available in a diet for maintenance to digestible energy consumed REG - ratio of net energy available for growth in a diet to digestible energy consumed * weighted average or sum

The course of CH_4 emissions from manure management is showed in table 2. Emission amounts in individual regions were influenced by the number of animals and emissions factor. Emission factors in individual regions recorded differences due to differences in gross energy intake which subsequently affected the amount of volatile solid excretion. The other parameters entering to the calculations were the same (fraction and methane conversion factors for solid storage of manure). The largest CH_4 emission from manure management was detected in region Žilina, in which the largest number of animals was identified.

Table 2. CH_4 emissions from manure management in individual regions of Slovakia and within Slovakia

Region	**BA**	**TT**	**TR**	**NR**	**ZA**	**BB**	**PO**	**KE**	**SK***
Ewe (number)	**221**	**429**	**16,085**	**3,799**	**45,908**	**43,060**	**36,471**	**13,962**	**159,935**
VS (kg day^{-1})	0.41	0.43	0.45	0.41	0.43	0.42	0.42	0.36	0.42
EF (kg CH_4 ewe^{-1} year^{-1})	0.29	0.30	0.31	0.28	0.30	0.29	0.29	0.25	0.29
Emission CH_4 (Gg year^{-1})	0.00006	0.0001	0.005	0.001	0.014	0.013	0.011	0.003	0.0466
Emission CH_4/ (t year^{-1})	0.06	0.13	4.98	1.08	13.70	12.65	10.57	3.46	46.64

VS - volatile solid excretion EF - emission factor * weighted average or sum

The course of N_2O emissions from manure management and grazing is showed in table 3. Emission amounts from housing and grazing in individual regions were given by the number of ewes and emission factors for housing or grazing. The emission factors for housing and grazing were default in all regions. The method and fraction of manure storage, duration of grazing and annual nitrogen excretion were also the same. Therefore, emission amounts in individual regions were affected by the number of ewes. The largest N_2O emissions from housing and grazing were identified in the region of Žilina.

Table 3. N_2O emissions from housing and grazing in individual regions of Slovakia and within Slovakia

Region	**BA**	**TT**	**TR**	**NR**	**ZA**	**BB**	**PO**	**KE**	**SK***
Ewe (number)	**221**	**429**	**16 085**	**3 799**	**45 908**	**43 060**	**36 471**	**13 962**	**159 935**
Live weight (kg)	60	60	60	60	60	60	60	60	60,00
Nex (kg ewe^{-1} year^{-1})	18.62	18.62	18.62	18.62	18.62	18.62	18.62	18.62	18.62
EF $_{housing}$ (kg ewe^{-1} year^{-1})	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**
EF $_{pasture}$ (kg ewe^{-1} year^{-1})	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**
Emission $_{housing}$ (kg year^{-1})	**16.0**	**31.1**	**1,166.6**	**275.5**	**3,329.7**	**3,123.1**	**2,645.2**	**1,012.7**	**11,600**
Emission $_{pasture}$ (kg year^{-1})	**33**	**63**	**2,372**	**560**	**6,770**	**6,350**	**5,378**	**2,059**	**23,584**

Nex - annual nitrogen excretion EF - emission factor * weighted average or sum

3. CONCLUSION: Sheep farming is an important source of landscape development in the foothills. It is a regional resource for livelihood of small farmers and provides the population of adjacent regions with a quality protein in the form of sheep products. It is therefore our effort to maintain and develop it, and thus preserve this tradition for other generations.

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CHARACTERISATION OF GASEOUS EMISSIONS FROM TUNNEL VENTILATED BROILER BUILDINGS DURING WINTER SEASON IN PORTUGAL

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ABSTRACT: Broiler husbandry is a significant source of gaseous emissions but scarce studies have been made under Mediterranean conditions. The aim of this study was to evaluate the NH_3, N_2O, CO_2 and CH_4 emissions on commercial broiler buildings under Mediterranean winter conditions. Three tunnel ventilated broiler buildings, with similar equipments and production practices, were selected in a commercial broiler farm located in central Portugal. The experiment started with 21000 broilers per house on 18-December 2015 and a fattening cycle of 42 days. The outdoor and indoor environmental conditions, gas concentrations and ventilation rates of each broiler building were measured intermittently during the fattening cycle. Tedlar bags were used to collect air samples from the inlet, middle and outlet of each broiler building and then analysis with a photoacoustic field gas-monitor. Results showed that the maximum gas concentrations did not exceed the threshold values recommended to maintain indoor air quality on broiler buildings. The average emission rates from broiler buildings under winter conditions 0.13±0.04, 0.041±0.002, 96.2±8.8 and 0.226±0.013 g day^{-1} $bird^{-1}$ for NH_3, N_2O, CO_2 and CH_4, respectively.

Keywords: Emission rates, Gaseous emissions, Mediterranean, Poultry husbandry

INTRODUCTION: Broiler husbandry is a significant source of gaseous emissions but scarce studies have been made under Mediterranean conditions. Gaseous emissions coming from the decomposition and fermentation of the litter and excreta can damage indoor and outdoor air quality. Regulations have been published in order to protect animals and workers health, with short period exposure limits of 20 and 3000 ppm (parts per million) for NH_3 and CO_2, respectively (CIGR, 1992). The aim of this study was to evaluate the NH_3, N_2O, CO_2 and CH_4 emissions on commercial broiler buildings under Portuguese winter conditions.

1. MATERIAL AND METHODS:

1.1. Experimental: Three tunnel ventilated broiler buildings (length=100 m, width=11 m, ridge=4.0 m and sidewall height=2.7 m), with similar equipments (climate system by Fancom; feeding and drinking systems by Roxell) and production practices, were selected in a commercial broiler farm located in central Portugal (Oliveira de Frades). The experiment started with 21000 broilers per building on 18-December 2015 and a fattening cycle of 42 days (2.4 kg $bird^{-1}$). New bedding material made with rice hulls (3-5 kg m^{-2}) was used during the experiment.

1.2. Measurements and data analysis: The outdoor and indoor environmental conditions, gas concentrations and ventilation rates of each broiler building were measured intermittently on days 1, 4, 10, 12, 18, 23, 26, 28, 32, 35 and 40 of fattening cycle. At each measurement date and at four different times (8 h, 11 h, 14 h and 18 h), Tedlar bags were used to collect air samples (1.5 L) from the inlet, middle and outlet of each broiler building and then analysis with a photoacoustic field gas-monitor (INNOVA 1412i-5, Lumasense Technologies). The outdoor and indoor environmental conditions were recorded from the climate controller (F37, Fancom) of each broiler house. The gas emissions of NH_3, N_2O, CO_2 and CH_4 of each broiler building were estimated by a mass balance (Calvet et al., 2011). Data were subjected to one-way analysis of variance and Tukey comparisons of means tests were carried out using the statistical software package Statistix 7.0.

2. RESULTS AND DISCUSSION:

2.1. Environmental conditions: The gas concentrations are shown in Table 1. During the fattening cycle, the outdoor average temperatures ranged from 2.5 to 18.5 ºC and the average relative humidity varied between 34.2 and 100%. The indoor average temperatures varied from 31.6 to 20.6 ºC while indoor average relative humidity ranged from 30.8 to 69.4%. The concentrations of NH_3, N_2O, CO_2 and CH_4 increased during the growing cycle, but maximum concentrations did not exceed 6, 1, 1600 and 10 ppm, respectively. Thus, the maximum gas concentrations did not exceed the threshold values recommended to maintain indoor air quality on broiler buildings (CIGR, 1992).

Table 1. Average gas concentrations and emissions (mean±standard deviation) from broiler buildings. Values with different superscripts within rows are significantly different (p<005).

Parameters	Building 1	Building 2	Building 3
Gas concentrations			
NH_3 (ppm)	1.1 ± 0.8^{a}	1.6 ± 1.6^{a}	1.8 ± 1.5^{a}
N_2O (ppm)	0.6 ± 0.1^{a}	0.6 ± 0.1^{b}	0.5 ± 0.1^{b}
CO_2 (ppm)	654 ± 174^{a}	852 ± 284^{a}	933 ± 267^{a}
CH_4 (ppm)	5.3 ± 1.5^{a}	4.7 ± 1.3^{a}	5.4 ± 1.7^{a}
Gas emissions			
NH_3 (g day^{-1} bird^{-1})	0.072 ± 0.024^{b}	0.144 ± 0.003^{ab}	0.181 ± 0.087^{a}
N_2O (g day^{-1} bird^{-1})	0.041 ± 0.007^{a}	0.039 ± 0.003^{a}	0.042 ± 0.005^{a}
CO_2 (g day^{-1} bird^{-1})	60.6 ± 30.1^{b}	105.0 ± 27.0^{ab}	122.9 ± 43.5^{a}
CH_4 (g day^{-1} bird^{-1})	0.185 ± 0.024^{b}	0.191 ± 0.004^{b}	0.302 ± 0.027^{a}

2.2. Emission rates: The gas emissions could be found in Table 1. The average NH_3 emission rate obtained in the present study was comparable with values reported by Guiziou and Béline (2005) in France (0.16 g day^{-1} bird^{-1}) but lower than emission rate measured by Calvet et al. (2011) in Spain (0.43 g day^{-1} bird^{-1}) under winter conditions. Results of this study were higher than data reported by Whates et al. (1997) who found a N_2O emission rate of 0.024 g day^{-1} bird^{-1} in UK but lower than emission rate obtained by

Calvet et al. (2011) in Spain (0.051 g day^{-1} $bird^{-1}$). Results are in line with previous studies (CIGR, 2002; Calvet et al., 2011) who reported an average CO_2 emission rate of 94.8 g day^{-1} $bird^{-1}$ in European broiler houses. The CH_4 emission rates observed in this study are higher than those reported in previous studies (Whates et al., 1997; Calvet et al., 2011), ranging between 0.010 and 0.045 g day^{-1} $bird^{-1}$ in European broiler buildings.

3. CONCLUSION: The average emission rates from commercial broiler houses under Mediterranean winter conditions were 0.13±0.04, 0.041±0.002, 96.2±8.8 and 0.226±0.013 g day^{-1} $bird^{-1}$ for NH_3, N_2O, CO_2 and CH_4, respectively.

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ENTERIC METHANE EMISSION ESTIMATED WITH THE SF_6 TRACER TECHNIQUE IS RELIABLE ON RUMEN CANNULATED SHEEP FED FORAGES SILAGES DIETS

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ABSTRACT: The aim of this work was to study the effect of rumen cannulation on methane emission estimated with the SF_6 tracer technique in sheep fed forages silages diets based on mixtures of grass and legumes. Ten castrated male Texel sheep were allocated into 2 homogenous groups of 5 animals in which sheep were equipped with a rumen cannula (C+) or without (C-). Each group was fed ad libitum with five silages diets of pure timothy (T), mixture of T and sainfoin (T-SF, 50/50), T and red clover (T-RC, 50/50), SF-RC (50/50), T-SF-RC (50/25/25) in a 5x5 Latin square design. Dry matter intake (DMI) was recorded daily. Methane emissions using the SF_6 technique was performed on 4 successive days. Dry matter intake (DMI, kg/day) was significantly lower for sheep in the group C+ than in the group C- (-11% on average; $P < 0.05$), and similar among diets within each group. Methane emission (g/day) was significantly lower for sheep in group C+ than in group C- (-14% on average; $P < 0.01$), and similar among diets within each group. Methane yield (g/kg DMI) was similar between groups C+ and C-, but differed among diets for both groups ($P < 0.01$): values were higher (+17% on average) with T diet than with other diets which were similar among them. In our experimental conditions, it can be concluded that enteric methane emission estimated with the SF_6 tracer technique was reliable in rumen cannulated sheep. Forages silages diets including legumes (sainfoin and/or red clover) reduced methane yield in sheep compared to a diet of pure timothy grass.

Keywords: enteric CH_4, SF_6, sheep, rumen cannula, measuring method

INTRODUCTION: The use of the SF_6 tracer technique on rumen cannulated animals offers the attractive option for frequent sampling of rumen contents in order to study the rumen microbial metabolism in conjunction with the estimation of methane (CH_4) emission. However, it has been suggested that estimation of CH_4 emission with the SF_6 technique could be biased on rumen cannulated animals because of non-uniform leakage of the different gases (SF_6 and CH_4) via the cannula (Boland et al., 2014).

Concerning feeding strategies to mitigate CH_4 emissions in ruminants, the effect of forages is less well documented than that of concentrates (Martin et al., 2010). The effect of forages on CH_4 production per unit of intake (CH_4 yield) is inconsistent probably because of differences in forages composition (stage of maturity, preservation mode, chemical composition, presence of bioactive compounds) and animal genotypes between studies.

The aim of this work was to study the effect of rumen cannulation in sheep on CH_4 emission estimated with the SF_6 tracer technique. The impact of different forages silages diets based on mixtures of grass and bioactive legumes on CH_4 emissions was also evaluated.

1. MATERIAL AND METHODS: Ten castrated male Texel sheep (12 months old, initial BW of 48.9 ± 4.0 kg and final BW of 57.5 ± 4.3 kg) were allocated into 2 homogenous groups (5 animals each) in which sheep were equipped with a rumen cannula (C+) or without (C-). Each group was fed ad libitum with five silages diets (on a DM basis) of pure timothy (T), mixture of T and sainfoin (T-SF, 50/50), T and red clover (T-RC, 50/50), SF-RC (50/50), T-SF-RC (50/25/25) in a 5 x 5 Latin square design. Each experimental periods comprised an adaptation period to diets (8 days) followed by a measurement period (6 days). Dry matter intake (DMI) was recorded daily. Methane emissions using the SF_6 technique was performed on 4 successive days (Martin et al., 2008). Permeation rate of SF_6 from the tubes was similar between groups and averaged 1.303 ± 0.070 mg/day and 1.340 ± 0.063 mg/day for the group C- and C+, respectively. Permeation tubes were introduced in the rumen 9 days prior the beginning of measurements and remained throughout the experiment. Representative breath samples from each sheep were collected on 24 hours in pre-evacuated collection devices by a capillary tube fitted to a halter. Concentrations of SF_6 and CH_4 in gas samples (breath, ambient) were determined by gas chromatography using a GC fitted with a pulsed discharge electron capture detector for the SF_6, or with a flame ionisation detector for the CH_4. Daily CH_4 production for each sheep was calculated using the known permeation rate of SF_6 and the concentrations (above the background) of SF_6 and CH_4 in the breath samples:

CH_4 (g/day) = SF_6 permeation rate (g/day) × $[CH_4]/[SF_6]$breath-ambient $[CH_4]/[SF_6]$molecular weight

Data of the two Latin squares were analysed together using the Mixed procedure of SAS (SAS 9.1 release, SAS Inst. Inc., Cary, NC, USA). Model included period, diet, group and diet × group interaction as fixed effects, and the animal nested within diet as random effect.

2. RESULTS: Dry matter intake (kg/day) was significantly lower for sheep in the group C+ than in the group C- (-11% on average; $P_{group} < 0.05$), and similar among diets within each group. Methane emission (g/day) was significantly lower for sheep in group C+ than in group C- (-16% on average; $P_{group} < 0.01$), and similar among diets within each group. Methane yield (g/kg DMI) was similar between groups C+ and C-, but CH_4 yield differed among diets ($P_{diet} < 0.01$): values were higher (+17% on average) with T diet than with other diets containing legumes which were similar among them, and that for both groups ($P_{group \times diet} = 0.73$).

3.DISCUSSION: Daily CH_4 emission (g/day) was lower in rumen cannulated sheep than in sheep without cannula. This was related to differences in DM intake between groups of sheep, and not to the presence of the rumen cannula since, expressed per unit of intake (g/kg DMI), CH_4 yield was similar in sheep with or without rumen cannula. Gas leakages via the cannula cannot be excluded in our study, but the proportions of SF_6 and CH_4 gas lost through it appear similar and without consequence on the CH_4/SF_6 ratios of concentration in breath gas samples. Our data support the fact that the rumen cannula does not have significant detrimental effects upon CH_4 yield estimation using the SF_6 technique (Boland et al., 2014). However, Beauchemin et al. (2012) pointed out that the type of rumen cannula can affect the extent of gas leakage from the rumen and the use of the SF_6 technique in cannulated animals. The authors advise to use tight-fitting cannula to minimize gas leakage and to increase the number of experimental animals to overcome additional variability of the SF_6 tracer technique when working with cannulated ruminants.

We observed significant lower values of CH_4 yield when sainfoin and red clover were present in the diet compared to pure timothy grass silage. That means that the presence of these legumes, despite their dilution in mixtures, allowed to reduce methanogenesis in the rumen of sheep. This may be due to the bioactive compounds content of these two legumes (condensed tannins for sainfoin and polyphenol oxidase for red clover) which can potentially mitigate the rumen methanogenesis (Niderkorn et al., 2016). In direct comparisons on sheep, a decrease in CH_4 yield was reported only for pure red clover silage but not for mixtures with cooksfoot silage (Niderkorn et al., 2015). No change in CH_4 yield has been found comparing pure or mixtures of fresh white clover with fresh ryegrass (Niderkorn et al., 2017). All these results confirm that the potential effects of legumes on methanogenesis are inconsistent and need further research.

Table 1. Dry matter intake and methane (CH4) emissions in sheep equipped with a rumen cannula (C+) or without (C-) and fed five silages diets including timothy (T), sainfoin (SF) or red clover (RC)

	Dry matter intake (DMI, kg/day)			**Methane emission (CH_4, g/day)**			**Methane yield (CH_4, g/kg DMI)**		
Item	C+	C-	**Mean**	C+	C-	**Mean**	C+	C-	**Mean**
T (100)	0.95	1.12	**1.03**	33.8	39.2	**36.5**	36.0	35.5	**35.8**
T-SF (50/50)	1.07	1.21	**1.14**	30.8	38.7	**34.7**	28.9	32.1	**30.5**
T-RC (50/50)	1.14	1.19	**1.17**	31.9	37.7	**34.8**	28.6	32.0	**30.3**
SF-RC (50/50)	1.10	1.31	**1.20**	31.6	35.7	**33.7**	28.6	27.7	**28.1**
T-SF-RC (50/25/25)	1.18	1.22	**1.20**	33.7	36.7	**35.2**	28.6	30.1	**29.4**
SEM		*0.083*			*2.59*			*1.96*	
P-value group		*< 0.05*			*< 0.01*			*0.29*	
P-value diet		*0.25*			*0.86*			*< 0.01*	
P-value group × diet		*0.81*			*0.90*			*0.73*	

CONCLUSION: In our experimental conditions, it can be concluded that enteric methane emission estimated with the SF_6 tracer technique was reliable in rumen cannulated sheep. From the environmental perspective, forages mixtures including some legume species (sainfoin and/or red clover) reduced methane yield in sheep compared to a forage diet of pure timothy grass.

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AMMONIA EMISSION IN A LAYING HENS BUILDING EQUIPPED WITH A EXTERNAL MANURE DRYING TUNNEL

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ABSTRACT: Manure drying tunnel (MDT) has been described as a promising technology to abate NH_3 emissions in hen layer barns. Farms equipped with MDT may have higher emissions than farms without them due to the manure permanence time in the farm. However, the whole period of emission, including the final storage, should be considered in order to account for the real saving of this technology. A lab scale study was performed to simulate the storage with and without drying process. NH_3 was continuously monitored by a photoacoustic multigas analyser INNOVA model 1312. Under laboratory conditions, it was shown that the process of drying limited the conversion to ammonia. It was observed a difference of 90% in NH_3 emissions between dried and wet treatments.

Keywords: Hen layer, NH_3, Manure storage, Drying tunnel, Mitigation strategies.

INTRODUCTION: The emission of ammonia (NH_3) has become an important environmental issue that is related to the negative impact on animals and human health and environmental pollution worldwide (Aneja *et al*, 2008). In order to mitigate NH_3 losses, EU adopted directive 2010/75/EU, according to which laying farms with more than 40.000 hens are obliged to implement best available techniques. In this sense, external manure drying tunnels (MDT) have been described as a promising technology to abate NH_3 emissions despite there is still scarce information on the real savings reached. Farms equipped with drying tunnels have higher emissions than farms that do not dry the manure due to the manure permanence time in the farm. However, the whole period of emission, including the final storage, should be considered in order to account for the real saving of this technology. The objective was to evaluate under laboratory conditions the ammonia emission of the manure after have been dried in the MDT.

1.MATERIAL AND METHODS: A lab scale study was performed to simulate the storage with and without drying process in two moments, from february to march to simulate a storage in winter conditions and from june to july to simulate a storage in summer conditions (47 days each one)**.** Temperature was monitored during the whole experiment. Manure was taken before and after the drying process from a cage laying hen farm equipped with a MDT located in basque country, northern Spain. Manure taken before drying process was considered wet manure and it was accumulated 3 days inside the building. Manure taken after drying process was considered dry manure and it was accumulated 3 days inside the building and 3 days in the MDT. Total nitrogen content, organic matter, ph and dry matter of the manure were analyzed before and after the test.

Three replicates for each treatment were measured using dynamic chambers (60x34x40cm). A continuously fresh airflow (2L/chamber) crossed the chambers to avoid

NH_3 accumulation inside them thanks to two air pumps that pumped air from the outside. NH_3 was continuously monitored by a photoacoustic multigas analyser INNOVA model 1312 (Figure 1).

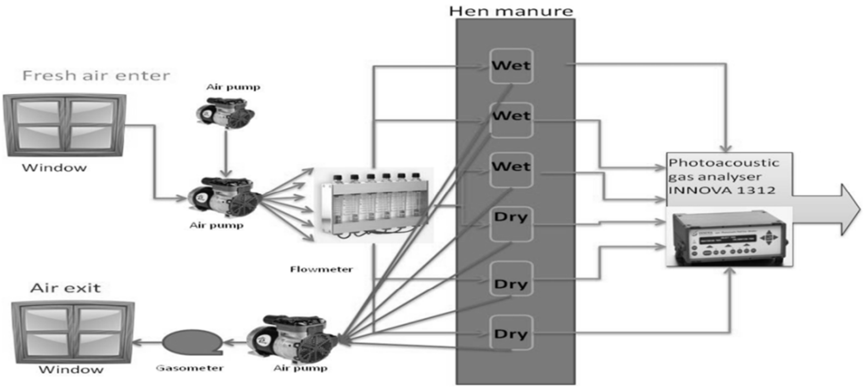

Figure 1. Scheme of laboratory test.

2. RESULTS AND DISCUSSION: It was shown that under laboratory conditions, the process of drying limited the conversion to ammonia. While scarce NH_3 emission was detected from the dry manure, the wet manure showed nh_3 emission for till 30 days. In the period february-march the accumulation was 3.2 and 0.2 g $NH_3 \cdot kg\ manure^{-1}$ in wet manure and dry manure respectively. In the period june-july, the accumulation was 4.1 and 0.4 g $NH_3 \cdot kg\ manure^{-1}$ respectively (figure 2). It was observed a difference of 90% in nh_3 concentrations between dried and wet treatments in both periods. NH_3 concentration of june-july period's wet manure was slightly higher because the higher temperature in this season.

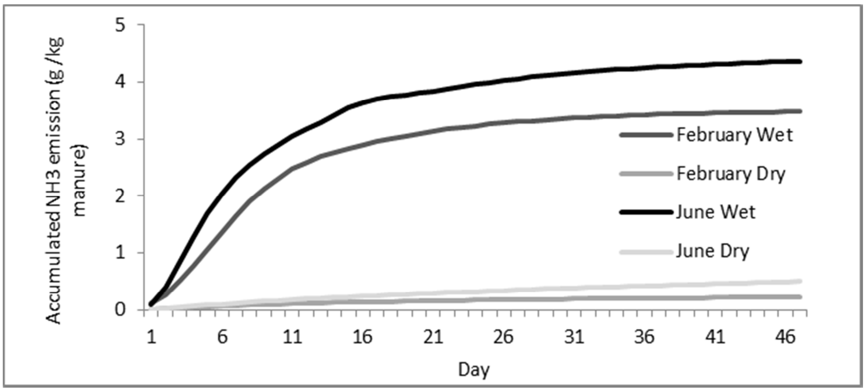

Figure 2. Accumulation of NH_3 emission per treatment over 47days.

Concerning the analysis of the manure, dry manure had no significant differences between the star and the finish of the experiments in total nitrogen content, organic matter and humidity percentage. On the other hand, wet manure experienced significant change in dry matter, total nitrogen content and organic matter (Table 1). This change was corroborated with the emissions data.

Table 1. Manure characteristics before and after the tests.

		Total N (% dry basis)	**Organic matter (% dry basis)**	**Dry matter (%)**
Wet manure	Start	6.21	38.80	21
	Finish	2.75	28.26	57
Dry manure	Start	5.35	35.22	81
	Finish	4.93	36.32	91

3. CONCLUSION: we conclude that storage after a drying process reduces the emission of NH_3. While dry manure did not experiment significant changes in the composition and there was scarce emission, wet manure experimented a decrease in total nitrogen content, organic matter and it was registered an ammonia emission till the moisture was lower. Moreover, wet manure emitted more ammonia under summer conditions, so the temperature is a factor that could affect in higher nh_3 emissions.

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TO CONCILIATE PRODUCTIVITY AND METHANE REDUCTION: FEEDING CATTLE WITH SELECTED SAPONINS

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ABSTRACT: The vegetal saponins constitute some innovative solutions to reduce methane emissions, but there is currently no product affordable on the market. We aimed at determining the efficacy of a product made with saponin-containing plants *in vivo*, and its possible mode of action. Firstly, twelve goats received either or not the saponins in feed. Placed successively in respirometry and metabolic chambers, the methane emissions, rumen ammonia and volatile fatty acids (VFAs), nitrogen digestibility and urine purines derivatives were measured. Secondly, rumen fluid was incubated with saponins at different concentrations (0-40 g.L^{-1}) to measure the production of VFAs associated to milk production. Thirdly, five commercial farms received either or not the saponins in feed. The milk production and the methane emissions were monitored. The emitted CH_4 was reduced by 27% in goats and 4% in cows. The decrease of 30% in the rumen ammonia, the reduction in isobutyrate and isovalerate (1.3-2 points) and the augmentation of purines derivatives (22%) suggested an effect on the protein metabolism. The increase in propionic acid may be related to the augmentation in the milk production. Our results globally suggest that the saponins decrease the methane emission by enhancing proteosynthesis, reducing proteolysis and increasing energy availability.

Keywords: CH_4, Cattle, Saponins, Mitigation strategy

INTRODUCTION: Budan et al. (2013) have screened the most efficient saponin-containing plants for CH_4 mitigation, to formulate a complementary feed. The aim of the present study was to evaluate the efficacy of this product and to decipher its mode of action.

1. MATERIAL AND METHODS:

1.1. Impact of saponins on protein metabolism: The assay was performed in the experimental station of Zaidín (CSIC) on 12 fistulated Murcian-granadian goats divided in two groups. The first group received a standard diet (maize and grass silages, concentrates (35/35/30)). The tested group received the saponin-containing product in the standard diet (3.3 g per animal and day). After 14 days of adaptation, the goats were placed in respirometry chamber for 2 days, to measure the CH_4 emissions. The feed intake was estimated based on the feed refusal weighing. The rumen fluid was then isolated on the 17th day, to measure the free NH_3 and VFAs. Urine and faeces were then collected to evaluate the digestibility and the purine derivatives production.

1.2. Impact of saponins on energy metabolism.

1.2.1. Production of volatile fatty acids: The assay was performed in the experimental site of Ghent University on 2 fistulated sheep. Their rumen fluid was incubated during 24h under shaking, at 38°C, in CO_2 saturated atmosphere, at pH 6.1, with phosphate and bicarbonate as buffer and standard diet as substrate (maize and grass silages, concentrates (35/35/30)), with a gradient of saponins concentration (0; 0.04; 0.1; 0.2; 0.3; 0.4; 20; 40).

1.2.2. Milk production: The trial was carry out in 5 commercial farms, on a total of 453 Holstein cows, between their 5th and 8th month of lactation. The animals received the standard diet (maize and alfalfa silages, concentrates, linseed) for 2 weeks. Then they received the saponin-containing product in feed (35 g per animal and day) for 6 weeks. After this second phase, the feed was not supplemented anymore. Each week, the volume of milk produced was recorded, and a global sample for each farm was used for infra-red analysis to evaluate the milk fatty acids (FAs) composition. The CH_4 emission was estimated *via* Profilia software, using the following equation:

$$CH_4 = (FAs \leq C16 / \text{total FAs}) \times (11{,}368 \times MP - 0{,}4274).$$

2. RESULTS AND DISCUSSION:

2.1. Impact of saponins on the protein metabolism: The CH_4 measurement revealed a decrease of 27% in the treated group, compared to the control one (27.73 *versus* 22.14 L per kilo of feed intake) (Figure 1).

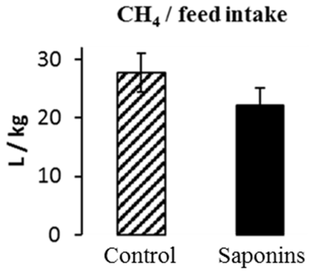

Figure 1. Volume of methane emitted in respiratory chambers, after 14 days of adaptation (mean and standard error).

As for the ammonia measured from the rumen fluid, the values were 30% lower in the group *Saponins* compared to the control group (Table 1). The saponins augmented the amount of VFAs, and the isobutyrate and isovalerate were decreased, relatively to the total amount of VFAs. These VFAs are associated to the degradation of amino acids. This suggests a reduction of the proteolysis allowed by the saponins.

Table 1. Amounts of free ammonia in the rumen fluid and volatil fatty acids, in particular isobutyrate and isovalerate, after 17 days of saponins feed supplementation.

	Control	**Saponins**
NH_3 (g.L^{-1})	0.217	0.151+
Total VFAs (mmol.L^{-1})	36.5	58.9+
of which: **isobutyrate (%)**	4.7	3.0*
isovalerate (%)	5.0	3.0*

$^{+:}$ $p < 0.10$; *: $p < 0.05$

The purine derivatives were found in higher concentration in the group *Saponins* (187 *versus* 229 mmol.day^{-1}) (Table 2). According to Tas and Susenbeth (2007), the increase in purine derivatives (22%) corresponds to a 28.2% augmentation of microbial nitrogen flow toward the duodenum, revealing a proteosynthesis enhancement.

Table 2. Digestibility and urine purine derivatives after 22 days of saponins feed supplementation.

	Control	**Saponins**
Digestibility N (%)	66.3	57.7
Purines derivatives (mmol.day^{-1})	187	229

2.2. Impact of saponins on the energy metabolism.

2.2.1. Production of volatile fatty acids: As observed in the first experiment (please refer to the *Figure 2*), the production of VFAs was globally augmented and the isobutyric acid decreased. Notably, the VFA that augmented the most were the propionic acid, a glycerol precursor associated to higher milk production.

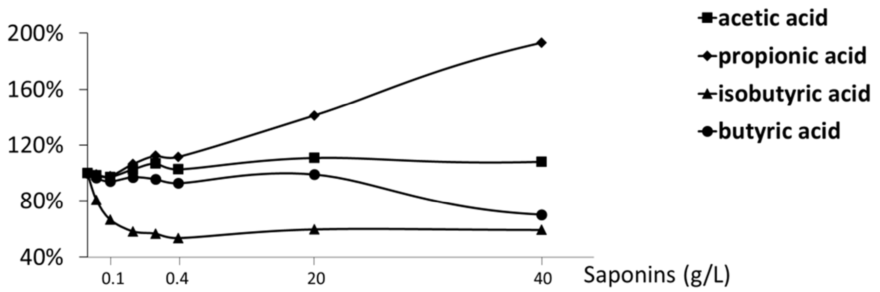

Figure 2. Production of VFAs after 24h of incubation of rumen fluid in conditions simulating the rumen environment. A gradient of concentrations was done to estimate a dose-response profile (0; 0.04; 0.1; 0.2; 0.3; 0.4; 20; 40 g.L^{-1}).

2.2.2. Milk production: The hypothesis that saponins may augment the milk production (please refer to 2.2.1.) is corroborated by the experiment carried out in field (*Figure 4*). The decrease of CH_4 emissions parallels the increase of the milk production. During the four weeks of saponins supplementation in the diet, the average CH_4 emission was lowered by 3.56% (14.34 g.L^{-1} *vs* 14.87 g.L^{-1}). After the supplementation period, the CH_4 emissions notably augmented (+14.22%: 16.38 g.L^{-1} *vs* 14.34 g.L^{-1}). During the four weeks of saponins supplementation in the diet, the average milk production was augmented by 3.29% (30.71 kg.day^{-1} *vs* 29.73 kg.day^{-1}). After the supplementation period, the milk production drastically fell (-12.63%: 26.83 kg.day^{-}1 *vs* 30.71 kg.day^{-1}).

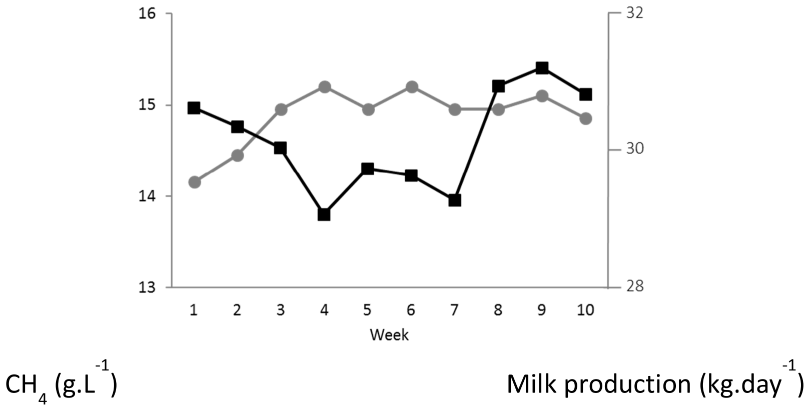

Figure 4. Volumes of methane emitted (■) and milk produced (●) before (1, 2 w), during (2-6 w) and after (7, 8 w) addition of the saponin-containing product in the diet.

This study corroborates the well described relation between milk production, productivity and CH_4 emissions (Gerber et al., 2011; Wina et al., 2005). Interestingly, we worked with a blend of saponins-containing plants (both extract and parts of plants), contrary to Holtshausen et al. (2009), who only tested *Yucca schidigera* and *Quillaja saponaria*. The interest of associating different sources of saponins is to limit the adaptation of the rumen bacteria, and then to ensure a longer effect of the product. A synergy between the saponins may also optimise their impact on the fermentations modulation (Budan et al., 2013).

3. CONCLUSION: The saponins lower the CH_4 production, allowing the carbon to be available for protein anabolism, and constituting a save of energy (Martin et al., 2006). Associated to the reduction of proteolysis, this effect would augment milk production performances. Supplementing the diet of the cows with selected saponin-containing plants around the peak of lactation would thus allow the dairy farmers to conciliate productivity and environmental considerations.

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THE EFFECT OF SLURRY TREATED BY BIOLOGICAL ADDITIVES (ACTIGLEN® AND ACTIPOST®) FOR PRODUCTION OF BIOGAS BASED ON THE MAIZE SILAGE AT LABORATORY BATCH BIOLOGICAL TESTS

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ABSTRACT: The present study is about the positive effects of two products, made by Timac Agro, on biogas production. Actiglene® and Actipost® are two biological additives which are used to treat slurry. The aim of the present study is to determine and to compare the potential of production of biogas from maize silage and slurry treated by additives. They were also compared to a control without additives in the slurry. The results obtained showed some great effects of the additives on two parameters. We could observed an increase of the production of CH_4 by 15.2% for the slurry and silage treated by Actiglene® and a performance characterized by a raise of 20.1% of the production of CH_4 for the treatment with Actipost®. Moreover, we also observed a reduction of the production of H_2S for the treatment with additives compared to the control. These results are really interesting in terms of efficiency of our products and news studies are conducted in order to check the activity of our products at different stages of using (Higher temperature, various inoculum etc.)

Keywords: CH_4, Slurry, additives, H_2S, biogas production, Emitting processes

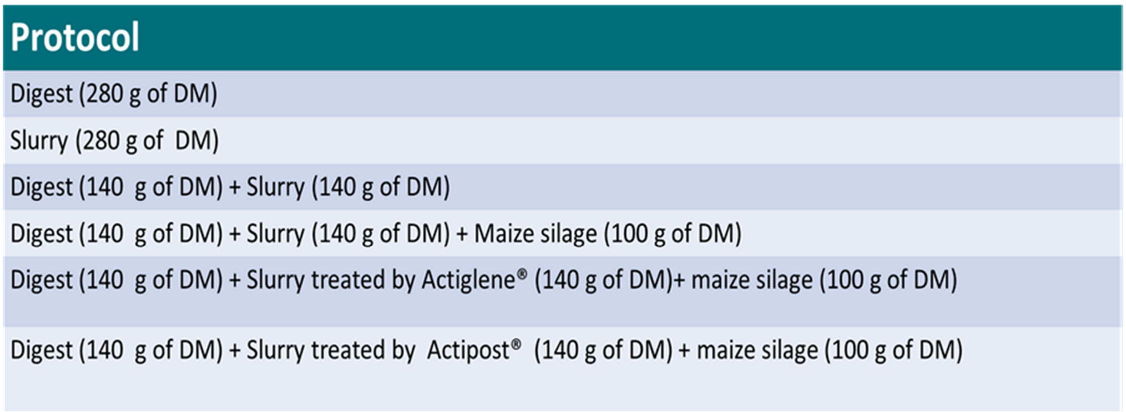
INTRODUCTION: Biogas production represents a new source of renewable energy and this emitting processes has a great potential of development. Biogas production is a key element of tomorrow agriculture. It is the bridge between the effluent/waste treatment and the production of energy or new resources like the return to the ground.

Two areas are important in this reaction: the composition of digestat and the gas production. (GRDF, 2016) About this second part CH_4 production is essential to create energy (thermic source or electricity). (Ademe, 2016) Furthermore reduction of H_2S is important to avoid the degradation of metal equipment (Igarashi et al, 2016, Sethupathi et al, 2017). The aim of the experiment was to determine the effect of Actiglene® and Actipost® on quality of slurry and to compare the potential of production of biogas from maize silage and slurry treated by both additives.

1. MATERIAL AND METHOD: First of all, many parameters of input material (maize silage, slurry, digestat, actiglene® and actipost® have been checked in order to determine the different qualities input. dry matter (DM), crude protein (CP), NDF, starch, Carbon (C), Nitrogen (N), C/N ratio and minerals such like : Calcium (CA), phosphorus (p), Sodium (NA), Potassium (K), Magnesium (MG), Molybdenum (MO), Boron (B), Manganese (MN), Zinc (ZN), Sulphur (S) have been analysed in different raw material. these data are required to see the evolution of different components after the fermentation process.

For the experiment a comparison between a mixes of material have been done. The different combination of input tested have been in the table below.

Table 1: Design of the experiment (every test has been done in triplicate)



Protocol
Digest (280 g of DM)
Slurry (280 g of DM)
Digest (140 g of DM) + Slurry (140 g of DM)
Digest (140 g of DM) + Slurry (140 g of DM) + Maize silage (100 g of DM)
Digest (140 g of DM) + Slurry treated by Actiglene® (140 g of DM)+ maize silage (100 g of DM)
Digest (140 g of DM) + Slurry treated by Actipost® (140 g of DM) + maize silage (100 g of DM)

The tested doses for the additives was the same that the current use of the product it corresponds to: 1 Kg of Actiglene® and/or Actipost® for 1000 Kg of slurry. The duration of a cycle of experiment was 28 days.

During the whole process gas production has been recorded. The total amount of gas product has been followed and also the gas quality with the production of methane (CH_4) and hydrogen sulfide (H_2S). These measures were determined with the use of a gas analyzer from Geotechnical instruments and they were recorded every 24 hours. At the end of the experiment a digestat analysis has been performed with the dosage of fermentative components: Acetic acid, Butyric acid, propionic acid and total Volatile Fatty Acid (VFA).

2. RESULTS AND DISCUSSION: The results could be separated in two parts: the digestat analysis that is very interesting for the return to the ground in farm and the gas production.

2.1. Digestat Analysis: The average of the results have been reported in the table below. (Table 2) An ANOVA statistical analysis was realized on three parameters in order to get the best significance. This analysis was realized on the three mixes and corresponds to two treatments and one control.

Table 2: Characteristics of fermentation process after 28 days of fermentation in minifermentors for digestat analysis. (The concentration of the different acid is in %FM)

Input material	DM	CP	C-Carbon	N-Nitrogen	C/N	pH	Acetic a.	Propionic a	Butyric a.	Total VFA
1. Digestát	8,07	14,95	42,90	2,59	16,57	8,31	0,04	0,21	0,12	0,37
2. Slurry	4,92	14,60	40,17	2,43	16,51	8,24	0,15	0,24	0,15	0,52
3. slurry + digestat	5,51	14,40	41,25	2,67	15,44	8,30	0,04	0,23	0,19	0,46
4. Slurry+ dig.+ maize	6,41	15,08	41,20	2,50	16,47	8,30	0,07	0,18	0,13	0,38
5. Actiglene®	7,25	14,51	41,66	2,43	17,21	8,28	0,11	0,23	0,07	0,39
6. Actipost®	7,03	14,60	41,54	2,55	16,34	8,35	0,10	0,24	0,25	0,59

We can observe an effect on DM ($p<0.001$***). At the beginning, the level of DM was the same for the mix with Actipost®, Actiglene® and the control (DM = 11%). Our results prove a persistence of DM that remains higher with our additives and which is very interesting for farmers who want to use return to the ground technic. The differences of DM between the different treatments are reported in the graph below.

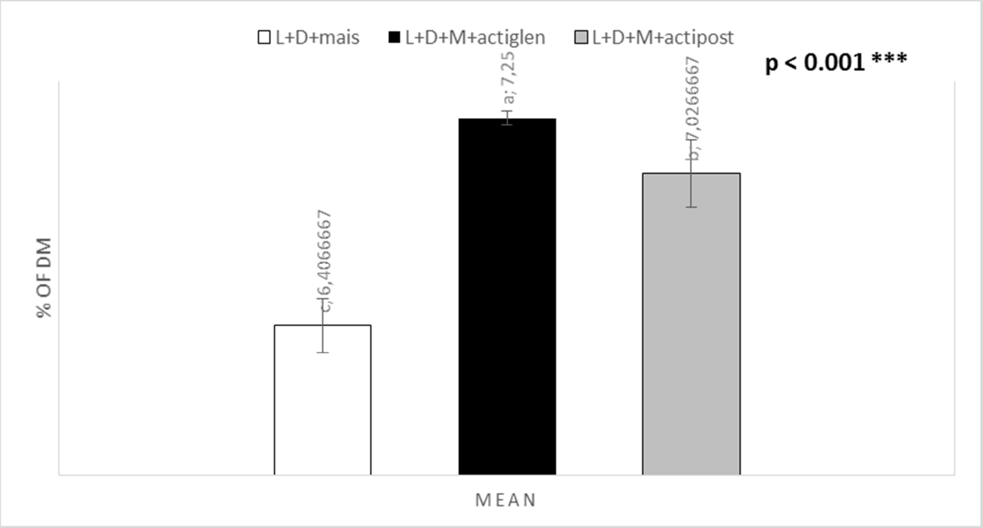


Figure 1: The effect of additives on DM after a month of fermentation

Moreover, the statistical analysis have shown some positive tendencies for few parameters such as: C, pH, Propionic acid, total VFA, and Mg and Mn. P value is around 10% but we can use the results as indication for future development and it is encouraging for some effects such like pH stabilization or organic matter restitution to the ground.

2.2. Gas Production: Gas production has been recorded during the whole process of fermentation. Two parameters were particularly important: CH_4 production and H_2S reduction.

In the following graphs (graph 2a and 2b), which represents the formation of CH_4, we observed during the last seven days that variants with additives have the same tendencies, but the control without additive got a lower production of CH_4 at the end of the experiment. After a month of fermentation, the production has increased by 15.2% in the variant with Actiglene® and 20.1% for the variants with Actipost®, compared to the control without additives. The comparison is better with the three mixes: Control, Actiglene® and Actipost®. (Graph 2b)

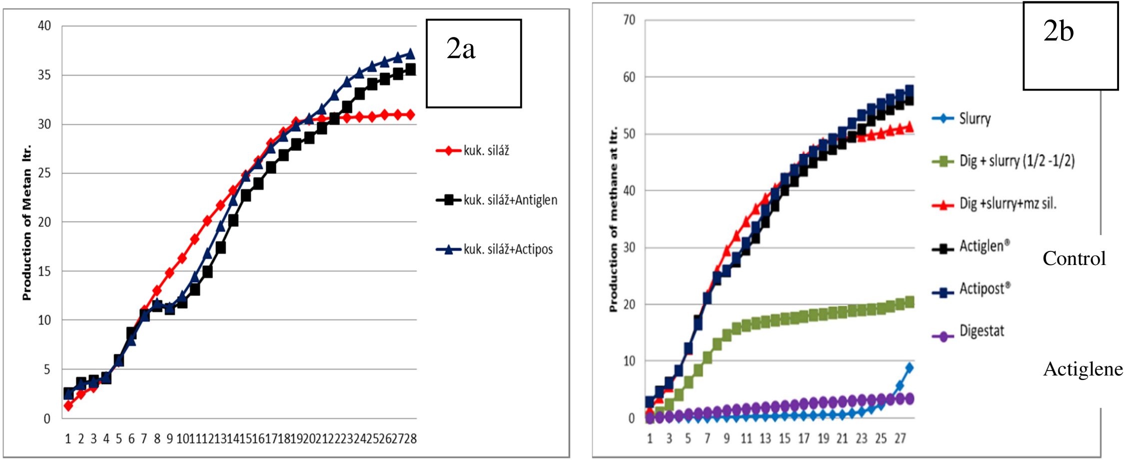
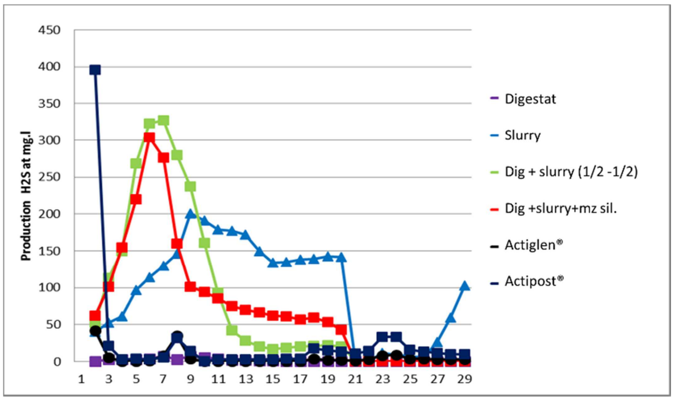


Figure 2a) Production of CH_4 with different substrats during 28 days of fermentation in plastic minifermentors in 2015. Figure 2b) Production of CH_4 with 3 different inputs, which include control and additives, during 28 days of fermentation in plastic minifermentors in 2015

H2S production has been recorded (graph 3) and we registered the effect of various substrates during fermentation. The highest content of H_2S was detected after one week of fermentation with a mixture of slurry and digestat. In a variant of slurry treated with Actiglene® and Actipost®, content decreased from the 3rd day of fermentation and the H_2S content was low until the end of fermentation monitoring.



Figureh 3: Production of H_2S with different substrats during 28 days of fermentation in plastic minifermentors in 2015.

3. CONCLUSION: These results are interesting in terms of efficiency of our products and news studies are conducted in order to check the activity of our products at different stages of using. (Temperature, various inoculum, impact on the ground etc.)

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NH_3 AND ODOUR REDUCTION EFFICIENCIES OF MULTI STAGE AIR SCRUBBERS AND BIOFILTERS AT PIG HOUSING FACILITIES IN FLANDERS, BELGIUM

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ABSTRACT: Air scrubbers and biofilters are applied as end-of-pipe techniques for the removal of various pollutants from the exhaust air from livestock production houses, such as NH_3 and odour. This project aims to gain insight in the NH_3 and odour reduction efficiency of multi stage scrubbers and biofilters installed in Flanders. In this ongoing project, 3 biofilters, 3 multi stage biological scrubbers and 1 multi stage chemical scrubber at pig housing facilities were monitored during winter. Mean NH_3 and odour reductions of 79 to > 99%, and 39 to 90%, respectively, were found, indicating that much higher reductions than the efficiencies for which they are currently accredited for can be achieved. Measurements during other seasons are needed before making conclusions.

Keywords: Air cleaning, NH_3, Odour, Reduction, Pigs

INTRODUCTION: As intensive livestock production needs to comply with stricter regulations and emission limits, the treatment of the exhaust air from livestock production houses has become increasingly important over the last years. This especially in densely populated areas, in regions characterised by high animal density or in vulnerable natural protected areas (European Integrated Pollution Prevention and Control, 2015). Currently, air scrubbers and biofilters are applied as end-of-pipe techniques for the removal of various pollutants from the exhaust air, such as NH_3 and odour. According to the European IPPC (2015), the use of stand-alone biofilters is nevertheless generally not considered suitable for the removal of NH_3. In Flanders, air scrubbers and biofilters are legally obliged to reach at least 70% NH_3 reduction efficiency during the whole year (MB31/05/2011), whereas in the Netherlands, Germany and Denmark, different types of air scrubbers are certified according to their respective removal efficiency for several pollutants (Van der Heyden et al., 2015). The Government of Flanders strives to expand the list of approved NH_3 reduction techniques, including air cleaning techniques that can meet higher reduction efficiencies than 70%. This project aims to determine, and gain insight, in the NH_3 reduction efficiency of multi stage scrubbers and biofilters installed in Flanders, and thus provide a solid basis for regulatory purposes. In addition, odour reduction efficiencies are also determined. Currently 30% and 40% odour reduction efficiencies are accredited to chemical and biological scubbers, respectively.

1. MATERIAL AND METHODS: In this ongoing project, 3 biofilters, 3 multi stage biological scrubbers and 1 multi stage chemical scrubber at pig housing facilities are monitored once every season over the course of one year. The measurements presented here were performed during the winter of 2017 (january till march). All measurements performed at the outlet of the air cleaning technique consisted of sampling at least 10% of the outlet surface, either by use of a tent or hoods (fig. 1).

Figure 1. Sampling systems: tent & hoods

1.1. Ammonia measurements: NH_3 concentrations at the inlet and outlet of the air cleaning technique were determined simultaneously using acid solution impingers. At each location, 3 consecutive samplings were performed in duplicate. Figure 2 shows a scheme of the measurement set-ups. During 30 to 45 min, air was drawn through a pair of impingers, connected in series and both containing 0.2 L of 0.1 N H_2SO_4, at a flow rate of 0.5 to 3.0 L min^{-1}. NH_3 is trapped by the acid. Afterwards, the NH_3 concentration was calculated from the sampled flow rate and the nitrogen content of the solution in the impingers determined using spectrometric detection.

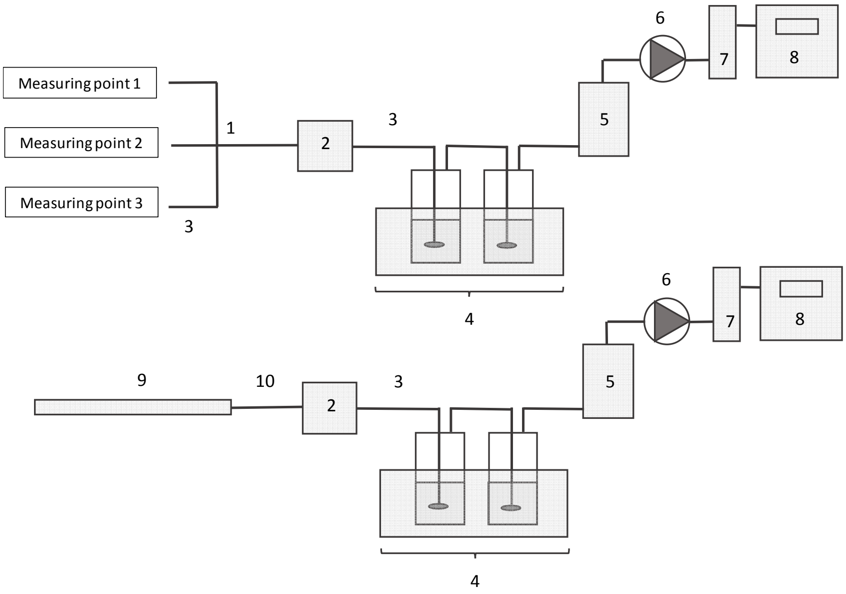

Figure 2. Schematic overview of the NH_3 measurement set-up at the inlet (upper) and outlet (under) of the air cleaning technique, with 1 - manifold; 2 - filter; 3 - Teflon tube; 4 - ice bath with 2 impingers filled

with 0.1 N H_2SO_4; 5 - dryer; 6 - pump; 7 - flowmeter; 8 - gas meter; 9 - heated sampling probe (105 °C); 10 - heated sampling line (105 °C)

1.2. Odour measurements: Odour samples were collected simultaneously at the inlet and outlet of the air cleaning techniques. In total, 3 consecutive 30 min samples were taken. The lung principle was used to collect the samples in 30 L Nalophan bags. Odour concentrations were determined by forced choice olfactometry according to EN 13725:2003. Each sample was analysed twice by 4 qualified panellists (8 ITE's).

2. RESULTS AND DISCUSSION: Table 1 and 2 present the nh_3- and odour reductions for the various locations determined during the winter of 2017.

2.1. Ammonia measurements: The analytical detection limit for determination of the nitrogen content was not always reached at the outlet of the air cleaning techniques, therefore only minimal NH_3-reductions can be given for 4 locations (Table 1). The results show that all air cleaning techniques had a mean NH_3-reduction higher than 70% and even up to more than 99%. Only one air scrubber, i.e. multi stage biological scrubber A2, did not reach the required minimum reduction in Flanders of 70% during one measurement. This scrubber was only operational since a few weeks. Furthermore, some sprinklers were clogged on the measurement day. Although the sprinklers were cleaned before starting the measurements and some recovery time was allowed, the scrubber did not reach equally high reductions over the entire surface of the outlet during the measurements. Probably the recovery rate was too short to allow the scrubber to reach it's maximal reduction efficiency.

Based on the results, it can be concluded that multi stage biological and chemical air scrubbers as well as biofilters are capable of achieving reduction efficiencies higher than 70%. It should be noted, however, that these measurements were performed during winter, when ventilation rates were relatively low. Measurements during other seasons, especially summer conditions, are necessary to assess the reduction efficiencies of the various air cleaning techniques.

Table 1. Overview of NH_3-reductions for the various locations (winter 2017).

Location	n	Min. (%)	Max. (%)	Mean ± SD (%)
Biofilter A	3	78	82	80 ± 2
Biofilter B	3	95	> 99	> 98 ± 2
Biofilter C	3	> 97	> 98	> 98 ± 1
Multi stage bio. scrubber A1	3	98	> 99	> 99 ± 1
Multi stage bio. scrubber A2	3	64	98	79 ± 17
Multi stage bio. scrubber B	3	76	85	82 ± 5
Multi stage chem. scrubber A	3	> 99	> 99.6	> 99 ± 0.3

2.2. Odour measurements: The results show a large variation in mean odour reductions by the various air cleaning techniques, ranging from 39 to 90% (Table 2). Highest reductions were obtained by the biofilters (68 to 90%). In Flanders, biofilters are currently not accredited for odour reduction as data is lacking. Comparable to the NH_3 measurements, lowest odour reductions were found for multi stage biological scrubber A2. Although the installation was relatively new and had suffered from clogged sprinklers some days before the measurements, the low odour reductions over the entire surface (≤ 45%) were more likely due to relatively low occupation rate during the measurements (ca. 80%) and low incoming odour concentrations (553 to 707 OU_E m^{-3}) rather than the microbiology not being fully developed. Nevertheless, during this measurement period all scrubbers reached the minimal odour reduction efficiencies for which they are accredited in Flanders, i.e. 30 and 40% for chemical and biological scrubbers, respectively. However, as mentioned earlier, measurements during the other seasons are required before drawing any conclusions on the overall reduction efficiencies of the air cleaning techniques.

Table 2. Overview of odour-reductions for the various locations (winter 2017).

Location	n	Min. (%)	Max. (%)	Mean ± SD (%)
Biofilter A	2	64	72	68 ± 4
Biofilter B	3	88	96	90 ± 5
Biofilter C	3	80	92	86 ± 5
Multi stage bio. scrubber A1	3	57	84	69 ± 11
Multi stage bio. scrubber A2	3	34	45	39 ± 5
Multi stage bio. scrubber B	3	35	79	57 ± 18
Multi stage chem. scrubber A	3	46	62	55 ± 7

3. CONCLUSION: NH_3 and odour reductions of 3 biofilters, 3 multi stage biological scrubbers and 1 multi stage chemical scrubber were determined at pig housing facilities during winter conditions. The results indicate that these air cleaning techniques are able to reduce NH_3 and odour emissions with the minimal required reduction efficiencies but even much higher reduction efficiencies were achieved. Measurements during other seasons are nevertheless essential before any conclusions can be made.

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The French partnership network on Livestock and Environment organized the 3rd edition of the EMILI conference (EMissions of gas and dust from Livestock) in Saint-Malo (France) from 21-24 May 2017.

This event constituted an opportunity to present the latest scientific advances from research on gas and dust emissions in animal agriculture and contributed to providing information that industry and governments need in order to achieve cost-effective gas and dust mitigation outcomes.

The Conference topics included:

- **Measurement methods**
- **Emission factors and air quality**
- **Modeling**
- **Mitigation strategies**
- **Inventories/Environmental assessment**

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