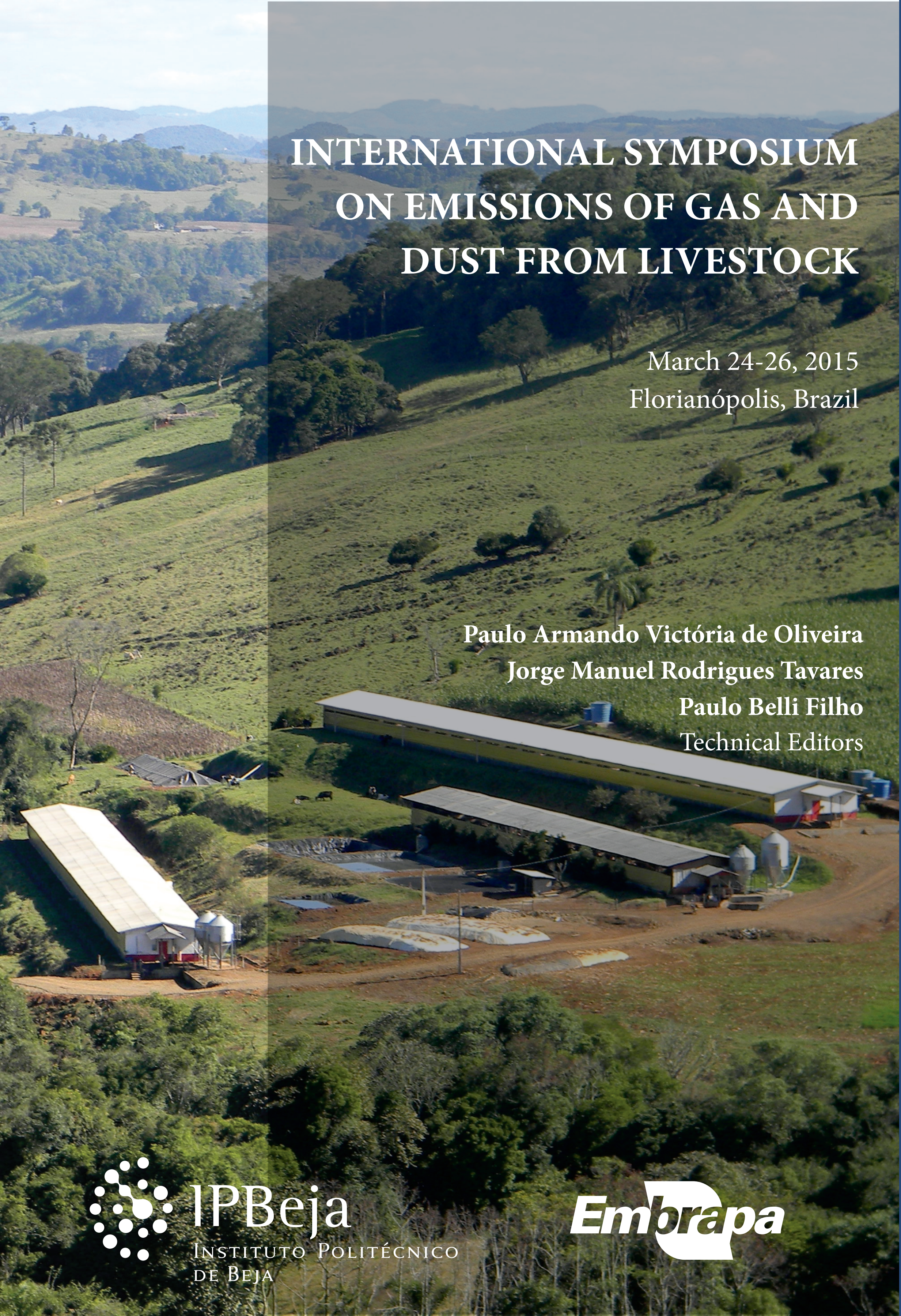

INTERNATIONAL SYMPOSIUM ON EMISSIONS OF GAS AND DUST FROM LIVESTOCK

March 24-26, 2015
Florianópolis, Brazil

Paulo Armando Victória de Oliveira
Jorge Manuel Rodrigues Tavares
Paulo Belli Filho
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Preface

This book of proceedings contains all 36 papers presented (as oral presentations, posters and invited papers) during the International Symposium on Emission of Gas and Dust from Livestock (EMILI 2015). This event took place from March 24-26, 2015, in Florianópolis, Brazil, and was organized by the Brazilian Agricultural Research Corporation – Embrapa Swine and Poultry and Federal University of Santa Catarina.

The main purpose of this symposium was to provide state-of-the-art research on gas and dust emissions from livestock and, also to bring up hot topics and relevant scientific questions. Scientists interested in livestock gas and dust emissions were able, in the second edition of this symposium, to meet and evaluate the experimental results obtained since EMILI 2012.

During the event with simultaneous translation (Portuguese-English-Portuguese), keynote speakers presented in plenary sessions the general issues surrounding gas and dust emissions and the potential use of available knowledge.

The conference was organized around two parallel sessions focusing on relevant topics: emission factors, emitting processes, measuring methods, mitigation strategies and environmental evaluation. Participants from several countries (North, Central, and South America, Europe), attended this event and had access to oral presentations, including the invited speakers. Exchanges also occurred during the poster session.

It is important to retain that on the day before of the symposium (March 23rd) a course was performed by Paul Robin and Mélynda Hassouna (INRAE, France) to give for agroindustry technicians, academic, technical, and scientific information regarding the new advances related to emission of gas and dust from livestock.

These proceedings are the final step of the second edition of EMILI. For attendees, this book is a good way to improve understanding and serve as a reminder of information presented during the conference. For others, this document will present following information and data for the knowledge about gas and dust emissions.

Finally, we would like to warmly thank all contributors for the success of this event:

- the attendees, for their presence, interests, and positive attitude,
- the organizing committee, for its logistic management and the communication process,
- the scientific committee, for the scope of the symposium, the reviewing process, and the selection of the papers,
- the sponsors: Embrapa, Icasa, UFSC-ENS, AgroBona, FarmControl, ODournet, Acav, ACCS, CNPq, Fapesc, Feagri, Sindicarne/SC, Inrae, and RMT.

Jorge Manuel Rodrigues Tavares
Paulo Armando Victória de Oliveira
Technical Editors

Contents

Chapter I

EMISSION FACTORS

AMMONIA AND GREENHOUSE GAS EMISSIONS FROM STRAW-BASED DEEP LITTER SYSTEMS FOR DAIRY CATTLE FED WITH CONTRASTING DIETS

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Abstract: the objective of the study is to acquire new knowledge about greenhouse gases and NH_3 emissions at the barn level for dairy cows on a straw-based deep litter and fed contrasting diets: a grass-based (fresh and hay, GD) and a maize-based diet (silage and concentrate, MD). Two groups of three Holstein dairy cows in late lactation were housed in two closed and controlled mechanically ventilated rooms, and kept on a straw-based deep litter accumulated under the animals during four weeks. Individual milk yields and dry matter (DM) intake were recorded daily. H_2O, NH_3, CO_2, CH_4 and N_2O emissions were measured continuously with an infrared photo-acoustic gas analyzer. The diet clearly affected GHG and ammonia emissions. The MD treatment involved higher CH_4 emissions mainly because of a higher DM intake while the GD treatment caused greater emissions of NH_3 due the higher diet protein content.

Keywords: dairy cattle, housing, CH_4, NH_3, ruminants.

EMISSÃO DE GASES DE EFEITO ESTUFA E AMÔNIA DE VACAS LEITEIRAS CONSUMINDO DIETAS CONTRASTANTES EM CONFINAMENTO COM CAMA SOBREPOSTA

Resumo: o objetivo deste estudo é ampliar o conhecimento sobre as emissões de gases de efeito estufa (GEE) e NH_3, em sistema de produção leiteira em confinamento em cama sobreposta e consumindo dietas contrastantes: uma à base de pasto (verde e feno, GD), e outra à base de milho (silagem e concentrado, MD). Dois grupos de três vacas da raça Holstein em final de lactação foram instalados em duas câmaras fechadas com ventilação mecânica controlada. Estes animais foram mantidos sobre cama de palha durante quatro semanas. A produção de leite individual e o consumo de matéria seca (MS) de cada grupo foram medidos diariamente. As emissões de H_2O, NH_3, CO_2, CH_4 e N_2O foram medidas continuamente com um analisador de gás fotoacústico infravermelho. A dieta afetou claramente a emissão de GEE e NH_3. O tratamento GD causou maior emissão de CH_4, principalmente devido ao

maior consumo de MS, enquanto que o tratamento MD produziu uma maior emissão de NH_3 devido ao maior teor de proteína da dieta.

Palavras-chave: vacas leiteiras, confinamento, CH_4, NH_3, ruminantes.

Introduction

Animal production has an important impact on pollutant emissions such as ammonia (NH_3) and greenhouse gases (GHG). In France, livestock systems are the biggest NH_3 and methane (CH_4) emission sources (74% and 75% respectively) and the second source of nitrous oxide (N_2O) emissions (8,6%) (Citepa, 2014). In Brazil, 35% of CO_2 equivalent emissions originate from farming activities, around 61% of this amount being linked to enteric fermentation or animal manure management (MCTI, 2013). Some greenhouse gases are the result of ruminal fermentation (CH_4) or microbial activity in manure (N_2O, CH_4). The NH_3 is especially formed by the conversion of urea in the urine (Hristov et al., 2010) while the N_2O, under specific environmental conditions, results from nitrification-denitrification processes of inorganic nitrogen in manure (Chadwick et al., 2011). NH_3 and GHG from animal housing therefore depend on manure management and diet. Deep litter systems are widely used in France, however the scientific literature on factors affecting the emission of NH_3 and GHG from these systems is scarce. Edouard et al. (2012), in an experiment testing contrasting manure managements, observed that GHG and NH_3 emissions from dairy cows on a straw-based deep litter accumulated during six weeks were higher compared to tie-stalls (+78 %, +33 %, +25% and +85% respectively, for C-CO_2, C-CH_4, N-NH_3 and N-N_2O) in the same nutritional conditions. This difference is mainly due to the litter which allows environmental conditions for microorganism's development. The diet can also influence NH_3 and GHG emissions. James et al. (1999) observed a decrease of NH_3 manure emission from Holstein heifers with a reduction of protein concentration in the diet. On the other hand, a reduction in grass N fertilization rate strongly increased cattle enteric CH_4 emissions through the modification of rumen degradation characteristics and associated changes in the carbohydrate composition and degradability of the feed (Bannink et al., 2010). This work has the objective to acquire new knowledge about GHG and NH_3 emissions at the barn level for dairy cows on a straw-based deep litter and fed contrasting diets: a grass-based (fresh and hay, GD) and a maize-based diet (silage and concentrate, MD).

Materials and methods

Experiments were performed at the INRA experimental farm in Méjusseaume (Brittany, France) in autumn 2014. Two groups of three Holstein dairy cows (541kg ±30) in late lactation were fed "ad libitum" with GD or MD based diet. The MD diet was composed of maize silage (74%) and a soybean meal based concentrate (26%). The GD diet was composed of grass from a mixed pasture cut every morning and kept at 4 °C to be distributed regularly during the day (66% of DM daily offered) and a second-cut hay (mixed pasture) provided during the night (34% of DM daily offered). Cows were housed in two closed and controlled mechanically ventilated rooms, and kept on a straw-based deep litter (15 kg of straw/cow/day) accumulated under the animals during four weeks. Individual milk yield and dry matter intake (DMI, average of the group) were recorded daily. Samples of feed, milk, straw and farm yard manure at the end of the accumulation period were analysed for chemical composition.

Ventilation rates were calculated from previous experimental data and were fixed at 767 and 700 m^3/h/cow for the two rooms, respectively. Gas concentrations (H_2O, NH_3, CO_2, CH_4, N_20 and C_2H_6O) were measured continuously with an infrared photo-acoustic gas analyzer (INNOVA 1412). The ethanol (C_2H_6O) was measured in order to correct NH_3 concentrations because of interferences observed in a previous experiment (Hassouna et al., 2013). Emissions were the result of the product between ventilation rates and the difference between inlet and outlet gas concentrations.

Results and discussion

The DM intake on MD treatment was 42% higher than on GD (Table 1). The same effect was observed on milk yield (+73% on MD) and CH_4 emission per animal unit (42% higher on MD, Table 2). On the other hand, no difference was detected between treatments when CH_4 emissions were related to DM intake (Table 2), DMI being the main variation factor for enteric CH_4 production. Referring to Bannink et al. (2010), we could have expected that the increase in the protein content of the diet could have reduced enteric CH_4 emissions. However, the present study reports emissions at the barn level, that is from animals and the litter. Therefore, a decrease of enteric CH_4 emissions could have been compensated by an increase in litter emissions. As expected, the higher crude protein (CP) content on GD treatment (Table 1) involved higher emission of NH_3. Protein content effect on NH_3 emission has been reported by several papers, and is usually associated with a higher urea excretion in the urine (James et al., 1999; Kulling et al., 2001).

The effect of diet CP content on NH_3 emissions is even more evident when looking at the kinetic over the measurement period, the difference between treatments being stronger in the two last weeks of litter accumulation (Figure 1). The N-N_2O emission was very low (0.35 g/d/LU), with a small increase in the fourth week of accumulation for the GD treatment (less than 2g/d/LU). The C-CO_2 mean emission was 5,649 g/d/LU showing no great difference between both treatments. The emission levels in this study were close to those found by Edouard et al. (2012) for straw-based deep litter systems, especially for C-CO_2 and C-CH_4 emissions. However, N-NH_3 emissions were higher for Edouard et al. (2012) as the accumulation period was two weeks longer and interferences with ethanol were not corrected.

Table 1. Diet composition and animal production (means and standard errors).

	Grass-based diets		Maize-based diets	
	Mean	SE[1]	Mean	SE[1]
DM Intake (kg)	14.3	1.8	20.3	2.0
% of DM intake				
Fresh grass	72.6	12.1	0	
Hay	27.4	12.1	0	
Maize Silage	0		74.1	1.3
Concentrate	0		25.9	1.3
g/kg of DM intake				
OM	902	8.5	955	0.2
CP	193	19.9	147	0.5
Milk Yield (kg)	13.3	1.8	23.1	2.4

[1] Standard error.

Table 2. Mean (and standard errors) ammonia and methane emissions for dairy cows fed contrasting diets and housed on straw-based deep litter systems over four weeks of accumulation.

Diet	N-NH_3 g/d/LU[1]		C-CH_4 g/d/LU[1]		C-CH_4 g/kg of DMI	
	Mean	SE[2]	Mean	SE[2]	Mean	SE[2]
Grass-based	21.0	14.1	317	24.4	24.0	1.84
Maize-based	12.8	5.5	449	35.3	23.9	1.88

[1] LU = 500kg live weight.

[2] Standard error.

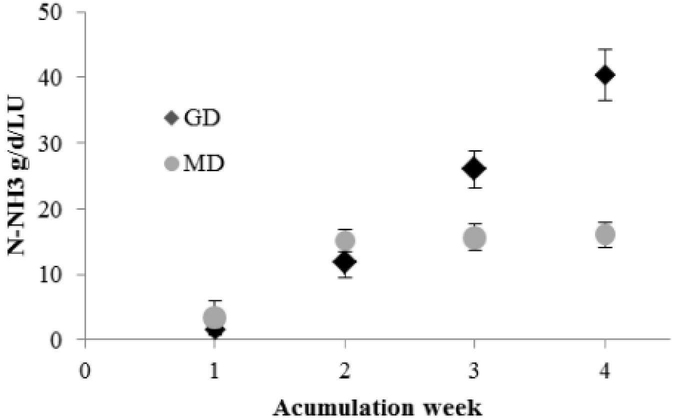

Figure 1. Emission of ammonia on Grass-based (GD) and Maize-based (MD) diets through litter accumulation time (means and standard errors for each week).

Conclusions

The diet clearly affected GHG and NH_3 emissions. The MD treatment provided a higher dry matter intake and consequently greater methane emission per animal. On the other hand, the GD treatment caused an increase in NH_3 emissions due the higher protein content of this diet.

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NITROGEN LOSSES AND NH_3 EMISSIONS FROM A COMMERCIAL BROILER HOUSE IN SOUTHERN BRAZIL

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Abstract: commercial production of broiler chickens emits low amounts of nitrous oxide and methane, however, the production of CO_2 and NH_3 is considerable. Several countries have sought to investigate the emissions of greenhouse gases (GHG) and ammonia (NH_3) in the production of broiler chickens since the information available in the literature is variable and uncertain. This study aimed to evaluate the nitrogen losses of commercial broiler houses in the Dark House system integrated into an agroindustry, located in southern Brazil. For identified of NH_3 emissions and concentrations, the air collection was performed directly by the INNOVA 1412 equipment with short intervals of time during the entire productive cycle studied. The mass balance was determined for N, and P. The average nitrogen emissions were 485 kg or 37 g/bird. Ammonia losses corresponded 60% of nitrogen default.

Keywords: broiler chickens, air quality, mass balance.

PERDAS DE NITROGÊNIO E EMISSÕES DE NH_3 EM INSTALAÇÃO COMERCIAL DE FRANGOS DE CORTE NO SUL DO BRASIL

Resumo: a produção comercial de frangos de corte emite pequenas quantidades de óxido nitroso e metano, no entanto, a produção de CO_2 e NH_3 é considerável. Vários países têm procurado investigar as emissões de gases de efeito estufa (GEE) e amônia (NH_3) na produção de frangos de corte, uma vez que a informação disponível na literatura é variável e incerta. Este estudo objetivou avaliar as perdas de nitrogênio de um aviário do tipo *dark house* integrado à agroindústria, localizada no sul Brasil. Para identificar as emissões e concentrações de NH_3, a coleta de ar foi realizada diretamente pelo equipamento INNOVA 1412 com curtos intervalos de tempo durante todo o ciclo produtivo estudado. O balanço de massa foi determinado para N e P. A perda média de nitrogênio foi de 485 kg ou 37 g/ave. As perdas de amônia corresponderam a 60% do default de nitrogênio.

Palavras-chave: frangos de corte, qualidade do ar, balanço de massa.

Introduction

Brazilian animal production has reached unprecedented levels in recent years, especially in relation to broiler breeding (ABPA, 2015). This is mainly due to the increased demand for animal products in developed countries. In this scenario, small farms with traditional production systems have been replaced by confined production facilities with high production densities. These intensive production systems present better economic results but they are known for their negative impacts on the environment (FAO, 2006) through the waste production in large quantities and emission of greenhouse gases and ammonia.

Gas emissions and air quality are important environmental topics for poultry production. The 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.

The objective of the study was to determine nitrogen losses and NH_3 emissions from one commercial broiler house (dark houses) in southern Brazil for reused litter.

Materials and methods

Aviary, bird and diet: the work was carried out in a dark house type located in the western region of Santa Catarina. The climate of the region is subtropical humid, presenting the variation Cfa according to the climatic classification of Köppen, with hot summers and cold or mild winters. The broiler house had dimensions of 80 m long by 12 m wide with a right foot of 2.30 m, with capacity of 13,000 birds and duration production cycles with 42 days and final average weight of 2.7 kg. The evaluation period was between November and December 2014. The broiler house ventilation system consisted of 8 exhaust fans, with a flow of 44,500 m/h/exhauster, which were located at the opposite end of the "Pad cooling". The litter had been reused for 14 batches.

Water consumption, production characterization, physical-chemical litter composition and diet: water consumption, physical-chemical litter characteristics and diet ingested by birds, were determined weekly.

Environmental variables: the temperature and relative humidity of the air were determined by means of three data-logger devices, TESTO® 174H, installed both in the interior (1.60 m of the floor) and outside the building (2.50 m from the ground). For air velocity monitoring, a multi-function memory measuring instrument, TESTO® 435, was used with speed probe and integrated temperature and humidity measurement at three points in the aviary and two external points. At each point, several measures were performed to obtain the average air velocity.

Concentration and gas emission: the methodology continues to provide a continuous measurement. In this case, the air collection is performed directly by the INNOVA 1412 equipment with short intervals of time during the entire productive cycle studied. In monitoring unit (UM) was installed the photo acoustic gas monitor - INNOVA 1412, connected to a multipoint sampler - INNOVA 1309, as recommended by Hassouna et al. (2010), Robin et al. (2006), Guingand et al. (2010). The equipment's were connected to a computer with internet access allowing the monitoring of the measurements in real time in any place.

Emissions: emission flow calculation was based on measured gas concentration in the production system. Emissions were calculated for the duration of the livestock production batch. The flow emissions were based on equations proposed by Robin et al. (2010).

Mass balance: this method allowed calculating the loss of nitrogen and phosphorus elements. Thus, a mass balance was performed considering all inputs and outputs of the production system.

Results and discussion

In Table 1 is possible observe the data of temperature, relative humidity and air velocity (internal and external), determined in broiler house.

Table 1. Average temperature, relative humidity and air velocity in broiler house.

	Temperature (°C)		Humidity (%)		Air velocity (m/s)
	Inside	Outside	Inside	Outside	Inside
Morning	26,69 ±1,87	21,64 ±1,56	70,05±10,81	79,81±11,14	0,81±0,9
Afternoon	27,43 ±1,91	25,04 ±1,88	68,04±12,32	67,05±14,27	0,83±1,0

The Figure 1 shows the date on ammonia concentration during the productive cycle in ppm-v. It is observed from the graph that the concentration of ammonia in the air during the cycle decreases with the course of days. The correlation between the age variable of the animals and the concentration of ammonia in ppm was significant ($p < 0.05$). There was also a correlation between NH_3 concentration and air velocity indicating that the concentration decreased at the end of the productive cycle due to air renewal rates.

The results also indicate that in the first days of production when ventilation is usually minimal, concentrations exceeded the 25-ppm limit recommendations. This result was also found by Carvalho et al. (2011).

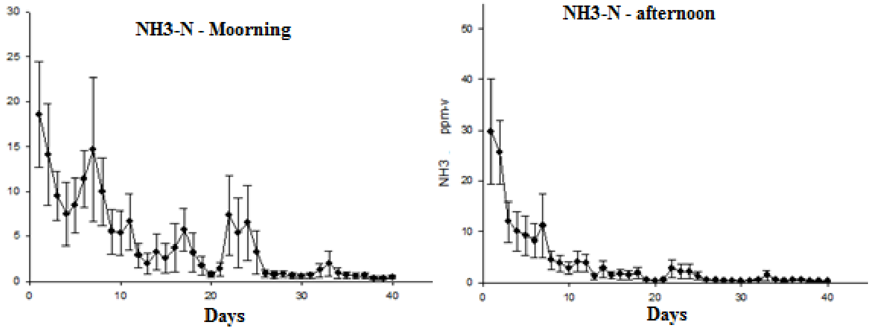

Figure 1. Concentrations of ammonia (ppm) inside broiler house.

In the Table 2 it was demonstrated that the average flow of NH_3 during the morning. The flow of ammonia emission increased significantly in the last weeks of production according to the development of the animals. This tendency was also observed by Moore et al. (2011). Through the mass balance (Table 3), it was observed that the loss of nitrogen during the production cycle was 485 kg. The N in the form of NH_3 represented 60% of all the lost nitrogen observed in the mass balance. Considering that the difference between the balance sheet default and the NH_3 emissions recorded corresponds to the nitrogen lost in the molecular form (N_2), the losses corresponded to 40%. The balance error for the phosphorus was about 10% which is within the acceptable range according to Robin et al. (2006).

Table 2. Weekly average of the NH_3-N emission flux in the morning period.

Production cycle (days)	NH_3-N (g/h)
1-10	164,39
11-20	172,64
21-30	197,08
31-41	224,47

Table 3. Mass balance in productive cycle.

Mass balance	P (kg)	N (kg)
Input	1.685,77	3.690
Output	1.534,30	3.205
Default	151,47	485.0
NH_3-N		294

Conclusions

The balance of N and P showed good results. The observed error for phosphorus was 10%, indicating that the balance is a good alternative to identify the losses of nitrogen and carbon in the production of broilers. During the 42 day period and according to the total input of N, nitrogen total losses were 485 kg or 37 g/bird. Ammonia losses corresponded 60% of nitrogen default.

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EFFECTS OF ANIMAL FAT-DERIVED BIODIESEL ON DIESEL ENGINE TAIL PIPE GAS EMISSION

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Abstract: the effects of two different biodiesel blends made from either chicken and swine fat (FW-1) or floating fat collected from slaughterhouse wastewater treatment processes (FW-2) on CO_2, CO, NO_x tailpipe emissions and fuel consumption was investigated. The experiments were performed using a stationary an unmodified diesel engine under idling conditions. Despite of the lower CO_2 emissions, negligible differences were observed among all biodiesel blends tested compared to petrodiesel. Significant reduction in CO emission was obtained for all blends except B5 from FW-2. A significant reduction in CO emission of 47% was achieved for B100 from FW-2. NOx emission for B100 was 20% lower than that obtained from petrodiesel alone. An increase in fuel consumption by up to 5% was only verified when using B100 from either FW-1 or FW-2. Overall, the results improved our current understanding on the effects of different fat-based biodiesel blends on CO_2, CO, NO_x emissions as well as fuel consumption by diesel engines operating under conditions that prevail in the slow traffic of urban areas.

Keywords: chicken and swine fat, fuel consumption, wastewater, GGE.

EFEITOS DO BIODIESEL DERIVADO DE GORDURAS ANIMAIS SOBRE AS EMISSÕES DE GASES

Resumo: foram investigados os efeitos de duas misturas diferentes de biodiesel produzidas a partir de gordura de frango e suíno (FW-1) ou de gordura do flotado, coletada dos processos de tratamento de efluentes do abatedouro (FW-2) nas emissões de CO_2, CO, NO_x e consumo de combustível. Os experimentos foram realizados utilizando um motor diesel não modificado em condições de estado estacionário. Apesar das menores emissões de CO_2, diferenças insignificantes foram observadas entre todas as misturas de biodiesel testadas em comparação com o petrodiesel. Obteve-se uma redução significativa na emissão de CO para todas as misturas exceto B5 a partir de FW-2. Uma redução significativa na emissão de CO de 47% foi obtida para B100 a partir de FW-2. A emissão de NO_x para o B100 foi 20% menor que a obtida apenas com o petrodiesel. Um aumento no consumo de combustível até 5% foi verificado quando se utiliza somente B100 a partir de FW-1 ou FW-2. Em geral, os resultados melhoraram o nosso entendimento atual sobre os efeitos de diferentes misturas de biodiesel à base de gordura nas emissões de CO_2, CO, NO_x, bem como o consumo de combustível por motores diesel operando em condições que predominam no lento tráfego de áreas urbanas.

Palavras-chave: gordura de suínos e aves, consumo de combustível, efluentes residuais, GEE.

Introduction

Brazil has voluntarily committed to reduce atmospheric greenhouse gas emissions (GGE) up to 39% by 2020 (Mapa, 2014). Consequently, the use of low emissions biofuels and in particular biodiesel blends is going to increase to a minimum of 7% volume basis in petrodiesel by November 2014 (DOU, 2014). Currently, soybean and bovine fat are the main feedstock sources accounting for 75 and 20%, respectively for biodiesel production in Brazil (ANP, 2014). Contradictorily, however, soybean-based biodiesel are known to increase NO_x emissions by up to 13% in comparison to petrodiesel (Cheung; Zhu; Huang, 2009; Canakci; Van Gerpen, 2003; Wyatt et al., 2005). The increase in NO_x emissions is typically associated with higher oxygen, cetane number and unsaturated compounds present in biodiesel (Xue; Grift; Hansen, 2011). Thus, fuel composition variations as result of different feedstock sources utilized could offset the environmental benefits of using biodiesel to reduce GGE. This strongly dictates the needs to continue our investigations on alternative feedstock sources for biodiesel production in order to identify the most suitable clean burn biodiesel fuels with lower GGE emission potential (Dwivedi; Jain; Sharma, 2011). Animal fat-based biodiesel seems reasonable since it has shown to decrease NO_x emissions by up to 6.2% in relation to soybean biodiesel blend B20 (Wyatt et al., 2005; Bousbaa et al., 2012). Yellow grease-based biodiesel was also reported to decrease NO_x emissions in relation to B20 and B100 soybean biodiesel despite of the higher oxygen and cetane number (Canakci; Van Gerpen, 2003). The use of animal fat as feedstock for biodiesel production can pose significant advantages for Brazilian market considering that the country is one of the largest meat producers worldwide generating large amounts of animal fat wastes from slaughterhouses that could be attained at considerably low costs (Cunha et al., 2013). Nonetheless, little information is available on the potential NO_x (and other GGE) exhaust gas emissions from animal fat-derived biodiesel blends in comparison to petrodiesel alone. For instance, GGE emissions from the use of mixed sources of biodiesel feedstock such as swine and poultry fats have yet to be established. Therefore, the objective of this study was to assess the effects of different biodiesel blends made from either chicken and swine fat or floating fat from slaughterhouse wastewater treatment processes on GGE exhaust emissions from a lab scale stationary diesel engine.

Materials and methods

Biodiesel feedstock: the crude fat residues used for the production of biodiesel were obtained from a chicken and swine meat processing slaughter industry in southern Brazil (Seara city, Santa Catarina, Brazil). Two different types of fat residues were obtained in solid form without rendering processing. The first named FW-1 (i.e., fat waste) referred to mix of fat residues from chicken and swine. The second one named FW-2 referred to the supernatant floating type fat collected from the slaughterhouse wastewater treatment processes. The fatty acid concentrations, physico-chemical properties as well as the optimal conditions utilized to produce the biofuel were previously reported (Cunha et al., 2013). Negligible differences in fuel characteristics were observed between FW-1 and FW-2. Biodiesel was tested as the sole source of fuel (B100) or blended with petrodiesel at different volumes percentages (v/v %) that are typically commercially available worldwide, i.e., B(5), B(20), and B(50). Petrodiesel alone was used as a negative control to discern variations in GGE from the use of biodiesel blends.

Engine type and operational conditions: a single cylinder, direct injection, air cooled and naturally aspirated stationary diesel engine (Yanmar NSB11S, Indaiatuba, SP, Brazil) was used in this study. The engine has a 20.3:1 compression ratio, 631 cm^3 displacement and develops a maximum horsepower of 9.7 KW (13 horsepower) at 2,400 rpm. The engine was kept idling for 60 min while the exhaust gas emissions (CO, CO_2, and NO_x) were continuously analyzed every 5 min. The volume of fuel consumed per time was measured directly from a graduated volumetric cylinder used as a tank reservoir to store the fuels.

Exhaust gases analyses: the concentrations of CO, CO_2, and NO_x were analyzed directly from the exhaust pipe outlet using the gas analyzer Dräger MSI 150 PRO II-i (Hagen, Germany). The sensor was placed 10 cm inside the exhaust pipe outlet to minimize surrounding atmospheric gases dilutions.

Statistical analysis: Data obtained from the engine exhaust were randomly used independently of the fuel tested (B5, B20, B50 or B100) for statistical variance analysis. Data were presented as a mean of four replicates. Statistical differences were performed using Tukey test ($P<0.05$). All statistical analyzes were performed using specific software (SAS Institute Inc., 2003).

Results and discussion

The effect of two different sources of animal fat-derived biodiesel blends on GGE from a stationary diesel engine was evaluated. Figure 1 shows that independently from the biodiesel used i.e., produced from a mix of chicken and swine (FW-1) or fat from slaughterhouse wastewater treatment processes (FW-2), GGE were statistically similar or even lower than petrodiesel. Among the biodiesel blends tested, B50 from FW-1 and B20 from FW-2 had a significant effect on the reduction of CO_2 emissions compared to other blends (Figure 1A). This can be attributed to the intrinsic C:O ratio as well as oxygen content at these particular biodiesel blends. While this effect can be perceived for low biodiesel concentration fuel blends, it is weakened with further addition of biodiesel volumes in the mixture (Randazzo; Sodré, 2011). Nonetheless, despite of the lower CO_2 emissions, negligible differences were observed among all biodiesel blends tested compared to petrodiesel. The most apparent effects of biodiesel blend on GGE reduction was observed for CO emissions (Figure 1B). A trend in CO emission reduction concomitantly to the increasing volumes of either FW-1 or FW-2 biodiesels in the mixture was observed. The lower CO emission was measured when using B100 from either FW-1 or FW-2. Significant reduction in CO emission was obtained for all blends tested except B5 from FW-2. Compared to petrodiesel fuel tested alone, the most significant reduction in CO emission (47%) was obtained for B100 from FW-2. It is known that CO_2 contributes to most gas emissions (85%) while NOx contributes to only 6% (EPA, 2010). Concerns on NO_x emissions reside on its reaction with moisture in the atmosphere producing harmful nitric acid which contributes to the particular matter (PM10 and PM2.5) and acid rain problems (De Nevers, 2000). Among all biodiesel ratios tested, NO_x emission utilizing B5 from FW-1 or B100 from FW-2 were lowest (20% lower compared to petrodiesel alone). Despite of the observed decrease in NOx emission obtained for all blends of biodiesel tested, these were not statistically different ($P<0.05$) from that observed for diesel fuel only (Figure 1C). A decrease in NO_x emission is associated with the biodiesel fuels intrinsic characteristics that lower internal combustion temperatures (Cheung; Zhu; Huang, 2009). It is also important to note that the feedstock biomass utilized to produce biodiesels plays an important role on changing the chemical properties of the fuel and consequently its combustion characteristics. For instance, a decrease in NO_x emission was demonstrated for B20 produced from lard, beef tallow, or chicken fat-biodiesels compared to soy-based B20 (Wyatt et al., 2005; Öner; Altun, 2009). NO_x emissions seem to be inversely proportional to the concentration of saturated fatty acids present in the biodiesel composition (Wyatt et al., 2005). This could explain why soybean-based biodiesel that has a high content of unsaturated fatty acids enhances NOx emissions. There are concerns about the use of biodiesel blends particularly regarding fuel mileage and consumption (Friedman;

Grossweiler, 2014). B100 has about 10% lower British thermal unit (BTU) energy compared to petrodiesel and thus an increase in fuel consumption is expected. An increase of approximately 5% of fuel usage was only verified for B100 from either FW-1 or FW-2 when compared to petrodiesel alone (Figure 1D).

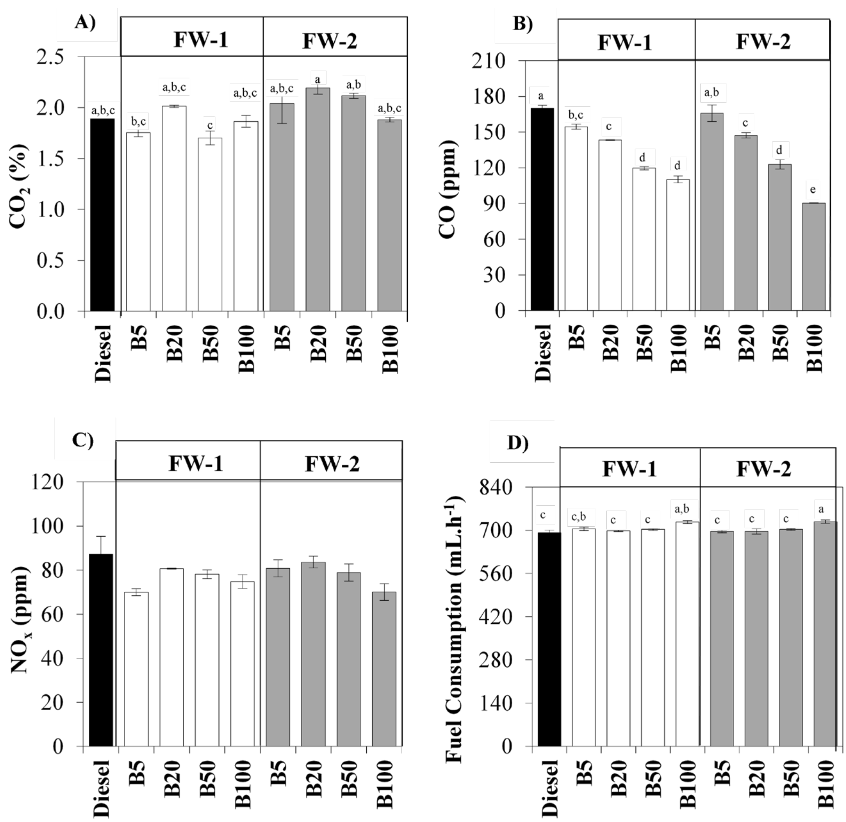

Figure 1. Variation of GGE and fuel consumption of different biodiesel blends compared to diesel.

Further studies are required, however, to investigate whether the biodiesel blends tested here are likely to adversely impact fuel consumption in modern and/or modified diesel engines under different operational loading regimes. Overall, it is important to emphasize that the results obtained in this work are unlikely to encompass emissions from a broad diversity of diesel engines operating under different loading regimes. Nonetheless, the information served to improve our current understanding on the effects of specific fat-based biodiesel on GGE as well as fuel consumption in an unmodified diesel engine under idling conditions that prevails in slow traffic of urban areas.

Conclusions

The effects of two different biodiesel blends made from either a mix of chicken and swine fat (FW-1) or floating fat from slaughterhouse wastewater treatment processes (FW-2) on GGE tailpipe exhaust emissions and fuel consumption was demonstrated. Significant decrease in CO emission of 47% was observed when using B100. CO_2 and NO_x emissions from the biodiesel blends were negligible as compared to petrodiesel. An increase of fuel consumption of 5% was estimated for B100. Overall, the results suggests that these animal fat-based biodiesels may have advantageous inferences on GGE if compared to the use of soybean-based biodiesel which is known to have negative effects on GGE, particularly NO_x emission. Further studies using different diesel engine types and operational conditions are warrant however to understand comprehensively the effects of these fuels on GGE potential.

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EMISSION OF GREENHOUSE GASES IN CONVENTIONAL AND DARK HOUSE BROILER PRODUCTION SYSTEMS

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Abstract: climate change and global warming are topics of scientific debate and public interest, and the "greenhouse gases" (GHG) identified as important causes. Among the GHG, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are considered the major contributors, being the presence of CH_4 and N_2O in the atmosphere lower than that of CO_2. Besides benefits of new technologies on the chickens live performance, it is necessary to consider its environmental impact. This study aims to estimate the impact on GHG of the modern "dark house" production system compared to conventional broiler houses based on feed intake, energy consumption, building area, fuel switching and use of wood shavings as conversion factors.

Keywords: GHG, dark house, broiler production systems.

EMISSÃO DE GASES DE EFEITO ESTUFA EM SISTEMAS DE PRODUÇÃO DE AVES CONVENCIONAL E DARK HOUSE

Resumo: as alterações climáticas e o aquecimento global são temas de debate científico e interesse público, sendo os "gases de efeito estufa" (GEE) identificados como uma das principais causas. Entre os GEE destacam-se o dióxido de carbono (CO_2), metano (CH_4) e óxido nitroso (N_2O), sendo a presença de CH_4 e N_2O na atmosfera menor que a de CO_2. Além dos benefícios das novas tecnologias no desempenho zootécnico dos frangos, é necessário considerar os seus impactos ambientais. Este estudo teve por objetivo estimar o impacto do novo sistema de produção "*dark house*" nas emissões de GEE em comparação com edifícios de alojamento convencionais de frango com base no consumo de ração, consumo de energia, área de construção, troca de combustível e uso de aparas de madeira como fatores de conversão.

Palavras-chave: GEE, *dark-house,* sistemas de produção de aves.

Introduction

Climate change is one of the most challenging environmental issues of the 21st century and solutions must be found to mitigate greenhouse gas (GHG) emissions on a global scale (IPCC, 2007). Among the GHG the CO_2, CH_4, and N_2O are considered the major contributors, being the presence of CH_4 and N_2O in the atmosphere lower than CO_2. Anyway, measurement of CH_4 and N_2O emissions shall be considered because of their high potential to the promotion of greenhouse effect. According to Snyder, Bruulsema and Jensen (2008), compared to CO_2, the potential is 23 times higher for CH_4 and 296 times higher for N_2O. Table 1 shows the historical evolution of poultry production in Brazil.

Table 1. Historical evolution of poultry production in Brazil (1930 to 2015).

Year	BW[1] (g)	ADG[2] (g)	Slaughter age (days)	Feed conversion	Mortality (%)
1930	1,500	13.9	108	3.55	20.0
1940	1,550	15.4	101	3.04	17.2
1950	1,580	22.0	72	2.58	15.2
1960	1,600	27.9	57	2.25	13.1
1970	1,700	33.9	50	2.15	11.2
1980	1,800	36.0	50	2.10	9.5
1985	1,890	38.7	49	2.08	8.8
1990	2,061	45.1	46	2.06	5.9
1995	2,187	47.9	46	2.02	5.5
2000	2,426	53.1	46	1.94	4.5
2005	2,481	54.7	45	1.86	4.3
2010	2,643	58.6	45	1.80	3.9
2015[3]	2,788	64.8	43	1.70	3.7

[1]BW – Body Weight; [2]Average Daily Gain; [3]Estimate.

Source: Publications, interviews and industry statistics.

Considering that Brazil is the major poultry meat exporter and occupies the third position in the world production rank, both national estimations as the mitigation of the greenhouse gases related to the production system are important in the current global environmental scenario (Lima et al., 2006; Lima et al., 2012). The development of poultry production in Brazil is based on continuous incorporation of technologies and on the high degree of organization and coordination of the business. Changes in the production scale have been observed since its inception in the 60s, when it was common to use rustic shed with only 100 m^2. In 1996, different production scales from poultry houses with 300 m^2, 600 m^2, 900 m^2 and 1,200 m^2 were observed in the West of Santa Catarina State (Canever et al., 1997). Currently, the sheds have an area greater than 1,000 m^2, where the emergence of large facilities (up to 4,800 m^2) is observed. The scale-up and the incorporation of new technologies have enabled continuous drop in the cost of production and the increase in the consumption and exports of poultry meat. According to the report "Agribusiness Projections 2011/2012 to 2020/2021" the Brazilian Ministry of Agriculture, Livestock and Supply (Mapa), held in partnership with the Brazilian Agricultural Research Corporation (Embrapa), chicken production is expected to grow annually, approximately 4.2%, from 2011 to 2022, reaching to 20 million tons of meat. Besides benefits of new technologies on the chickens live performance, it is necessary to consider their environmental impacts. This study aims to estimate the impact on GHG of the modern "dark house" production system compared to conventional broiler houses, based feed intake, energy consumption, building area, fuel switching and use of wood shavings, as conversion factors.

Materials and methods

Determination of GHG emissions based on IPCC: in order to compare the generation of GHG for both Conventional (CV) and Dark House (DH) broiler systems, the simulation of the GHG emissions followed the equations and estimations recommended by the IPCC (IPCC, 2006). The characteristics of the evaluated buildings were: CV aviary: 1,200 m^2, with 13.3 birds/m^2 (total: 15,960 birds), with an average weight of 27.93 kg/m^2; DH aviary: 2,400 m^2 with 16.2 birds/m^2 (total: 48,880 birds), with an average weight of 34.02 kg/m^2. The data for the study was provided by Sindicarne -SC and Ubabef (Table 2).

Additionally, it was considered that Brazil processes: a total of 6,232.5 x 10^6 broilers/year which corresponds to 13,088 x10^3 tons of BW and 23,297 x 10^3 tons of feed consumed, annually.

Table 2. Summary of the general building characteristics as well as the statistical and technical data related to broiler chickens produced at both Conventional and Dark Horse buildings used in the simulations of this study.

Items	Conventional	Dark House
Cooling system	Positive pressure	Negative pressure
Heating system	With petroleum gas	With firewood
Lighting system	Incandescent bulbs	Fluorescent and LED lamps
Bedding replacement	Annually	Every two years
Number of flocks per year	6.75	7.02
Density (birds/m^2)	13.3	16.2
Slaughter weight (kg)	2.1	2.1
Age at slaughter (days)	42	40

Items	Conventional	Dark House
Feed Conversion (kg feed/kg BW)	1.78	1.70
Mortality (%)	4.0	4.0

Results and discussion

The results are presented at Table 3. It is observed that emissions of GHG are smaller in the modern dark house system (13,322 x 10^3 ton.eq.CO_2/year) than the conventional production system (15,044 x 10^3 ton.eq.CO_2/year). Comparing the contribution of different technologies for the whole production system, the most impacting improvements were obtained for the feed conversion (40.2%), followed by the heating system (29.3%) and the lighting system (25.1%). The impact for animal density was not important (only 5.1%) because the advantage on less area building materials is diluted in the 25 year time. Improvements in feed conversion result on better environment offered to the chickens by the dark house system. The effect of feed conversion on the GHG emissions is important due to less agricultural area needed for the production of same animal weight, specially corn and soybean, as well as lower emissions from the wastes (excreta). Regarding the heating system, there is a considerable impact by replacing fossil fuels (petroleum gas) by firewood, a renewable heat source. Although firewood is an abundant source, only recently automated technologies for easy and efficient use in broiler houses were made available in Brazil. Similarly, in recent times the LED lamp technology has been turned a real practical possibility for use in chicken farms, representing important economic and environmental advantages. Together, it was observed with this comparative study that the total reduction of GHG emissions 1,722.3 x 10^3 ton.eqCO_2/year. Such difference, promotes the adoption of the higher technology used at dark house system, indicating that, besides technical performance advantages, the high technology promotes the environmental issues in the case of broiler production system.

From the evolution of poultry production in Brazil in the last 40 years (Figure 1), represented by production indicators over time, GHG emissions were estimated using the equations recommended by IPCC (IPCC, 2006), better detailed and already applied in Oliveira et al. (2012). There is a reduction (62.54%) in GHG emissions during this period, which represents an important return to the society of public resources invested in the research and development institutions and universities, as well as in private companies.

Table 3. Annual GHG emissions presented (ton.CO_2eq/year) for conventional and dark house broiler production system.

Items	Conventional production system	Dark house production system	Difference in Annual GHG Emission (ton CO_2eq.)	Where the difference comes from?
Feed conversion	12,138,735.39	11,446,448.36	692,287.03	Lower GHG emissions because of less need for feed, crop area and reduction in total excreta production for the same volume of live weight production
Heating system	524,478.93	19,115.89	505,363.05	Renewed source of fuel and automation of firewood equipment (high efficiency in the use of the heat source)
Bedding replacement	18,397.24	14,522.99	3,874.25	Reduction in the use of wood shavings as well as lower volume of bedding residues to be disposed in the environment
Lighting system	1,945,117.95	1,512,375.12	432,742.84	Less environmental impact due lower electric power need by using fluorescent or LED lamps
Density	417,874.29	329,874.64	87,999.64	A 20% (420,000 m^2) decrease in de building area, with the correspondent lowering needs in building materials (wood, concrete and others).
Total	15,044,603.80	13,322,337.00	**1,722,266.80**	

Conclusions

This comparative study among the conventional and a dark house production system for broilers demonstrates the possibility of reducing GHG using modern high technological buildings. Based on the methodology proposed by the IPCC, a reduction of 1.7 x10^6 ton.CO_2.eq/year is estimated if the Brazilian poultry production adopts the dark house production system, contributing on the agricultural reduction target established in the agriculture program of low carbon. Therefore, the modernization of the Brazilian broiler production system seems to be the great challenge for the Country´s poultry industry in the coming years.

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MODELLING NITROGEN AND CARBON INTERACTIONS DURING COMPOSTING OF ANIMAL MANURE IN NATURALLY AERATED PILES

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Abstract: composting animal manure with natural aeration is a low-cost and low-energy process that can improve nitrogen recycling in millions of farms world-wide. Modelling can decrease the cost of choosing the best options for solid manure management in order to decrease the risk of loss of fertilizer value and ammonia emission. Semi-empirical models are suitable, considering the scarce data available in farm situations. Eleven static piles of pig or poultry manure were monitored to identify the main processes governing nitrogen transformations and losses. A new model was implemented to represent these processes in a pile considered as homogeneous. The model is based on four modules: biodegradation, nitrogen transformations and volatilization, thermal exchanges, and free air space evolution. Most parameters are generic and estimated from literature. Some specific parameters were calibrated with the data set. This work focuses on the nitrogen module. The results showed that microbial growth can reduce ammonia volatilization. Greatest nitrogen conservation was achieved when microbial growth was limited by nitrogen availability.

Keywords: Composting, manure, nitrogen, ammonia, nitrous oxide.

MODELAGEM DAS INTERAÇÕES DO NITROGÊNIO E CARBONO DURANTE A COMPOSTAGEM DE DEJETO ANIMAL EM LEIRAS AERADAS NATURALMENTE

Resumo: a compostagem de dejeto animal com aeração natural é um processo de baixo custo e baixa energia que pode melhorar a reciclagem do nitrogênio em milhões de propriedades por todo o mundo. A modelagem pode diminuir o custo de seleção das melhores opções para o manejo dos dejetos sólidos, de modo a diminuir o risco de perda do valor fertilizante e da emissão de amônia. Modelos semi-empíricos são adequados, considerando a escassez de dados disponíveis à escala da propriedade. Onze leiras estáticas de dejeto sólido de suíno ou de frango foram monitoradas para identificar os principais processos que regem as transformações e as perdas de nitrogênio. Um novo modelo foi implementado para representar esses processos em uma leira considerada homogênea. O modelo é baseado em quatro módulos: biodegradação, transformações e volatilização do nitrogênio, trocas térmicas e evolução do espaço livre poroso. A maioria dos parâmetros é genérica e foram estimados da literatura. Alguns parâmetros específicos foram calibrados a partir de um conjunto de dados. Este trabalho se concentra no módulo do nitrogênio. Os resultados mostraram que o crescimento microbiano pode reduzir a volatilização da amônia. A grande conservação do nitrogênio foi alcançada quando o crescimento microbiano foi limitado pela disponibilidade do nitrogênio.

Palavras-chave: composto, dejeto, nitrogênio, amônia, óxido nitroso.

Introduction

Solid manure management is an economic and environmental issue for millions of livestock farms at global scale. Annual production of animal manure is estimated at 7 billion tons. Its management concerns nitrogen recycling, carbon stocks in soils and transport costs (Steinfeld et al., 2010). Composting is a traditional management process to recycle nutrients excreted by animals, stabilize organic matter before its transport and use, manure hygienization and, more recently, to reduce emissions of odours, ammonia and greenhouse gases (Bernal et al., 2009). Modelling can help to reduce the uncertainty in national inventories, to choose the best options for manure management, to understand the causes of poor performance in existing composting process, and to reduce the cost of experiments. In recent years, models representing the interactions between physical and biochemical characteristics have been developed for composting (Vlyssudes et al., 2009). These models represent the stabilization of organic matter (OM), the decrease in chemical oxygen demand (COD), the production and exchanges of heat, and the emission of gases. To the best of our knowledge, such models have not previously been established for the composting of animal manure in static piles. The originality of this particular case lies in the high nitrogen content, the feedbacks between biomass growth, heat production, natural convection and oxygenation of the pile, and the absence of measurements that can be used as forcing variables (e.g. temperature, ventilation, pH, concentrations). The main challenge in designing a model suited to agriculture is to choose a representation of the processes using (i) low-cost, farm-level parameters that will describe specifically an initial pile of solid manure, (ii) parameters that can be estimated from national references and grey literature, such as the information used in national inventories, (iii) generic parameters that can be based on international peer- reviewed literature. Our objective was to develop a dynamic model suitable for on-farm use. It should represent nitrogen transformations, including nitrogen stabilization, ammonia and total nitrogen losses, and should need as few parameters as possible. In the following sections, the main processes to be represented from an observed dataset are discussed and then the model is described. The calibrated parameters and the resulting outputs are discussed.

Materials and methods

Model Structure

Global model: the model is based on four modules: (i) the COD biodegradation module includes heterotrophic cell growth on biodegradable COD. Cell growth depends on temperature, moisture, oxygen and available nitrogen. In this module, cell decay and CO_2 and CH_4 emission are also considered; (ii) the heat module represents the thermal budget resulting in an average temperature. It includes natural ventilation depending on climatic variations, and the associated convective losses of sensible and latent heat. Natural ventilation depends on total porosity and water content; (iii) the porosity module, in which free air space depends on total porosity and water content dynamics. Oxygen transfer towards the biofilm is also considered; (iv) the nitrogen module models nitrogen biological transformations including N incorporation into the heterotrophic and autotrophic cells, nitrification and denitrification. These are responsible for N immobilization and for N emissions through NH_3, N_2O and N_2 in the gas phase.

Nitrogen module: structure of this module is presented in Figure 1.

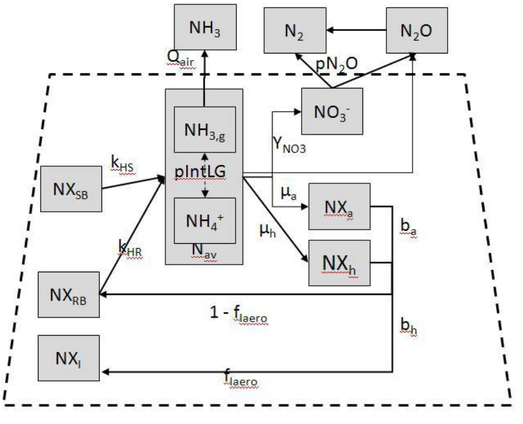

Figure 1. Compartments and flows represented in the nitrogen module.

Ammonification is represented by the hydrolysis of two compartments (NX_{SB}, NX_{RB}) characterized by a slow and a rapid rate of reaction. Their hydrolysis rates are k_{HS} and k_{HR} respectively. Ammonification increases the stock of nitrogen that is available for microbial growth (N_S). Two biomasses grow on the available nitrogen: the heterotrophic (N_{Xh}) and autotrophic (N_{Xa}) biomasses. The nitrogen assimilated by heterotrophic biomass is proportional to the growth calculated in the biodegradation module. The mortality of biomass is represented by the constant decay rates b_h and b_a. The specific growth rates μh and μa depend on the maximal specific growth rates (respectively μh_{max} and μa_{max}). Nitrate production is proportional to the growth of autotrophic biomass, the yield of nitrate production (Y_{NO3}) being constant. The net production of N_2 and N_2O from the NO_3- stock is represented by using the NEMIS representation (Hénault; Germon, 2000). Denitrification is proportional to the stock of nitrates. Assimilation of N_2O and N_2 into biomass is neglected, which is equivalent to considering net fluxes and not raw fluxes. The temperature can limit the transformations. The temperature used in the limitation functions of nitrification and denitrification is the temperature of the area of nitrification (T_{nit}), as for the volatilization process. The water-filled pore space changes the proportions of N_2 and N_2O in the total nitrogen denitrified. Hydrolysis, growth, decay and volatilization are influenced by temperature and humidity, substrate and oxygen availability. More details of the modules are given in Oudart (2013).

Calibration data: to calibrate this model, experimentations presented by Paillat et al. (2005) and Abd El Kader et al. (2007) were used. All details are given in these papers. Results of calibration for heap B, F and G are presented here. The first heap is composed of pig manure and urea, the second of pig slurry, wheat straw and sawdust and the third of pig slurry, wheat straw and sugar beet molasses. All the three heaps had the same humidity (70%) and porosity (72%) but different soluble to total nitrogen ratio (respectively 55, 65 and 75%) and soluble to total dry matter ratio (respectively 30, 30 and 53%). This model contains 73 parameters including 12 specific parameters which depend on the substrate nature (initial fractionation) and on the physical characteristics of the initial pile. The model works on an hourly time step. It has been programmed with the Vensim® software (Ventana System, USA).

Results and discussion

Figure 2a, representing CO_2 emission during the first 30 days of composting, allows the main differences in CO_2 emissions between the piles to be detected: the time interval between pile settling and rise in CO_2, and the differences in peak value. These results show that the representation of organic matter biodegradation, including its limitation by temperature, nitrogen, oxygen and humidity, can be considered as acceptable. The ammonia volatilization is correctly predicted (Figure 2b). The simulations reproduce the observed differences in peak emission of NH_3 and also the time interval between the emission increases of the various piles. Most N_2O emission was observed during the first week after setting up the pile. The relative differences between total emissions observed or simulated were respectively 1%, 11%, 27% for piles B, F and G after 40 days. The total N_2O emission was around 1% of ammonia emission and less than 1% of initial nitrogen. The relative differences between observed and simulated N_2O dynamics were much higher than for CO_2, H_2O or NH_3 emissions.

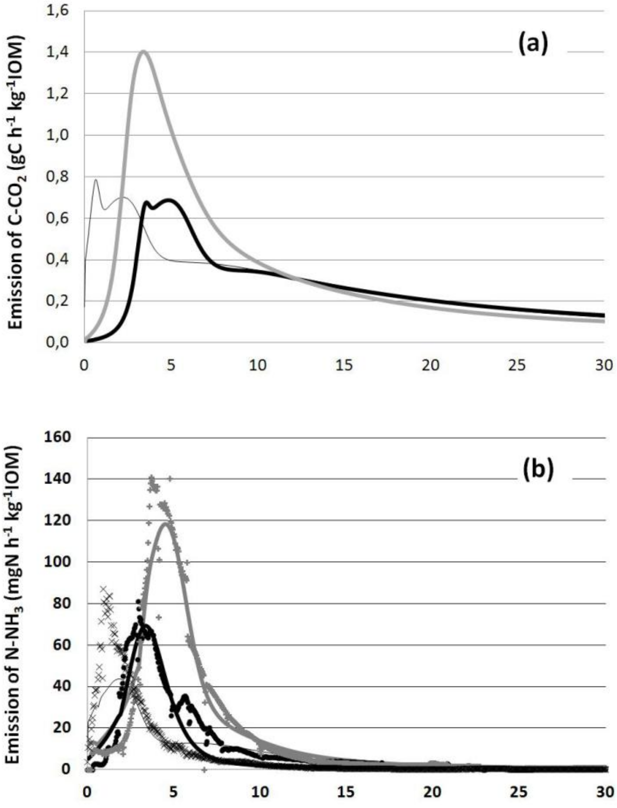

Figura 2. Simulated dynamics of CO_2 (a) and NH_3 compared to observed dynamic (b). Pile B (thin black line); pile F (thick black line); pile G (thick grey line).

The parameter pIntLG, influencing NH_3 emission, showed consistent values: it was equal to 1 for piles B and F (no restriction, as for the majority of the 11 piles) while it was equal to 0.4 for pile G, where the biodegradation of molasses could produce acid compounds that promoted ammonia retention for further assimilation. It was not necessary to introduce a temporal variation of the parameter pIntLG. Therefore, the choice to globally represent the processes of NH_3 emission by only one parameter, pIntLG, can be considered appropriate for modelling solid manure composting on farms.

Conclusions

The proposed model shows a degree of complexity sufficient for the simultaneous simulation of the physical and biochemical behaviour of solid manure during composting in static piles. The dynamics of variables used to describe the main processes are well handled (temperature, emissions of CO_2, H_2O and NH_3). Therefore, it was possible to predict gas emissions for 11 study cases characterized by contrasting initial compositions and operating conditions. This model can be used to improve the understanding of interactions between mechanisms occurring in composting and to help choosing strategies to decrease emissions at farm scale. Further work with parameter prediction is needed to use the model to predict the emissions for a specific pile.

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GREENHOUSE GAS EMISSIONS IN GROWING-FINISHING SWINE PHASE

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Abstract: the environmental impact caused by the livestock activities is increasing the number of researches taking into consideration the pollution effects. The livestock activities have a great contribution to ammonia (NH_3) and greenhouse gases (GHG) emissions. Ammonia contributes to eutrophication and acidification of ecosystems. Greenhouse gases, including CO_2, CH_4, N_2O and H_2O vapor are considered the main responsible gases for the global warming and the climate changes. In this context, the present research aims to characterize the NH_3 and GHG emissions in one swine housing building, focusing on the growth physiological stage and on the finishing stage, basing in a simplified methodology. Furthermore, we aim at verify the obtained results through the simplified methodology, considering the nutrient balance: this one enables us to evaluate the data's consistency using the simplified methodology. This research was developed in a commercial farm in Concórdia/SC, Brazil The gas mensuration was accomplished by the simplified methodology. The concentrations of gases in the air were measured by the gas analyzer, named INNOVA 1412. The average gas emissions were estimated, taking into consideration the ventilation rate and the difference between concentration gases inside and outside parts of the housing building. The emission flow obtained by the simplified methodology in [g/swine/day] was 2,689 to CO_2, 0.30 to N_2O, 4.39 to CH_4, 13.55 to NH_3 and 3,273 to water vapor. Comparing theses values to the mass balance, the simplified methodology presented a greater consistency in relation to the obtained data.

Keywords: climate change, gas emissions, CH_4, methodologies, simplified method.

EMISSÕES DE GASES DE EFEITO ESTUFA NA FASE DE CRESCIMENTO E TERMINAÇÃO DE SUÍNOS

Resumo: o impacto ambiental causado pelas atividades pecuárias está aumentando o número de pesquisas, levando em consideração seus efeitos poluidores. As atividades pecuárias têm participação nas emissões de amônia e gases de efeito estufa. A amônia contribui para a eutrofização e acidificação dos ecossistemas. Os gases de efeito estufa (GEE), incluindo CO_2, CH_4, N_2O

e vapor de H_2O são considerados os principais gases responsáveis pelo aquecimento global e as mudanças climáticas. Neste contexto, a presente pesquisa teve como objetivo caracterizar as emissões de amônia e gases de efeito estufa em um edifício de produção de suínos na fase fisiológica de crescimento-terminação, com base numa metodologia simplificada. Além disso, objetivamos verificar os resultados obtidos pela metodologia simplificada, por meio do balanço de nutrientes: este permite avaliar a consistência dos dados utilizando a metodologia simplificada. Esta pesquisa foi desenvolvida numa granja comercial em Concórdia/SC, Brasil. A mensuração do gás foi realizada pela metodologia simplificada. As concentrações de gases no ar foram medidas pelo analisador de gás (INNOVA 1412). As emissões médias de gases foram estimadas, levando em consideração a taxa de ventilação e as diferenças de concentração de gases entre o ar interior e exterior da instalação. O fluxo de emissão obtido pela metodologia simplificada em [g/suíno/dia] foi de 2.689 para CO_2, 0,30 para N_2O, 4,39 para CH_4, 13,55 para NH_3 e 3.273 para água. Comparando os valores obtidos com o balanço de massa, conclui-se que a metodologia simplificada apresentou maior consistência em relação aos dados obtidos.

Palavras-chave: mudanças climáticas, emissões gasosas, CH_4, metodologias, metodologia simplificada.

Introduction

The impacts related to the animal production have been researched worldwide focusing on the attempt to conclude what is the real contribution to the air pollution and climate changes. The increase of the greenhouse gases concentration in the atmosphere is viewed as a possible cause for the global warming. Some of the main responsible gases for this phenomenon are: water vapor, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). It is estimated that the greenhouse gases emissions through the livestock production are approximately 18% - the swine breeding covers 13% of this total presented (Steinfeld et al., 2006) and the measure of the gas production from this activity is based on the European and North American measurement patterns. Moreover, there are some inconvenient aspects of this measurement – this is not precise, because it offers us unreliable data and this is not suitable to all the situations. Furthermore, the cost of this application is high to a great number of places. While in COP 15, in Copenhagen (UNFCCC, 2009), Brazil assumed the responsibility to help reducing the greenhouse gas emissions, but there is still no exact number of the real contribution of the swine breeding in the pollution. For this reason, it is necessary to consider the European measurement patterns, even within the Brazilian situation, as there is no national pattern that could handle the statistics of our emissions. This article focus on categorizing the ammonia

(NH_3) emissions and greenhouse gases (GHG) in a swine breeding station in the physiological phase: growing-finishing phase, considering the pattern proposed by Robin et al. (2010) and to verify the results obtained by two methodologies, through the balance of nutrients – it is possible, by following this steps, to evaluate the data's coherence using these methodologies.

Materials and methods

The experiment was conducted between November and February, 2014, in a commercial swine farm, located in Alto Bela Vista/SC, Brazil. There were 144 pigs, selected based on different genetic types, considering the light meat deposition (Landrace and Large White), females and growing-finishing barrows. The temperature and humidity were monitored in the inside and outside parts of the building, using the thermohygrometer TESTO®, considering a period of 30 minutes. There were collected two weekly samples of the consumed food, as well as the effluent resulted from this activity, which were analyzed according to their physical and chemical characteristics (ex: N, C, P, K, organic and dry matter). Water consumption and slurry production were estimated using the proposed models (Tavares, 2012). The air collection was done in the inside/outside of the building, using a suction bomb ELITE®, connected to a collector bag - TEDLAR® (SKC®). The gases concentration was measured in a period of twelve days at 9 am and 2 pm, respectively, in the inside and outside of the building. The air in the inside part of the building was collected from each pen. The outside air was collected during the whole building extension, in their parallel sides, in an approximated distance of 3 m during 45 minutes. After the air collection in the TEDLAR bags, the content was analyzed with the use of INNOVA 1412. In the calculus of gas fluxes, the outflow air, the volumetric characteristics and the concentration difference (inside/outside) and the outside part of the building (N and C) were considered in the math in the following equation (1):

$$\varphi = Q_{air} \times \rho_i \times (C_i^m - C_e^m)$$

The symbol φ stands for the gas emissions (ex: in mg $N\text{-}NH_3$/h/animal) estimated, considering the air flow in the building (Qair, m^3/s); (*Cim –Cem*) is the difference of the gases concentrations (ppm) between the inside and outside of building; ρi is the volume conversion of the air flux that goes through the building in m^3 for the mass flux in kg of dry air per hour, that allows the implementation of the mass and energy conservations laws. To present this math, we use the following equation (2):

$$\rho_i = \left[\frac{P_{vap}}{47{,}1 \times (T_{ref} + t_i)} + \frac{P_{atm} - P_{vap}}{29{,}27 \times (T_{ref} + t_i)}\right] \times \frac{1}{grav}$$

Grav means the acceleration of the gravity (9.81 m/s2): 4.71 and 29.27 are the two constants of the perfect gases for the water vapor and dry air; T_{ref} is the temperature of the water critical point (273.15 Kelvin); P_{vap} is the water vapor partial pressure, also known as the moisture reason and P_{atm} is the atmosphere pressure. The building outflow air was estimated from the proposed equations used for the animal production. The outflow air calculus in buildings with natural ventilation is particularly a difficult task, because it is associated with no precision, so the outflow air was measured through the heat production, according to the equations proposed by Comission Internationale Gènie Rural (2002). The results obtained by the research were subjected to a preliminary analysis, through the application of the Microsoft Excel Software® to the elimination of possible errors. To present the results, we present below a statistical descriptive analysis of data.

Results and discussion

Observing the gases concentration data and the psychometric characteristics of the air (inside and outside), it was determined the air flux in the inside part of the building, aiming at obtaining the productive variable in gas grams that were collected through the mathematical modeling, using the proposed models (Robin et al., 2010), Table 1.

Table 1. Means and standard deviations of the gas flow, water vapor and ammonia in the commercial production of pigs in growing-finishing phases.

N.º of observations	CO_2	N_2O	CH_4	NH_3	H_2O
	(g/pig/day)				
13/01/14	1,908.0	0.18	4.67	8.00	386.0
15/01/14	3,533.0	0.24	10.80	16.00	5,040.0
17/01/14	2,523.0	0.23	3.69	16.00	907.0
20/01/14	1,563.0	0.05	6.65	9.00	5,806.0
22/01/14	1,670.0	0.10	1.87	7.65	427.0
24/01/14	1,999.0	0.23	0.90	8.57	1,879.0
27/01/14	5,467.0	0.50	2.83	28.67	11,637.0
29/01/14	1,229.0	0.13	2.03	4.26	748.0
31/01/14	1,385.0	0.08	4.75	8.49	2,205.0
03/01/14	4,284.0	0.76	2.55	24.49	1,881.0
05/02/14	2,954.0	0.45	6.20	16.04	900.0
07/02/14	3,755.0	0.56	5.63	14.22	7,460.0
Average	2,689.0	0.30	4.39	13.55	3,273.0
Maximum	5,467.0	0.76	10.82	2z8.67	11,637.0
Minimum	1,229.0	0.05	0.90	4.26	386.0
SD (±)	1,328.0	0.22	2.72	7.35	3,517.0

The average CO_2 emissions observed was 2,689.0 g/pig/day. The main origins of carbon dioxide in the building are the animals breathing and the fermentation of the manure presented on the floor. The average NH_3 emissions obtained by the simplified method were 13.55 g/pig/day; similar data were obtained by Guingand, Quiniou and Courboulay (2010). The average emission for N_2O was 0.30 g/pig/day. These data were lower than values found by Robin, Oliveira and Kermarrec (1999), with emissions of 8.0 g/pig/day. However they were similar to those obtained by Osada, Takada and Shinzato (2011). In the case of CH_4, the average value was 4.39 g/pig/day. The literature presents considerable variations, from 2.0 to 30.0 g/pig/day (haeussermann et al., 2008).

The water vapor produced per pig was 3,273.0 g/pig/day, a number that is considered high when compared to those obtained by other authors (Comission Internationale Gènie Rural, 2002). The validation or verification of the simplified methodology is performed by comparing it with the data obtained by the mass balance. The deficit in the mass balance represents the gaseous losses occurred in the building. Table 2 shows the total of carbon and nitrogen emissions measured by the simplified methodology in comparison to the mass balance.

Table 2. Means and standard deviations of the gas flow, water vapor and ammonia in the commercial production of pigs in growing-finishing phases.

Element	SM Emissions (kg)	Mass Balance (kg)
Carbon	2,919.0	2,869.0
Nitrogen	45.72	133.05[1]

[1]30-60% of this value corresponds to molecular nitrogen.

Comparing the emissions obtained by the simplified methodology with the mass balance, it was obtained a difference of approximately 2% for the carbon. It is concluded that the simplified methodology showed to be coherent (Hassouna et al., 2010). The total nitrogen obtained by the mass balance considering the molecular nitrogen (N_2) and this form of nitrogen are not detected by the sensors of the INNOVA gas analyzer. According to Ponchant et al. (2009), molecular nitrogen can correspond to 30% to 60% of the volatilized nitrogen. Comparing the values obtained by mass balance, we found a difference of approximately 14%. This difference is considered acceptable by Hassouna et al. (2010) and Guingand et al. (2010).

Conclusions

Under these experimental conditions, the simplified methodology showed to be coherent in its results, being verified by the mass balance. Considering the ratio production of meat and gaseous emissions, to produce one kilogram of meat are emitted into the atmosphere 2.2 kg of CO_2, 0.2 g of N_2O, 4.0 g of CH_4 and 12.0 g of NH_3.

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GREENHOUSE GAS AND AMMONIA EMISSIONS FROM COMMERCIAL GROWING-FINISHING PIG FARM

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Abstract: nowadays, there are a few studies developed in Brazil to estimate the greenhouse gases and ammonia emissions from pig production systems. In this context, the aim of this work was to measure the greenhouse gases and ammonia emissions from a commercial growing-finishing pig farm, through the simplified methodology developed in INRA/France. The water disappearance, manure production and gas emissions by pigs were determined according to the methodology presented in Tavares et al. (2014) and Robin et al. (2010), respectively. The results obtained for water disappearance and manure production were 7.32±1.31 and 2.93±0.56 L/pig/d, respectively. The concentration values obtained for the gases evaluated (ppm-v), inside the housing building, were: 591.07 (CO_2), 8.24 (CH_4), 0.26 (N_2O) and 1.32 (NH_3), corresponding to the following emissions by pig (g/d): 456.23±129.29 ($C\text{-}CO_2$), 33.69±20.38 ($C\text{-}CH_4$), 0.24±0.15 ($N\text{-}N_2O$) and 3.04±1.77 ($N\text{-}NH_3$). The values obtained showed the effect of natural ventilation in growing-finishing pig farm when compared with the data presented in several studies in Europe with mechanical ventilation.

Keywords: emissions, greenhouse gas, ammonia, pigs, growing-finishing.

EMISSÃO DE GASES DE EFEITO ESTUFA E AMÔNIA EM GRANJA COMERCIAL DE SUÍNOS NA FASE DE CRESCIMENTO-TERMINAÇÃO

Resumo: atualmente, existem poucos estudos desenvolvidos no Brasil para estimar a emissão de gases de efeito estufa e amônia em sistemas de produção de suínos. Neste contexto, o objetivo deste trabalho foi medir a emissão dos gases de efeito estufa e amônia em uma granja comercial de suínos de crescimento-terminação, através da metodologia simplificada desenvolvida no INRA/França. O consumo de água, a produção de dejetos e a emissão de gases foram determinadas de acordo com a metodologia apresentada por Tavares et al. (2014) e Robin et al. (2010). Os resultados obtidos para o consumo de água e produção de dejetos foram respectivamente: 7,32±1,31 e 2,93±0,56 L/suíno/d. Os valores de concentração obtidos para os gases avaliados (em ppm-v), no interior dos edifícios de alojamento, foram: 591,07 (CO_2), 8,24

(CH_4), 0,26 (N_2O) e 1,32 (NH_3), correspondendo às seguintes emissões por suíno (g/d): 456,23±129,29 (C-CO_2), 33,69±20,38 (C-CH_4), 0,24±0,15 (N-N_2O) e 3,04±1,77 (N-NH_3). Os valores obtidos mostraram o efeito da ventilação natural na granja de suínos em crescimento-terminação quando comparados com dados apresentados em diversos estudos na Europa em condições de ventilação mecânica.

Palavras-chave: emissões, gases efeito estufa, amônia, suínos, crescimento-terminação.

Introduction

Nowadays, the preparation of the national inventory of greenhouse gas emissions in Brazil uses assumptions and values referred to in foreign literature. This procedure disregards several particularities of pig production in Brazil at both the regional and national level, generating an imprecise quantification of greenhouse gases and ammonia, unrepresentative and difficult to apply in future gas mitigation policies. In order to reduce the uncertainty of values, it is essential to develop our knowledge of gaseous emissions in pig production in Brazil. In this sense, and in the absence of a scientific consensus on the standard methodology to be adopted for the determination of emissions, several proposals have been presented, however, many of them being onerous and difficult to apply in the field (Paillat et al., 2005, ROBIN et al., 2010). The simplified methodology is one of the available options allowing the reduction of sample time, the costs per sample and maintaining the accuracy of the experimental data obtained (Guingand et al., 2011). The aim of this work was to measure the gaseous emissions (ammonia and greenhouse gases) from a commercial growing-finishing pig farm located at the west of Santa Catarina State in southern Brazil.

Materials and methods

Farms and equipment: one commercial growing-finishing farm was monitored and evaluated between October 2012 and January 2013, considering a housing period of 105 days. The pigs were distributed randomly by sex in both sides of the housing building, each with pens for 10 pigs. Every pen measured 3.5 m x 3.5 m (12.25 m^2; 1.225 m^2/pig), had a fully concrete floor and contained a single water drinker (nipple) situated at the midpoint of the end wall. One single feeder measuring 0.2 m x 3.5 m was located at the front of the pen. The manure produced was cleaned manually, at least one time per day, by the producers (dry cleaning). The farm was naturally ventilated through a system of double-sided curtain.

Growing-finishing pigs: during 105 days, 620 animals were housed at the growing-finishing farm. All pigs had a Large White x Landrace mother and a Large White x Pietrain boar father. The pigs (9 weeks old and 27.7

kg average BW) were fed manually with restricted daily feed intake by the producers (3 times per day: 8:00 am, 12:00 pm, and 6:00 pm). During each production cycle, the pigs had access to 9 different nutritionally balanced diets (corn and soybean; crude protein content ranging between 21% and 14%) produced by the agroindustry company and formulated according to National Research Council (NRC, 1998) and Brazilian tables for poultry and pigs (Rostagno et al., 2011).

Water disappearance and manure production measurements: water use was measured by a total of four water meters (Unimag Cyble PN 10, Itron Inc., Liberty Lake, Washington) installed in all water delivery lines at farm, which supplied the 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 building and the storage system. The manure produced and stored in the pits ditches outside the housing building 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 the farm for physico-chemical characterisation (Tavares et al., 2014).

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 the growing-finishing farm (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 two days per week, amounting 18 samples in the study, and the gradient for all gases was determined by the difference between the internal and external concentration of air in the building. 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 emissions for CO_2 and other gases have been estimated according to the Eq. 2 and Eq. 3, 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. To determine the different gases emissions were also used the Eq. 4 and Eq. 5, respectively. For this purpose, the temperature, relative humidity and air velocity (internal and external air of the building) were determined during the lot and on the specific day of air samplings (Paillat et al., 2005; Robin et al., 2010).

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

$$\text{Emission}_{C\text{-}CO2} = \text{Loss}_{C}/[1+(\text{Grad}_{C\text{-}CH4}/\text{Grad}_{C\text{-}CO2})] \quad (2)$$

$$\text{Emission}_{Gas} = \text{Loss}_C/[1+(\text{Grad}_{Gas}/\text{Grad}_{C\text{-}CO2})] \quad (3)$$

$$\varphi = Q_{air} \times \rho_i \times (C_i^m - C_e^m) \quad (4)$$

Results and discussion

The results obtained for water disappearance and manure production were 7.32 ± 1.31 and 2.93 ± 0.56 L/pig/d, respectively. The average values, to both mentioned parameters, shows a good water management by the producer in the farm as reported by Tavares et al. (2014). The performance of the pigs at the end of the monitored cycle was: mortality (%) - 1.78; feed conversion ratio (kg/kg) - 2.36; average daily gain (kg/d) - 0.83.

Table 1 shows the temperature, relative humidity and air velocity (internal and external) determined at the monitored pig farm. Table 2 presents the gas concentrations of air taken, outside and inside the commercial housing building.

Table 1. Temperature, relative humidity and air velocity at monitored pig farm.

Items		Mean	σ[1]	Max.	Min
Temperature (°C)	Int.	25.2	2.0	27.7	20.5
	Ext.	24.5	2.2	28.1	20.0
Relative Humidity (%)	Int.	67.4	9.0	90.0	56.0
	Ext.	68.3	8.8	86.7	61.3
Air Velocity (m/s)	Int.	0.59	0.22	1.15	0.26
		0.77	0.45	1.92	0.19

[1]Standard deviation.

Table 2. Internal and external concentrations of ammonia and greenhouse gases.

Gas concentration (ppp-v)		Mean	σ[1]	Max.	Min
CO_2	Int.	591.01	45.13	687.61	514.22
	Ext.	558.94	53.37	666.24	466.69
CH_4	Int.	8.24	5.33	21.14	0.32
	Ext.	11.48	5.57	21.61	3.64
N_2O	Int.	0.26	0.02	0.29	0.23
	Ext.	0.26	0.01	0.29	0.24
NH_3	Int.	1.32	0.53	2.46	0.65
	Ext.	1.13	0.37	0.65	0.55

[1]Standard deviation.

The concentration of CO_2 and CH_4 obtained fits when compared with other results reported in the literature (Robin et al., 2010; Guingand et al., 2011). In this sense, it is important to write that CO_2 average value can be used in the future as the standard value of comparison with other studies and as a parameter for the minimum rates of air renovation. In relation to CH_4, the highest concentration observed outside was due to the storage/treatment structures of the manure produced (pit ditch and anaerobic lagoon), located near the housing building. The average concentration of N_2O was lower than those reported in the literature. This result can be associated with the daily management of the producer and to the distance between the housing building and the farming site where the manure produced is released by spreading technique. For NH_3, the results were consistent with other values reported for warm season (summer; <5.0 ppm).

Table 3 presents the ammonia and greenhouse gas emissions at growing-finishing farm. On average, the emissions of C-CO_2 and N-NH_3 were lower than those reported in the literature [C-CO_2: 637.0 and 676.0 g/pig/d; N-NH_3: 8.9 and 10.8 g/pig/d (Guingand et al., 2010; Guingand et al., 2011)]. However, a study performed by Robin et al. (2010) showed higher values for N-NH_3. Such difference can be explained, in part, by the different type of building floor (fully concrete), the manure removal strategy and type of ventilation (natural) used by the producer in this study when compared, for example, with France (partial or fully slatted floors and mechanical ventilation). For C-CH_4, the results obtained in the study were higher than the values presented by other authors [7.4 and 10.1 g/pig/d; Guingand et al., 2010; Guingand et al., 2011).

Table 3. Ammonia and greenhouse gas emissions at growing-finishing farm.

Gas emissions (g/pig/day)	Mean	σ[1]	Max.	Min
C-CO_2	456.23	129.29	950.16	113.03
C-CH_4	33.69	20.38	92.67	4.48
N-N_2O	0.24	0.15	0.52	0.02
N-NH_3	3.04	1.77	10.86	0.56

[1]Standard deviation.

Conclusions

Concentrations of ammonia and greenhouse gases, inside the housing building, were below the tolerable levels for animals and producer's health. Due to the type of floor, manure removal strategy and natural ventilation used in the growing-finishing commercial farm, the values of N-NH_3 were low. Although C-CO_2 and N-NH_3 emissions were low in this study, C-CH_4 emissions were higher when compared with several European results.

Given the conflicting results obtained when compared to other studies, new researches, more comprehensive, must be performed.

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DETERMINATON OF AMMONIA AND GREENHOUSE GAS CONCENTRATIONS AT POST-WEANING PIGLETS PRODUCTION

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Abstract: the greenhouse gases and ammonia concentrations vary in pig production systems, both in internal and external air of the housing buildings, according to the physiological phase of the animal, the type and amount of feed ingested, the environmental conditions and the management of the manure produced. Nowadays, Brazil shows a lack of information regarding to the data that give information about the concentrations of the gases taking inti account the different physiological phases and their management, in the production chain. This work aimed to determine the greenhouse gases and ammonia concentrations, as well as the respective gradient in four post-weaning piglets' farms, considering one cycle per farm, using the simplified methodology. For this purpose, internal and external air samples were taken from the housing buildings with the aid of a low-flow air pump and TEDLAR® bags (closed and airtight - 10 L). Each sample was analysed through the photoacoustic gas monitor INNOVA 1412. The average gradients obtained for the gases analysed were: 936 ppm (CO_2), 3.8 ppm (NH_3), 0.2 ppm (N_2O) and 5.2 ppm (CH_4). Although the maximum average value of CO_2 obtained inside the housing buildings was 1,696±796 ppm, significant variations were observed between the air concentrations of the two sampled periods (morning and afternoon). This fact should be, mainly, due to inadequate management of the curtains and the environmental control system in the housing building by the producers.

Keywords: concentrations, greenhouse gas, ammonia, piglets, post-weaning.

DETERMINAÇÃO DA CONCENTRAÇÃO DE GASES DE EFEITO ESTUFA E AMÔNIA NA PRODUÇÃO DE LEITÕES PÓS-DESMAME

Resumo: a concentração dos gases de efeito estufa e amônia variam na produção de suínos, tanto no ar interno como externo aos edifícios de alojamento, de acordo com a fase fisiológica do animal, o tipo e quantidade de ração ingerida, as condições de ambiência e o manejo dos dejetos produzidos. No Brasil observa-se um vazio de informação face a dados que informem sobre as concentrações dos gases em função das diferentes fases fisiológicas e seu manejo, na cadeia produtiva. Este trabalho teve como objetivo determinar a concentração dos gases de efeito estufa e amônia, bem como os respetivos gradientes em quatro granjas de leitões pós-desmame, considerando um lote por granja, com recurso à metodologia simplificada. Para tal, foram efetuadas amostragens de ar interno e externo aos edifícios de alojamento com o auxílio de uma bomba de ar de baixa vazão e sacos TEDLAR® (fechado e estanque – 10 L), sendo cada uma delas analisada através do monitor de gases fotoacústico INNOVA 1412. Os gradientes médios obtidos para os gases analisados foram: 936 ppm (CO_2), 3,8 ppm (NH_3), 0,2 ppm (N_2O) e 5,2 ppm (CH_4). Embora o valor médio máximo do CO_2 no ar interno tenha sido 1.696±796 ppm, foram observadas variações significativas entre as concentrações dos dois períodos amostrados (matutino e vespertino), devendo-se tal fato, majoritariamente, pela inadequação do manejo das cortinas e do sistema de controle ambiental no edifício de alojamento por parte dos produtores.

Palavras-chave: concentrações, gases efeito estufa, amônia, leitões, pós-desmame.

Introduction

According to the World Bank, the Greenhouse Gas (GHG) emissions associated to the Brazilian agricultural sector amounted to 23% based on the total value estimated for 2008 (Banco Mundial, 2010). The report "Annual estimates of greenhouse gases emissions in Brazil" indicated a total of 35% of emissions (year 2010), whereby methane (CH_4) and the nitrous oxide (N_2O) dominated among the other gases [carbon dioxide (CO_2) and ammonia (NH_3), as a precursor] (Brasil, 2013). The Intergovernmental Panel on Climate Change (IPCC) indicates that the emission of GHG and NH_3 should be calculated considering the referred emission factors for the different livestock categories and manure storage/treatment systems. However, such factors do not exist for pig production in Brazil, so the values presented in the reports have a gap of information on the premises used in their determination for the activity. It is worth mentioning that pig productive models changed considerably since the 70's decade, in which the traditional were replaced by the confined animal systems, so that scientific, technical and technological developments have been continuously implemented in Brazil (Tavares et al., 2014). Therefore, it is essential to determine the GHG and NH_3 concentrations inside and outside the housing buildings to subsequently calculate the respective emissions in function of the physiological phase of the swine production chain. The aim of this work was to determine the concentrations of GHG and NH_3, and the respective gradients in four post-weaning piglets' farms using the simplifying methodology developed by the National Institute for Agricultural Research (INRA/France).

Materials and methods

Farms and equipment: four commercial post-weaning farms, similar in size and lodging capacity, were monitored and evaluated between July and September 2014, considering a housing period of until 42 days. The piglets were distributed randomly by sex in both sides of the housing buildings, each with pens for 40±2 piglets (number of pens varied according to the housing capacity). Every pen measured 3.2 x 4 m (12.8 m^2; 0.32 m^2/piglet), 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).

Post-weaning piglets: in total 6,619 piglets were housed at the four post-weaning farms chosen during one production cycle monitored and evaluated. All piglets had a Landrace x Large White mother and a Landrace x Large White or Pietran boar father. The piglets were fed ad libitum during production cycle, and 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 (NRC, 1998) and Brazilian tables for poultry and pigs (Rostagno et al., 2011). Table 1 shows the performance of the piglets per farm.

Table 1. Performance of the piglets per farm.

Items	Post-weaning farms (Pw)			
	1	2	3	4
N. piglets	1,910	1,999	1,370	1,340
Initial Body Weight (kg)	8.15	8.01	7.30	8.02
Final Body Weight (kg)	25.22	25.37	22.33	25.74
Average Daily Gain (kg/d)	0.46	0.46	0.40	0.46
Feed Conversion Ratio (kg/kg)	1.37	1.40	1.37	1.44
Mortality (%)	1.10	1.50	2.19	3.88

Water disappearance and manure production measurements (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 building and the storage system. The manure produced was 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 physicochemical characterisation of samples was performed at Embrapa Swine & Poultry, Concórdia/SC, Brazil.

Gas concentrations measurements (ppm): were estimated according to the concentration ratios method defined in the simplified methodology (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). For this purpose, internal and external air samples were taken with the aid of a low-flow air pump and TEDLAR® bags (closed and airtight - 10 L). The gradient for all gases was determined by the difference between the internal and external concentration of air in the building (Eq. 1).

$$\text{Gradient}_{\text{Gas}} = [\text{Gradient}]_{\text{Int}} - [\text{Gradient}]_{\text{Ext}} \quad (1)$$

Environmental conditions: for this purpose, the temperature, relative humidity and air velocity (internal and external air of the building) were determined during the lot and on the specific day of air samplings (Paillat et al., 2005; Robin et al., 2010).

Results and discussion

Table 2 exhibits the average water disappearance and manure production for the post-weaning farms monitored evaluated during one cycle.

Table 2. Average water disappearance and manure production for the post-weaning farms monitored evaluated during one cycle.

Farms	n (days)	Water disappearance (L/piglet)				Manure production (L/piglet)			
		Mean	SD[1]	Min.	Max.	Mean	SD[1]	Min.	Max.
PW_1	36	3.83	1.26	1.94	5.97	2.96	1.52	1.08	5.15
PW_2	41	1.99	0.97	0.56	3.67	1.01	0.61	0.26	2.10
PW_3	41	2.61	1.08	1.33	4.53	1.71	0.94	0.78	3.72
PW_4	41	3.31	1.15	1.67	4.83	2.05	0.95	0.80	3.35

[1]Standard deviation.

The results obtained for the average water disappearance have shown values in accordance with literature [minimum: 1.20 L/piglet; maximum: 5.16 L/piglet (Ferreira et al., 2006)]. With exception of farm PW_2, the water disappearance determined was higher to the values obtained by Torrey et al.

(2008) for conventional nipple drinker. Regarding the manure production, the values obtained for each farm were consistent with others presented in specific literature (Levasseur, 1998), but also smaller to the generated by Ferreira et al. (2006).

The internal and external concentrations of CO_2 and NH_3, as well the respective gradients are presented in Table 3.

Table 3. Internal and external concentrations of carbon dioxide and ammonia, as well the respective gradients.

Farms	$[CO_2]$ (ppm)[1]			$[NH_3]$ (ppm)[1]		
	Internal	External	Gradient	Internal	External	Gradient
PW_1	1,472±652	489±41	983	3.7±1.8	1.0±0.4	2.7
PW_2	1,696±796	512±18	1,184	7.1±3.3	1.0±0.4	6.1
PW_3	1,256±454	505±49	751	5.0±1.7	1.3±0.9	3.7
PW_4	1,456±642	629±49	827	4.1±2.0	1.4±0.4	2.7

[1]Mean ± Standard deviation.

The results obtained for CO_2 show that the concentration gradient in the four cycles monitored and evaluated ranged from 751 in PW_3 to 1,184 ppm in PW_2. Although the highest average value for $[CO_2]$ was 1696±796 ppm, there were certain periods in which the gas concentration was superior to 3,000 ppm, value considered prejudicial in some countries for the pigs. Regarding NH_3 concentration, the values determined inside the buildings were inferior to the value reported by Guigand (2003), which was 7.8 ppm. For N_2O and CH_4, although the results were not presented at Table 3, the average concentration gradients achieved for the four cycles were 0.2 and 5.2 ppm, respectively.

Conclusions

Concentration of CO_2, inside housing building, fits according to the range recommended by different authors. However, it was observed a significant variation between the sampling periods (morning and afternoon) due to inadequate management of the double curtains and the environmental control system inside the housing building. The values obtained to NH_3 were lower due to the farm's ventilation system (natural ventilation vs. mechanical ventilation).

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Chapter II

EMITTING PROCESSES

CONTRIBUTIONS OF NITRIFICATION AND DENITRIFICATION TO N_2O EMISSIONS ACORDING TO SOIL TILLAGE AND ORGANIC FERTILIZATION

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Abstract: we investigated the impact of mineral and organic N sources on N_2O emissions from a Nitisol under contrasting soil disturbance levels. The tested treatments were undisturbed (US) and disturbed soil (DS) and N sources [140 kg N/ha as urea (UR), raw swine slurry (RS), anaerobically digested swine slurry (ADS), composted swine slurry (CS), and a control treatment without N (CTR)]. N_2O emissions were correlated with soil abiotic factors [temperature, water-filled pore space (WFPS), dissolved organic carbon (DOC), ammonium (NH_4^+-N) and nitrate (NO_3^--N) contents] and dominant catabolic genes involved in the nitrification and denitrification bioprocesses (*amoA, narG, nirS,* and *qnorB*). No differences were found among fertilization treatments under DS. However, higher N_2O-N emissions were registered in the US amended with RS, CS and UR (5.6, 4.7, and 3.5 kg N_2O-N/ha, respectively) in relation to CTR (1.8 kg N_2O-N/ha). N_2O emissions were augmented in the US due to the higher soil WFPS in comparison to DS. The application of RS provided concomitant inputs of labile C and mineral N to the soil enhancing denitrification and N_2O emission from the US. The additive contribution of heterotrophic nitrification and denitrification processes explained the augmented N_2O emission from the US amended with CS.

Keywords: qPCR, no-tillage, composting, anaerobic digestion, swine slurry.

CONTRIBUIÇÕES DA NITRIFICAÇÃO E DESNITRIFICAÇÃO NAS EMISSÕES DE N_2O DE ACORDO COM A MOBILIZAÇÃO DO SOLO E FERTILIZAÇÃO ORGÂNICA

Resumo: foi investigado o impacto das fontes de N mineral e orgânico nas emissões de N_2O a partir de um Nitossolo, sob níveis contrastantes de perturbação no solo. Os tratamentos testados foram: sem perturbação (US) e perturbação no solo (DS) e fontes de N [140 kg N/ha como ureia (UR), dejeto suíno bruto (RS), dejeto suíno digerido anaerobicamente (ADS), dejeto suíno composto (CS) e tratamento controle sem N (CTR)]. As emissões de N_2O foram correlacionadas com fatores abióticos do solo [temperatura, saturação de água no solo (WFPS), teor de carbono orgânico dissolvido (DOC), íon amônio ($N\text{-}NH_4^+$) e nitrato ($N\text{-}NO_3^-$)] e genes catabólicos dominantes envolvidos nos bioprocessos de nitrificação e desnitrificação (*amoA, narG, nirS* e *qnorB*). Não foram encontradas diferenças entre os tratamentos de fertilização DS. No entanto, foram registradas emissões de $N\text{-}N_2O$ superiores no US alterado com RS, CS e UR (5,6 e 4,7 e 3,5 kg $N\text{-}N_2O$/ha, respectivamente) em relação ao CTR (1,8 kg $N\text{-}N_2O$/ha). As emissões de N_2O aumentaram no US devido ao maior WFPS do solo em comparação com o DS. A aplicação de RS forneceu dados concomitantes de C lábil e N mineral ao solo aumentando a desnitrificação e as emissões de N_2O do US. A contribuição adicional dos processos de nitrificação heterotrófica e desnitrificação explicaram o aumento das emissões de N_2O do US alterado com CS.

Palavras-chave: qPCR, plantio direto, compostagem, digestão anaeróbica, dejeto suíno.

Introduction

Soil tillage and fertilization practices can affect soil abiotic factors (e.g., pH, temperature, water saturation, mineral N and labile organic carbon contents) and consequently the abundance of nitrifying and denitrifying bacteria communities known to regulate N_2O efflux from soils (Dobbie; Smith, 2003; Bateman; Baggs, 2005; Giles et al., 2012). The objective of this study was to investigate the impact of mineral and organic N sources on N_2O emissions from a Nitisol under contrasting soil disturbance levels.

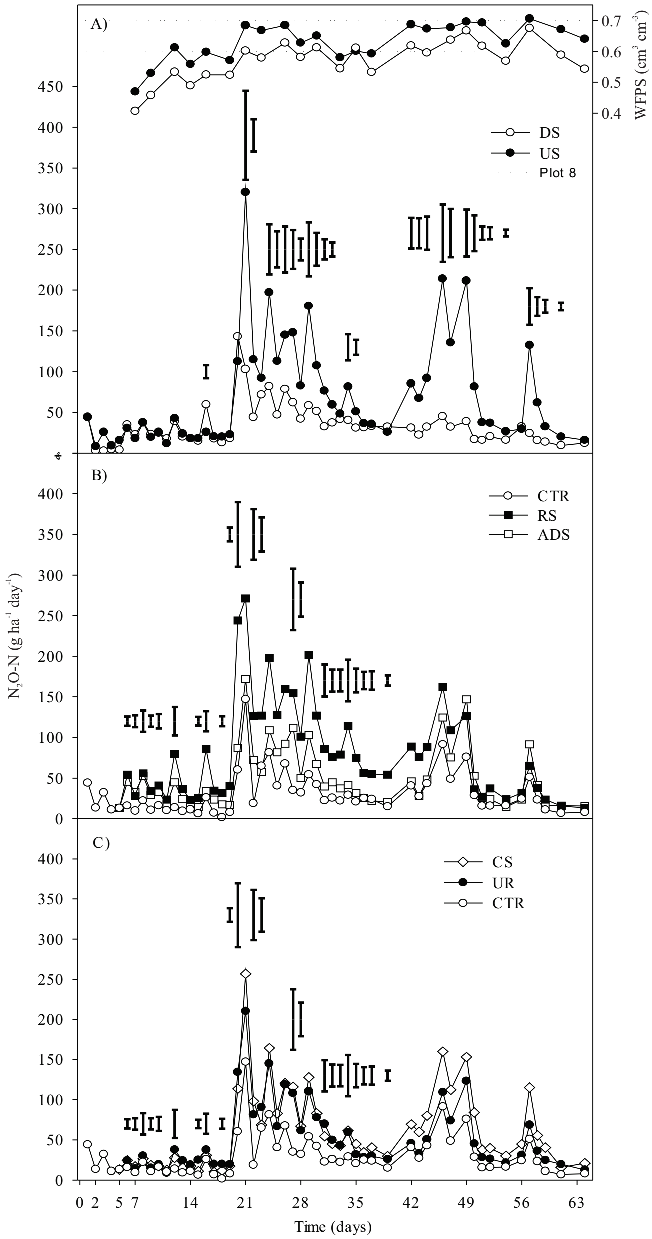
Materials and methods

We evaluated short-term N_2O emission from a Rhodic Nitisol under contrasting soil disturbance [undisturbed (US) and disturbed soil (DS)] and N sources [140 kg N/ha as urea (UR), raw swine slurry (RS), anaerobically digested swine slurry (ADS), composted swine slurry (CS), and a control treatment without N (CTR)] (Grave et al., 2015). N_2O emissions were correlated with soil abiotic factors [temperature, water-filled pore space (WFPS), dissolved organic carbon (DOC), ammonium (NH4+-N) and nitrate (NO_3^--N) contents] and dominant catabolic genes involved in the nitrification and denitrification bioprocesses. Real-time quantitative PCR (qPCR) was used to quantify bacteria communities harboring specific catabolic nitrifying-ammonium monooxygenase (amoA), and denitrifying nitrate- (narG), nitrite- (nirS), nitric oxide- (norB) and nitrous oxide reductases (nosZ) genes (ANGNES et al., 2013).

Results and discussion

No interaction between soil disturbance (Figure 1a) and fertilization (Figure 1b-c) was detected on soil N_2O-N efflux, thus, the results presented in Figure 1 address the main effects of these treatments. Soil N_2O-N emission showed wide variation from 1.5 to 320.0 g/ha/day and were markedly affected by soil WFPS (Figure 1a). Lower N_2O-N emission (< 100 g/ha/day) were registered during the first 19 days of the experiment when low rainfall volumes maintained WFPS < 0.6 cm^3/cm^3. Increased N_2O-N emission in the following period was coincident with higher rainfall frequency (Grave et al., 2015) and volumes and WFPS > 0.6 cm^3/cm^3. Daily N_2O-N emissions from US were consistently higher than DS during most of the evaluation period. Among fertilization treatments, increased daily N_2O-N emissions were registered in the first 30 days after RS amendment. Daily N_2O-N emissions from ADS, UR, CS and CTR treatments were not distinguishable during the evaluated period.

The cumulative N_2O-N emission from DS ranged from 1.4 to 2.5 kg/ha in CTR and RS treatments, respectively (Table 1). Although no significant differences were found among fertilization treatments under DS, cumulative N_2O-N emission was clearly affected by N source in the US. Higher N_2O-N emissions were registered from RS, CS and UR amended soils (5.6, 4.7, and 3.5 kg N_2O-N/ha, respectively) in relation to CTR treatment (1.8 kg N_2O-N/ha). Cumulative N_2O-N emission from US amended with ADS (2.9 kg N_2O-N/ha) was similar to CTR but still comparable to CS and UR treatments, respectively. No differences were noticed on cumulative N_2O-N emission from CTR, UR and ADS treatments under contrasting soil disturbance levels (US and DS). However, cumulative N_2O-N emission from US amended with RS and CS were approximately 120 and 200% higher than verified on DS.



DS: disturbed soil; US: undisturbed soil; CTR: control without fertilization; UR: urea; RS: raw swine slurry; ADS: anaerobically digested swine slurry; CS: composted swine slurry. Means separation bars denote the Fisher's test LSD (p<0.05).

Figure 1. WFPS (a) and daily N_2O-N emission according to the main effects of soil disturbance (a) and fertilization treatments (b, c).

Table 1. Cumulative soil N_2O-N emission according to soil disturbance and fertilization treatments.

Fertilization	Soil disturbance		Fisher's LSD p-value
	DS	US	
	------------------- kg/ha --------------------		
CTR	1.42 ± 0.18	1.85 ± 0.73 c(1)	0.948
UR	1.87 ± 0.72	3.52 ± 0.65 ab	0.120
RS	2.55 ± 0.51 B	5.60 ± 1.38 A a	0.050
ADS	2.10 ± 0.40	2.94 ± 1.18 bc	0.606
CS	1.56 ± 0.13 B	4.67 ± 1.70 A ab	0.017
Fisher's LSD p-value	0.443	0.004	-

DS: disturbed soil; US: undisturbed soil; CTR: control without fertilization; UR: urea; RS: raw swine slurry; ADS: anaerobically digested swine slurry; CS: composted swine slurry. (1) Means ±s.e; (n=4) followed by the same lowercase letter in the columns and uppercase letters in the lines are not different according to the Fisher's LSD test.

Soil disturbance treatments (US and DS) remarkably affected N_2O emissions (Figure 1a). We investigated the soil abiotic factors and nitrifying and denitrifying microbial communities regulating N_2O-N emissions according to soil disturbance by utilizing the Pearson's correlation analysis (Table 2). Among soil abiotic factors, N_2O emission was mostly regulated by soil WFPS (r=0.753, p<0.001) in the US. Nonetheless, soil NO_3^--N and DOC contents (r=0.667, p<0.01 and -0.572, p<0.01) and DOC/NO_3^--N ratio (r=-0.459, p<0.05) were the main abiotic factors regulation N_2O emission from DS. Soil temperature and NH_4^+-N content had no significant correlations with N_2O emissions regardless the investigated treatments. Soil WFPS was substantially higher in the US in comparison with the DS during most of the evaluated period (Figure 1a).

Previous studies related an exponential increase of N_2O emission with soil WFPS>0.6 cm^3/cm^3 (Dobbie; Smith, 2003; Bateman; Baggs, 2005). Nitrification was reported as the main process contributing to N_2O emissions when soil WFPS increases up to 0.6 cm^3/cm^3. However, under increasing soil moisture the contribution of denitrifying activity becomes more relevant becoming the major process for N_2O emission when soil WFPS=0.7 cm^3/cm^3 (Bateman; Baggs, 2005).

Table 2. Pearson's coefficients obtained for the correlations between N_2O-N emissions, soil abiotic factors and the abundance of nitrifying and denitrifying catabolic genes in the 0-0.10 m soil layer according to soil disturbance and fertilization treatments.

Parameter	Soil disturbance[(1)]		Fertilization[(2)]					All[(3)]
	US	DS	CTR	UR	RS	ADS	CS	
Soil temperature	-0.362	-0.055	-0.229	-0.227	-0.159	-0.341	-0.171	-0.198
WFPS	**0.753**[a]	0.302	0.553	0.452	**0.776**[c]	0.552	0.637	**0.565**[a]
NH_4^+-N	0.372	0.017	0.250	-0.137	0.255	-0.186	0.130	0.018
NO_3^--N	0.438	**0.667**[b]	0.420	0.371	0.567	0.398	0.409	**0.383**[c]
DOC	0.253	**-0.572**[b]	0.280	0.276	-0.197	-0.634	-0.065	0.003
DOC / NO_3^--N	-0.103	**-0.459**[c]	-0.081	-0.178	-0.366	-0.103	-0.035	-0.148
amoA / 16S rDNA	0.113	-0.059	0.341	-0.273	-0.104	0.336	**0.751**[c]	0.134
narG / 16S rDNA	**0.528**[c]	**0.505**[c]	0.143	0.671	**0.789**[c]	0.328	**0.870**[b]	**0.609**[a]
nirS / 16S rDNA	-0.018	-0.132	0.258	0.049	-0.263	-0.170	0.420	0.138
qnorB / 16S rDNA	0.242	-0.057	0.371	0.082	0.511	-0.390	0.626	**0.343**[c]
nosZ / 16S rDNA	**-0.604**[b]	-0.303	0.277	-0.640	-0.363	-0.438	-0.333	-0.307

a: $p<0.001$; b: $p<0.01$; c: $p<0.05$;. [(1)] n=20; [(2)] n=8; [(3)] n=40.

Contrastingly, Pearson's correlation analysis revealed that denitrification was the main processes contribution to soil N_2O emission in our study (Table 2). Significant correlations between the abundance of *narG* gene (*narG*/16S *rDNA*), encoding for the reduction of NO_3- to NO_2- during denitrification, and soil N_2O emissions were noticed for both US ($r=0.528$, $p<0.05$) and DS ($r=0.505$, $p<0.05$) treatments. Increasing on the abundance of *nosZ* gene (*nosZ*/16S *rDNA*), encoding for the reduction of N_2O to N_2, had negative correlation with soil N_2O emissions in the US. Such results indicate that truncation of the denitrification process under high soil WFPS and NO_3^- -N contents (for review see Giles et al., 2012) resulted in higher N_2O emission from the US.

Among fertilization treatments, CTR, UR and ADS had no significant correlations with the investigated soil abiotic factors and microbial communities regulating soil N_2O emissions. However, soil amended with RS presented significant correlations between N_2O emission and soil WFPS ($r=0.776$, $p<0.05$) and the concentrations of *narG*/16S *rDNA* ($r=0.789$, $p<0.05$), suggesting denitrification as the main process regulation soil N_2O emissions. The application of RS increased soil NH_4^+-N content which was promptly reduced to NO_3^--N (data not shown). Additionally, RS also provided a high labile C input enhancing the soil denitrification rates and soil N_2O emission (Giles et al., 2012). Contrastingly, soil N_2O emissions from the CS treatment presented significant correlation with the concentrations of both *amoA*/16S *rDNA* ($r=0.751$, $p<0.05$) and *narG*/16S *rDNA* ($r=0.870$. $p<0.01$). The *amoA* gene encodes for the reduction of NH_4^+-N during both autotrophic and heterotrophic nitrification, suggesting either of these processes as major contributors for soil N_2O emission in this treatment. Previous studies related heterotrophic nitrification (organic N oxidation) as the main pathway for N_2O emission from forest soils with high soil organic matter content under increasing soil WFPS (Zhang et al., 2011). Thus, the recalcitrant profile of the CS with high org-N content could have enhanced soil heterotrophic nitrification and N_2O emission when soil WFPS ranged from 0.6 to 0.7 cm^3/cm^3 in the US. The additive contribution of both heterotrophic nitrification and denitrification processes could explain the augmented N_2O emission from the CS amended soil, contrarily to what would be expected due to the low mineral N content in the CS.

Conclusions

N_2O emissions were augmented in the US due to the higher soil WFPS in comparison to DS. Denitrification was the main pathway for N_2O production in both US and DS. The application of RS provided concomitant inputs of labile C and mineral N to the soil enhancing denitrification and N_2O emissions especially in the US. The additive contribution of heterotrophic nitrification and denitrification processes explained the augmented N_2O emission from the US amended with CS.

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CASE STUDY: EFFECTIVE ODOUR CONTROL OF A LARGE SCALE POULTRY SLAUGHTERING HOUSE

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Abstract: the main purpose of this study was to identify an effective odour control plan for a large scale poultry slaughtering house in order to reduce the risk of odour impact to an acceptable level. This paper describes the main actions undertaken during the study including: Review of operations, measurement of odour emissions according to EN13725, assessment of the odour impact using AERMOD dispersion model, and review of the relevant literature to identify the general techniques which are available to the poultry slaughtering sector for odour control. Although prevention of odour generation at source is the preferred approach to minimizing odour impacts, the results of this study show that effective odour management relies on a combination of end of pipe treatment techniques and optimization of operational procedures. The BAT implementation in the production stages and in the wastewater treatment has a potential to reduce the odour affected area to less than 15% of its original size.

Keywords: odour, odour impact, dispersion modeling, odour control, poultry slaughtering.

ESTUDO DE CASO: CONTROLE DE ODOR EFETIVO EM UM ABATEDOURO DE AVES DE GRANDE PORTE

Resumo: o principal propósito deste estudo foi identificar um plano efetivo de controle de odor em um abatedouro de aves de grande porte, a fim de reduzir o risco de impacto de odor a níveis aceitáveis. Este documento descreve as principais ações tomadas durante o estudo, incluindo: revisão de operações, medição de emissão de odor de acordo com a EN13725, avaliação do impacto do odor utilizando o modelo de dispersão AERMOD e revisão das literaturas relevantes para identificar as técnicas gerais que são disponibilizadas ao setor de abatedouros para controle de odor. Embora a prevenção da geração de odor na fonte seja a abordagem preferida para minimizar os impactos de odor, os resultados desse estudo mostram que o tratamento efetivo do odor resulta de uma combinação de técnicas no fim do tubo e otimização no processo operacional. A implementação das BAT em fase de produção e no tratamento de água utilizada, tem potencial para reduzir a área afetada pelo odor para menos que 15% de sua proporção original.

Palavras-chave: odor, impacto de odor, modelo de dispersão, controle de odor, abatedouro.

Introduction

Environmental agencies around the world have worked for decades with businesses and society to make a cleaner and healthier world for us and future generations. Special attention has been given to the air we breathe, the water we drink, and the soil where we stand. More recently, environmental issues that were once considered as purely aesthetic, such as odours, have been included in the agenda due to increased public expectation and awareness.

After all, when a population is exposed to odours that are perceived as unwanted or unpleasant, it creates a negative appraisal of the local environment, ultimately affecting the use and enjoyment of property. Furthermore, the related detriment to quality of life has the potential in extreme cases to cause stress related health effects in the population such as anxiety, headaches, sleeping disorders, high blood pressure, among others. This is why odours are rarely referred to as "traditional pollutants", but more as "environmental stressors" in the same manner as noise or unwanted lighting.

Unlike other pollutants, people do not need specialist equipment and environmental expertise to assess the situation. All they need is a working sense of smell, and their personal appraisal to determine if an odour is unwanted and unacceptable.

Materials and methods

The study was carried out in a poultry slaughterhouse processing over 500,000 birds per week that received more than 100 odour complaints over the course of one year. The site is located in the United Kingdom in a mixed land use zone containing agricultural fields and residential properties, with closest sensitive receptors located less than 100m from site limits.

The site operations consisted on four main process stages:

1. bird delivery, storage and hanging;
2. killing, defeathering, evisceration and carcass preparation;
3. waste handling;
4. wastewater treatment.

The magnitude of odour emissions from each identified source was estimated in terms of European odour units (ouE/m^3) using a combination of data from published literature sources, and measured data collected at the site. It was ensured that all data reviewed and applied in this study was collected using the CEN standard for olfactometry (CEN 13725: 2003). The level of dilution of odours achieved between the source and the receptor (atmospheric dispersion) was estimated with the AERMOD model version 14134, issued by the US Environmental Protection Agency (EPA) during June 2014.

AERMOD model was chosen or the following reasons:

1. it is the most widely used model for predicting Odour exposure levels around the vicinity of an industrial site;
2. it is capable of making predictions in a manner consistent with the indicative criteria presented in applicable local odour legislation (e.g. 98th percentile of hourly average concentrations).

In order to identify appropriate techniques that could be considered to represent indicative BAT, a review was conducted of the following literature sources:

1. VDI 2596 (1991);
2. European Commission (2003);
3. Infomil (2000);
4. Environmental Agency (2003);
5. Environmental Agency (2002).

Results and discussion

The most significant contributors to site odour emissions from an impact perspective were found to be the releases from bird handling, defeathering and evisceration, and the wastewater treatment plant. A summary of the relative contribution of each source is summarized in Figure 1.

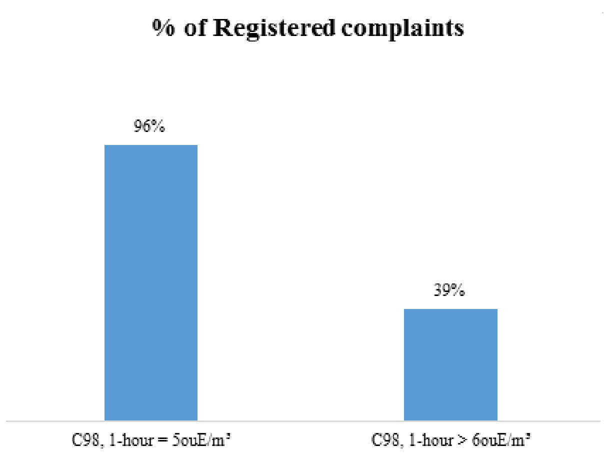

Figure 1. Summary of odour emissions contributions.

A fully integrated odour emissions data set from the site, along with suitable topographical and meteorological data was input to the US EPA atmospheric dispersion model AERMOD version 14134. The modeling results were then presented in the form of contours (or isopleths - lines connecting points with equal frequency of occurrence) for a 1-hour average limit concentration of x ouE/m^3 as a 98th percentile. In short notation: $C_{98, 1\text{-hour}}$ = x ouE/m^3. From this view, if the model predicts that the 1 ouE/m^3 contour is located 100m from the site, this indicates that the concentrations will exceed 1 ouE/m^3 for more than 175 hours of the year in this area. For this particular site, the value of 5 ouE/m^3 98^{th} percentile was selected to identify the area where odour impact is likely to occur.

Additionally, an insight into the levels of odour which led to odour complaints in the surrounding community under the current operational regime was gained by comparing the isopleths generated by the model to the location of the odour complaints reported. It is clear from this comparison that majority (96%) of odour complaints occur within 250m from the site limits at a predicted odour exposure levels of $C_{98, 1\text{-hour}}$ = 5 ouE/m^3. A breakdown of the analysis is presented in Figure 2.

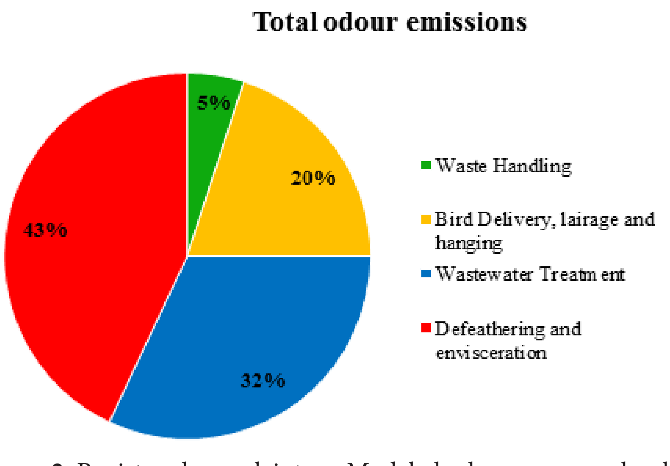

Figure 2. Registered complaints vs Modeled odour exposure levels.

If we refer to the green contour of $C_{98, 1\text{-hour}}$ = 5 ouE/m^3, presented in Figure 3 (a), which defines the area where it´s considered to be reasonable cause of odour annoyance in the baseline situation, and where the majority of complaints were registered, it is clear that a combination of odour reduction and control measures are required to reduce odour exposure to acceptable levels. The Figure 3 (b) shows the expected odour exposure levels after applying a series of BAT measures.

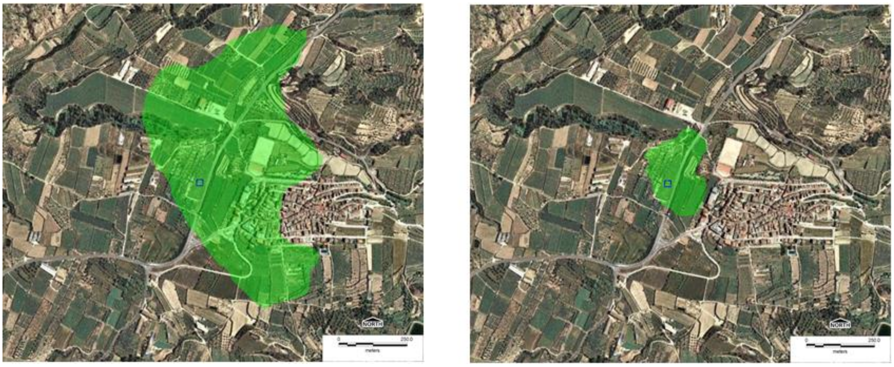

Figure 3. (a) Baseline situation, (b) After BAT implementation - $C_{98,\,1\text{-hour}}$ = 5 ouE/m^3 98th percentile (green contour).

Bird delivery, storage and hanging: the odours released from the birds present at the site currently present a potential risk of impact to residential properties off-site. Due to the size of the site, the proximity of neighboring sensitive receptors and the requirement to maintain a constant supply of birds to the process, relocation of the lairage to a location further away from potentially sensitive receptors is not viable at this particular site. Similarly, it is understood from information supplied by the site operator that significantly reducing the number of birds currently stored on site at any given time is unlikely to be achievable due to the requirement to maintain a sufficient number of birds to support the process and prevent operational delays, and as a result of the complexity of the scheduling and delivery procedures. The option of enclosing the bird handling areas and either treating or release emissions via an elevated stack has therefore been identified as the more appropriate option for the site.

Defeathering and evisceration: the odour emissions from defeathering activities accounted for the main source of odour emissions from site. The combination of the odour control system (comprising a catalytic ion oxidation unit in combination with a 25m stack and ventilation system) and formalized maintenance procedures are considered to reflect BAT for odour control from the defeathering / evisceration activities.

Waste handling: on the basis of the emissions contribution and the dispersion modeling results, the provision of major changes to the waste handling operations such as refrigeration of waste, enclosure of storage, etc. are not recommended or considered to be justified in terms of odour reduction.

Wastewater treatment: the odours released from the effluent treatment activities currently present a potential risk of impact to residential properties off-site, and account for approximately 32% of the total site emissions. These emissions are primarily due to the inherently odorous nature of the effluent handled by the plant, and the open nature of the tanks currently used for effluent treatment. In order to reduce the risk of impact offsite, it will almost certainly be necessary to reduce the odour emissions from the main effluent treatment sources (e.g. crude pit, effluent screen, balancing tank, anoxic tank and aeration tank) substantially and release any residual odours through an elevated stack. Furthermore, it is advised that the tanker loading of the sludge from the sludge tank is conducted by back venting the displaced air to an appropriate odour filter.

The odour abatement techniques which could be considered to achieve this reduction in emissions are as follows:

1. Techniques with the potential to reduce the odour generation potential of effluent at source (e.g. dosing of effluent with suitable chemicals or the use of biotechnological solutions);
2. End of pipe techniques, such as catalytic ion oxidation, chemical scrubbing, biofiltration or adsorption (e.g. activated carbon);
3. The use of the aeration basin as a liquid biological filter for treatment of ventilated air from other odour sources.

Conclusions

Understanding the causes of Environmental Odour annoyance is a complex and difficult challenge. Many factors influence the level of odour annoyance experienced around a site. Effective site odour management requires a detailed understanding of each specific industrial process involved, and how each part may contribute to odour-induced annoyance. A thorough and systematic approach to assessing the odour emissions and exposure levels caused by a site is essential for selecting the most cost-effective way to manage them. By adopting an effective odour management strategy at a site, an operator can ensure that all appropriate measures are applied to ensure that the risk of odour annoyance in the surroundings is negligible or minimized. An effective strategy includes reduction, control, monitoring, and contingency procedures. Careful consideration must be given to meteorological, topographical, social, cultural and economic factors in the area.

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AMMONIA AND GREENHOUSE GAS EMISSIONS FROM AIR SCRUBBERS AT PIG HOUSING FACITILIES

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Abstract: a measurement campaign was conducted at a chemical, a biological and a two-stage air scrubber installed at pig housing facilities in Flanders. Ammonia, nitrous oxide and methane were measured continuously during one week at the ingoing and outgoing air. Ventilation rate influenced the incoming concentrations and consequently the removal efficiency of the gases. The chemical air scrubber did not always reach the legally required 70% removal efficiency. Nitrous oxide and methane were not removed. The biological air scrubber achieved the best ammonia removal but nitrous oxide was produced inside this scrubber, resulting in an increased outlet concentration of more than 200%. This was also observed in the two-stage air scrubber, which contained a biological scrubber stage. None of the scrubbers showed significant removal efficiencies for methane.

Keywords: Air scrubbers, NH_3, N_2O, CH_4, removal efficiency.

EMISSÃO DE GASES DE EFEITO ESTUFA E AMÔNIA EM LAVADORES DE GASES INSTALADOS EM EDIFÍCIOS DE ALOJAMENTO DE SUÍNOS

Resumo: foi realizada uma campanha de medição em lavadores de gases químico, biológico e de dois estágios. instalados em edifícios de alojamento de suínos na Flandres. A amônia, o óxido nitroso e o metano foram mensurados, continuamente, durante uma semana no ar de entrada e de saída dos equipamentos. A taxa de ventilação influenciou as concentrações de entrada e, consequentemente, a eficiência de remoção dos gases. O lavador de gases químico nem sempre atingiu a eficiência de remoção legalmente requerida, isto é, 70%. O óxido nitroso e o metano não foram removidos. O lavador de gases biológico alcançou a melhor remoção de amônia, mas dentro desse lavador foi produzido óxido nitroso, resultando uma concentração de saída superior em mais de 200%. No lavador de gases de dois estágios também foi observado essa produção. Nenhum dos lavadores mostraram remoções significativas de metano.

Palavras-chave: lavador de gases, NH_3, N_2O, CH_4, eficiência de remoção.

Introduction

Ammonia can harm the environment as it involves a risk for eutrophication and acidification, consequently leading to biodiversity loss (Oenema et al., 2012). As 94% of the ammonia emissions can be attributed to agriculture (UNECE/LRTAP, 2012), this sector is faced with a regulatory framework regarding ammonia emission reduction. Since 2004, newly built pig buildings in Flanders are legally obliged to implement low ammonia emission housing techniques. This can be achieved e.g. by installing an air scrubber. Intense contact between the exhaust air and the washing water ensures mass transfer of water soluble pollutants (e.g. ammonia) from the air to the washing water, where a chemical equilibrium is established. In a chemical air scrubber an acid is added to the washing water to decrease the pH and thereby increasing the driving force as more ammonia is converted to ammonium. In biological air scrubbers, ammonium captured in the washing water is oxidized to nitrite (NO_2-) and subsequently to nitrate (NO_3^-). In a combined air scrubber, two or more scrubbing stages are placed in series. These stages can involve a chemical, a biological or water step.

Measurements at animal housing facilities show that the legally required removal efficiency of ammonia, i.e. 70%, is not always reached (Mosquera et al., 2011). Furthermore, there is a growing international concern for the livestock related greenhouse gasses methane and nitrous oxide (Gerber et al., 2013). Still little attention is being paid to the performance of air scrubbers in terms of the reduction or production of greenhouse gases. In this paper, the results of a measuring campaign on a chemical, a biological and a two-stage air scrubber are shown. The incoming and outgoing concentrations of ammonia, nitrous oxide and methane were continuously measured during one week to get insight in the performances of the scrubbers.

Materials and methods

Locations of the measurement campaign: the study was conducted at three pig housing facilities, located in Flanders, Belgium. The chemical air scrubber was installed at a commercial fattening pig barn with 1344 animals (Asse, Belgium). The biological air scrubber was located in Linter (Belgium), cleaning the exhaust air of a barn housing 144 sows and 3000 piglets. The two-stage air scrubber (Mollem, Belgium) consisted of a water scrubber, followed by a biological step. This scrubber was installed at a fattening pig housing facility for 1515 animals.

Measuring equipment: indoor concentrations of NH_3, CH_4 and N_2O were measured for one week using an Innova photoacoustic gas monitor 1314 connected to a CBISS multipoint sampler (LumaSense Technologies, Denmark). Samples were taken on average every 20 minutes sequentially at five sampling points (4 after and 1 before the scrubber). Each sampling consisted of at least 6 consecutive measurements with a 3 minutes time interval. Only the last measurement was taken into account to overcome a possible measuring delay of the gas monitor. In case the consecutive measurements did not reach a stable value, no measurement was taken into account. The removal efficiency was calculated for each sampling point using the subsequently measured incoming concentration and the average of the respective four calculated removal efficiencies was plotted. However, it should be noted that this implies a time difference between the measured incoming and outgoing concentration of max. 1 hour and 24 min which could have led to variations. Ventilation rate was estimated by measuring the pressure difference before and after the ventilation fans with a P26 differential pressure transducer (halstrup-walcher, Germany) and expressed as a percentage of the maximum ventilation rate. The washing water of each scrubber was analysed at least three times during the measuring campaign.

Results and discussion

Figure 1 shows the incoming and outgoing concentrations of ammonia, nitrous oxide, methane and their respective removal efficiencies for a representative measurement day.

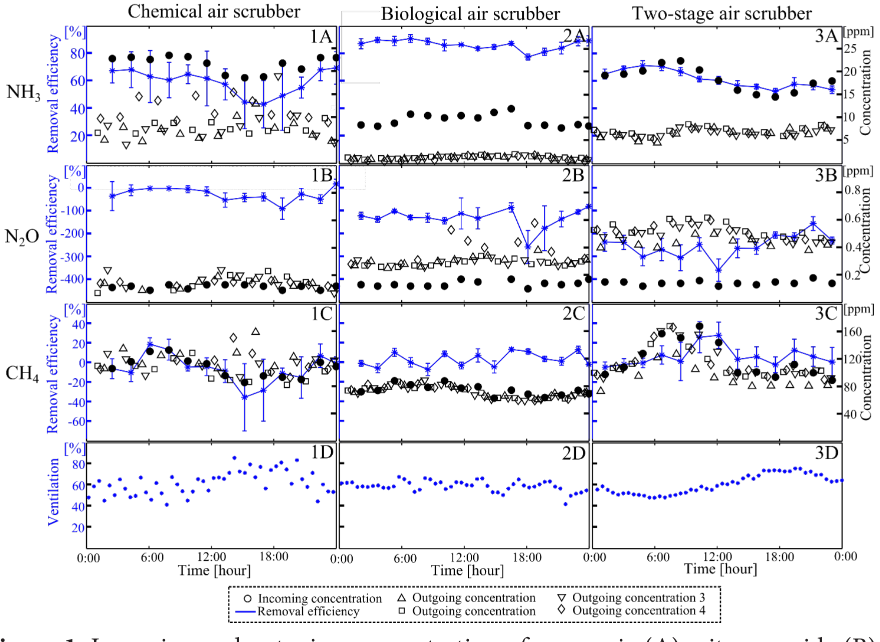

Figure 1. Incoming and outgoing concentration of ammonia (A), nitrous oxide (B) and methane (C), with their corresponding removal efficiency, and ventilation rate (D) for a chemical (1), biological (2) and combined (3) air scrubber.

Influence of ventilation rate on the incoming pollutant concentrations: at all scrubbers, the incoming pollutant concentrations were influenced by the ventilation rate. The ammonia concentrations were slightly higher at night due to lower ventilation rates. In the day, the ventilation rate rose, resulting in lower concentrations. This can be explained by dilution of the incoming air. The same effect was noticed in a study of Melse et al. (2012). The dilution effect could also be seen for methane. In the biological air scrubber, the ventilation rate was quite constant, which was also reflected in a more constant incoming ammonia concentration. Also the methane concentration profile showed this effect, but to a lesser extent. Overall, nitrous oxide concentrations were less affected by the ventilation rate. It must be noted that the observed concentrations were relatively small.

Chemical air scrubber: in the chemical air scrubber, the ammonia concentration for the shown day decreased from 21.8 ± 1.8 ppm in the incoming air to 8.7 ± 1.4 ppm in the outgoing air. An ammonia removal efficiency of 59.5 ± 9.1 was found. The outgoing ammonia concentrations showed large variations (on average 4.0 ppm difference) over the different sampling positions resulting in relatively large deviations of the removal efficiency (on average 18.5% difference). These deviations could be caused by local ammonium sulphate accumulation in the scrubber. This accumulation of salt was also visible outside the scrubber. Overall, the removal efficiency decreased with increasing ventilation rate and decreasing ingoing concentrations. The greenhouse gases nitrous oxide and methane were not removed in the chemical air scrubber. This can be linked with the low water solubility of these gases.

Biological air scrubber: ammonia was efficiently removed by the biological scrubber. The required removal efficiency of 70% was reached throughout the measurements. The outgoing concentration was rather constant, i.e. 1.3 ± 0.4 ppm, despite the changing incoming concentration (9.4 ± 1.3 ppm). The same was experienced by Juhler et al. (2009). The nitrification reactions resulted in an increase in the nitrous oxide concentration in the outgoing air. A production of -128 ± 45 % on average was measured. Methane was not removed nor produced since the removal efficiency was 3.3 ± 7.1%.

Two-stage air scrubber: despite the additional scrubber stage, the two-stage air scrubber did not reach the required 70% removal. Analysis of the washing water showed that the bacteria where inhibited, as 59% and 38% of the total nitrogen in the washing water was respectively nitrite and ammonium instead of nitrate (4%). The biological step caused a relatively high nitrous oxide production (-252 ± 51%). The concentrations and removal efficiency of methane showed similar trends as observed at the chemical and biological air scrubbers with a removal efficiency of 6.7 ±10.3%.

Conclusions

Overall, the incoming concentrations of all measured pollutants depended on ventilation rate. The chemical and the two-stage air scrubber did not perform as well as expected since the removal efficiency of ammonia not always reached the required 70%. Nitrous oxide could not be removed in the chemical air scrubber and was produced in both the biological and the two--stage air scrubber. Methane was not removed in any of the scrubbers under study, which is probably the result of the low water solubility of this gas.

Acknowledgments

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Chapter III

MITIGATION STRATEGIES

PHOTOCATALYTIC DEGRADATION OF AMMONIA FROM AGRO-INDUSTRY

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Abstract: the gas ammonia (NH_3) is one of the main nitrogenous compounds present in industrial processes, agricultural industries and livestock. This gas reacts mainly in the respiratory system and causes corrosive and irritant effects. Its inhalation causes cough, breathing difficulty, mucus or saliva secretions and eye irritation. For broiler chickens and breeding pigs, NH_3 is related to appetite suppression, convulsion and breathing difficulty. These factors harm health of workers and labor productivity. Also, they cause environmental discomfort, mostly in communities adjacent to agricultural industries, chicken and pig breeding. In this challenging context, studies proposing unconventional treatments for odor reduction are being developed increasingly. One of them is the use of Advanced Oxidation Processes (AOP) like heterogeneous photocatalysis with titanium dioxide nanoparticles (TiO_2). This work presents a global vision about heterogeneous photocatalysis as unconventional treatment proposal for odor reduction of NH_3 gas coming from agricultural industries.

Keywords: photocatalysis, titanium dioxide, odor, NH_3.

DEGRADAÇÃO FOTOCATALÍTICA DE AMÔNIA PROVENIENTE DE AGROINDÚSTRIA

Resumo: a amônia (NH_3) na fase gasosa é um dos principais compostos nitrogenados encontrados em processos industriais, agroindustriais e em sistemas de confinamento animal. Este gás age principalmente no sistema respiratório e exerce uma ação corrosiva e irritante. A sua inalação causa tosse, dificuldades respiratórias, formação de catarro, salivação excessiva e irritação nos olhos. Aos animais, tais como frangos e suínos, a NH_3 está associada com a redução de apetite, convulsão e problemas respiratórios. Esses fatores prejudicam também a saúde dos trabalhadores, reduzindo a produtividade laboral. Além disto, causam desconforto ambiental, principalmente nas comunidades adjacentes às agroindústrias e às propriedades rurais suinícolas e avícolas. Neste contexto desafiador, estudos propondo tratamentos não convencionais de redução de odores estão ganhando espaço. Um exemplo é a utilização de Processos Oxidativos Avançados (POA) como a fotocatálise heterogênea com nanopartículas de dióxido de titânio (TiO_2). Este trabalho apresenta uma visão geral sobre a fotocatálise heterogênea como proposta de tratamento não convencional para a redução de odor do gás NH_3 proveniente da agroindústria.

Palavras-chave: fotocatálise, dióxido de titânio, odor, NH_3.

Introduction

In the last decades, environmental issues related to air pollutant have become increasingly frequent due to various causes: vehicle fleet growth, industrial and urban development, deforestation and bushfires. In particular, nowadays the odorous gas emissions from rural and industrial activities represent a serious concern. Among the various agricultural industries, pig and chicken breeding are one of the most important odor generators. The urban pressure pushes to build life spaces in empty areas close to agricultural industries. In consequence, there are complaints from population about the environmental discomfort caused by odors. To avoid these inconveniences, there is already a restriction related to pig and chicken breeding building areas (Instituto Ambiental Paraná, 2002; Fundação Meio Ambiente, 2008).

An odor is constituted of a mix of organic or mineral volatile molecules which affects the nasal mucosa due to physicochemical properties (Belli Filho; Lisboa, 1998). Issues related to odors are complex to be solved because the evaluation of an odorous gas is subjective. Each one has a different sensibility from one chemical compound to another.

Among several odorous gases, the gas ammonia (NH_3) is one of the main nitrogenous compounds present in industrial processes, agricultural industries and livestock. Generally, the NH_3 is characterized by a pungent odor (detected by human between 5-20 ppm), colorless, toxic and lighter than air. This gas reacts mainly in the respiratory system and causes corrosive and irritant effects. In humid conditions, its inhalation causes cough, breathing difficulty, mucus or saliva secretions and eye irritation (Michel, 2000).

These factors harm health of workers and labor productivity. Also, they cause environmental discomfort, mostly in communities adjacent to agricultural industries, chicken and pig breeding. The NH_3 is considered by Ferreira (2010) as one of the most damaging gas for livestock animal's respiratory system.

In this challenging context, studies proposing unconventional treatments for odor reduction are being developed increasingly. One of them is the use of Advanced Oxidation Processes (AOP). An AOP is classified as homogeneous or heterogeneous system. In both cases, the hydroxyl radical can be generated with or without ultraviolet irradiation. Among them, it could be mentioned processes involving ozone and hydrogen peroxide use, catalytic decomposition of the hydrogen peroxide in acidic environment

(Fenton or photo-Fenton reaction) and semiconductors like titanium dioxide (heterogeneous photocatalysis) (Huang et al., 1993).

AOP are able to promote an effective degradation of pollutants to be treated by altering deeply chemical structures of organics or inorganics contaminants (Morais; Zamora, 2005). These results can be obtained thanks to the generation of highly oxidative species through photocatalytic or chemical catalysis reactions. Usually, these highly oxidative compounds are hydroperoxyl radicals (HO_2), superoxide radicals (O^{2-}) and mainly hydroxyl radicals (OH•). These radicals react quickly and, usually they do not present selectivity with most of organic compounds (Canizares et al., 2009).

The photocatalytic or chemical catalysis reaction enables the mineralization of organics or inorganics pollutants. If the reactive is organic, the product will be non-toxic (CO_2 and H_2O). If the reactive is inorganic, the product will be less toxic (Suri et al., 1993). For example in the photocatalytic reaction of NH_3, are the main reaction product is the N_2, in other words, an environmentally friendly compound (Kolinko; Kozlov, 2009).

In this context, this work presents a global vision about heterogeneous photocatalysis with titanium dioxide nanoparticles as a proposal for unconventional treatment for odor reduction of NH_3 gas coming from agricultural industries.

Materials and methods

Principle of the photocatalysis heterogeneous: the principle of photocatalysis in heterogeneous systems consists in activating a semiconductor (the most used is TiO_2) by solar or artificial lighting (wavelength lower than 350 nm). Semiconductors are characterized by their valence band (VB) and conduction band (CB). The zone between them is named bandgap. The photon absorption, with energy higher than the bandgap energy, results in a displacement of an electron from the VB to the CB. This movement causes a gap (H^+) in the VB. These gaps present a positive electrical potential (from +2.0 to +3.5 V). This potential is positive enough to generate radicals OH• from water molecules absorbed in the semiconductor surface (Equations 1 to 3). Then, the radicals OH• will oxidize the organic and inorganic contaminants (Hoffmann et al., 1995).

The efficiency of the photocatalysis depends among other factors on the competition between two processes: when the electron is removed from the semiconductor surface and the recombination of electron/gap pair. Heat is generated during the reaction (Equation 4) (Hoffmann et al., 1995).

$$\mathbf{TiO_2 \longrightarrow TiO_2\,(e^-_{BC} + h^+_{BV})} \qquad (1)$$

$$\mathbf{h^+ + H_2O \longrightarrow HO\cdot + h^+} \qquad (2)$$

$$\mathbf{h^+ + OH^- \longrightarrow HO\cdot} \qquad (3)$$

$$\mathbf{TiO_2\,(e^-_{BC} + h^+_{BV}) \longrightarrow TiO_2\,\Delta} \qquad (4)$$

Titanium dioxide nanoparticles (TiO_2 NP): among the different photocatalysts, the TiO2 is the most studied and used. It presents an excellent oxidative capacity. Its electrical, optical and structural properties are unique. In harsh conditions (temperature, humidity and pH), the TiO_2 presents a high stability. Moreover, it is durable, non-toxic and cheap (Fujishima et al., 2007). By definition, a nanoparticle measures 100 nm maximum in one of its dimensions. The reduction of the material size offers a new property which did not exist at original size (scale bulk). The application of nanophotocatalysts like TiO_2 is new and demonstrates promising results in the treatment of various compounds like. Synthesis methods of TiO_2 nanoparticles are easily realized and descripted in the literature. The use of TiO_2 at nanoscale as photocatalyst is a major trend (Brandão, 2008).

The efficiency of the photocatalyst activity in light absorption conditions is directly linked to the particle size, contact surface area, volume and number of pores of the semiconductor (Chen; Mao, 2006). When the size of the particles decreases, the surface area increases. Therefore, the charge transfer on the semiconductor surface is optimized. Also, as the gap energy is higher, optical, electric and magnetic parameters are modified too. As an example, TiO_2 nanoparticle (5–10 nm) in anatase crystalline form has a gap energy increased by 0.1-0.2 eV (Chen et al., 2011).

The development of new TiO_2 morphologies like nanoparticles (Brandão, 2008), nanospheres (Chen et al., 2011), nanofites, nanotubes (Nakata et al., 2011), nanofibers (Cheng et al., 2010), improves and functionalizes the semiconductor (Xiang et al., 2011). The TiO_2 photoactivity is linked to its crystalline form (Qing et al., 2015). The TiO_2 exists in three main forms: anatase, the most interesting for researchers because there are many applications in the nanostructured form (Chen; Mao, 2006); rutile and brookite. The TiO_2 in anatase form presents the most important photoactivity for degradation of compounds. Consequently, synthesis methods are developed to obtain TiO_2 in this form (Oliveira, 2011).

Results and discussion

Photocatalysis for NH_3 odor reduction treatment: the application of the photocatalysis with TiO_2 nanoparticles for odor reduction, especially of NH_3 coming from agricultural industries, is promising and challenging. It is very important to known that many factors influence the process, for example: initial concentration of the pollutant, temperature, humidity, oxygen, dosage of the photocatalyst end among others. The technology is more efficient when using low concentrations of NH_3 (Brancher, 2012). Moreover, when these factors are not monitored throughout the reaction, it facilitates the undesirable formation of the following by-products: amines (NH_2), nitrous oxide (N_2O), nitrite (NO_2^-) nitrate (NO_3^-) (Kolinko; Kozlov, 2009).

Nevertheless, in many natural environments, NH_3 exists with a high level of concentration. In livestock the NH_3 concentration can exceed 100 ppm, depending on hours of the day, quantity and animal types (poultry or pig) (Sampaio et al., 2006). In this case, an alternative process is necessary to reduce the starting concentration level. It could be the combination of conventional treatments: adsorption, absorption like washing treatment, dilution, biologic processes. At a final stage, the photocatalysis will contribute to remove completely the ammonia from a pre-treated pollutant.

Conclusions

The insertion of low-cost and efficient alternative technologies is doubtless a priority in the odor treatment systems market. Researches on Brazilian technologies foster projects and develop products compatibles to solve local issues. The Brazilian agricultural industry has cutting-edge technologies and advanced treatment systems for solid and liquid effluents. Nevertheless, for odorous gases there is still a lot to do. In this context, the heterogeneous photocatalysis with TiO_2 nanoparticles is a promising way.

The application of photocatalytic oxidation in the treatment of NH_3 gas is attractive because of the main product generated from the reaction is N_2. However, many research studies investigate the by-products generated from this reaction, which can be as polluting as NH_3. In this scenario, it is evident the importance of complementary studies, since the photocatalytic oxidation is still recent and has the capacity to be improved.

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POULTRY LITTER ENERGY RECOVERY B METHANE PRODUCTION USING ANAEROBIC DIGESTION

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Abstract: the poultry production is an activity of outstanding economic importance in South of Brazil. This activity requires significant energy demand and generates significant quantities of waste. There is a requirement to establish scientific knowledge about treatment methods or intended processes to eliminate or recover waste. In this context anaerobic digestion appears to be an attractive route, since it adds value by means of energy production of biogas (methane) utilization and partially treat the residue, mitigating the environmental impact. However, are almost non-existent technical and scientific data standardized and/or standard concerning the specific biogas production or broiler bed methane. This paper presents the results of tests conducted biokinetic under controlled laboratory conditions, as recommended by the European VDI 4630, by batch tests using eudiometer tubes to measure the gas volume produced. The poultry litter sample was reused during the production of nine lots of poultry. There was obtained a mean value of 500 ± 7 $mL_{Nbiogas}$/gSV with methane concentration of 62%. The specific methanogenic potential was found to be 312 ± 4 mL_{NCH4}/gSV, which corresponds to 0.219 m^3_{CH4}/kg poultry litter. The residue proved to be an attractive substrate for the biogas production, presenting satisfactory characteristics for use in co-digestion processes.
Keywords: biodigestion, bioenergy, biogas.

RECUPERAÇÃO ENERGÉTICA ATRAVÉS DA PRODUÇÃO DE METANO VIA DIGESTÃO ANAERÓBIA DE CAMA DE FRANGO DE CORTE

Resumo: a produção de frangos de corte é uma atividade de destacada importância econômica na região Sul do Brasil. Essa atividade requer significativa demanda energética e gera apreciáveis quantidades de resíduos. Existe a necessidade de estabelecer conhecimentos científicos sobre métodos de tratamento ou processos que propõem eliminar ou aproveitar os resíduos. Neste contexto a digestão anaeróbia aparenta ser uma rota atraente, uma vez que agrega valor por meio da produção e aproveitamento energético de biogás (metano) e tratar parcialmente o resíduo, mitigando o impacto ambiental. Porém, são quase inexistentes dados técnico-científicos normatizados e/ou normalizados referente a produção específica de biogás ou metano de cama de frango de corte. Este trabalho apresenta resultados de ensaios biocinéticos efetuados em condições laboratoriais controladas, conforme recomendações da norma Europeia VDI 4630, por meio de ensaios em batelada e utilizando-se tubos eudiômetros para mensurar o volume de gás produzido. A amostra de cama de frango estudada foi reutilizada durante a produção de nove lotes de frangos de corte. Foi obtido o valor médio de 500 ± 7 $mL_{Nbiogás}$/gSV, com concentração de metano em 62 %. O potencial metanogênico específico encontrado foi de 312 ± 4 mL_{NCH4}/gSV, o que corresponde a 0,219 m^3_{CH4}/kg cama de frango. O resíduo demonstrou-se um substrato atrativo para obtenção de energia renovável por meio da produção de biogás. Apresenta características satisfatórias para ser utilizado em processos de codigestão.

Palavras-chave: biodigestão, bioenergia, biogás

Introduction

Poultry production has been an efficient way for animal protein producing for human consumption around the world. However, as all intensive animal production, the waste production also occurs, and if mismanaged, could involve high risks to environmental resources, including water, soil and air (Oviedo-Rondon, 2008).

The most commonly adopted practice by poultry producers is to subject the poultry litter for composting process, followed by application as a soil fertilizer (Orrico et al., 2012). Another option for the stabilization and treatment of poultry litter is the anaerobic digestion. This option is an attractive route, which may add value (biogas and biofertilizer) and partially stabilize the residue, mitigating some environmental impacts (Glatz et al., 2011). Knowledge about the characteristics of organic waste, such as biodegradability and biogas yield, is fundamental to support decision about anaerobic treatment pathway. Among the important parameters, stands out the biochemical biogas or methane potential, since it allows to analyse if the waste could be used as substrate to biogas plant, besides to be an important information for the anaerobic reactor design (Steinmetz et al., 2014).

This study presents the anaerobic biological degradability of poultry litter under mesophilic anaerobic conditions, according to standard internationally recommendations (VDI 4630, 2006). Its objective is to demonstrate the potential for energy recovery of anaerobic digestion using controlled lab tests to provide standardized technical-scientific data about the specific methane production.

Materials and methods

Sampling: the studied poultry litter sample was collected in Marechal Candido Rondon, Paraná-State, Brazil. The poultry litter sample was reused during the production of 9 lots of poultry.

Laboratory tests: to characterize the sample, chemical and physical analyses were performed at the Laboratory of Physical and Chemical Analysis of Embrapa Swine & Poultry, Concórdia, Santa Catarina State, Brazil. In the laboratory, sample was homogenized using food processor. Aliquots of the homogenized sample were used for analysis of total solid (TS), fixed solids (FS), volatile solids (VS), total nitrogen and total carbon. The determinations were made according to APHA (2012). After biochemical methane potential test, samples were collected to perform the Volatile Fatty Acid and Total Alkalinity relation (VFA/TA) test, according Tapparo et al. (2014).

Biochemical methane potential assays: anaerobic digestion experiments were carried out at mesophilic temperature conditions according to VDI 4630 (2006) in triplicate. The tests were preceded in 250 mL reactor flasks and the gas volume was measured using eudiometer graduated tubes. The gas production was read daily by displacement of the column of liquid sealant in the eudiometer tube and the dried biogas volume was corrected to 273 K and 1013 hPa. The mesophilic anaerobic inoculum was prepared mixing anaerobic sludge from reactor fed with swine manure, sludge from reactor fed with food waste and dairy cattle manure (1:1:1 v/v). Two weeks before the test, the mixture of biomass was acclimatized (37 ± 1 °C) in a CSTR reactor, fed at of 0.3 $kgVS/m^3/d$ for 7 consecutive days. After this, the inoculum remained 7 days without fed, in order to reduce the biogas baseline production (Steinmetz et al., 2014). After test, biogas production was considered stabilized when the daily biogas production becomes equal to or less than 1% of the total volume produced (VDI 4630, 2006). For biogas composition evaluation (CH_4 and CO_2), samples were analysed by infrared electrochemical and sensors (Dräger X-am® 700).

Inferior calorific power: the analysis of the Inferior Calorific Power (by raw energy) was carried out in a calorimeter AC 500 LECO.

Results and discussion

After the poultry litter sample analysis, the concentrations and energy values are shown in Table 1. Studying poultry litter, Santos and Lucas Júnior (2004) found average energy coefficients around 3,640.5 (kcal/kg) with sample litter reused during the production of 8 lots of poultry production. The value is close to found in the present study.

In parallel, the anaerobic kinetic tests were performed under mesophilic conditions. Figure 1 shows the cumulative biogas production during the test. The black geometric shapes represent the mean of the three replicates of the biogas from poultry litter whereas the grey´s one represents the positive control test result.

According to VDI 4630 (2006) standard, was used as positive control high purity microcrystalline cellulose. The reference value for cellulose is between 740 and 750 mLN/gSV and is considered satisfactory test progress with value over of 80%, indicating the positive activity of the inoculum activity. In this study, the value was 729 ± 37 mLN/gSV, corresponding about 97.2% recovery.

Table 1. Chicken litter composition of studied sample.

Parameter	Average
Organic carbono (%)	34.40
Total nitrogen (%)	4.17
Total solid (kgTS/kg Poultry litter)	0.87
Fixed solid (kgFS/kg Poultry litter)	0.17
Volatile solid (kgVS/kg Poultry litter)	0.71
Inferior Calorific Power (kcal/kg)	3,214.99
Inferior Calorific Power (kJ/kg)	13,460.52

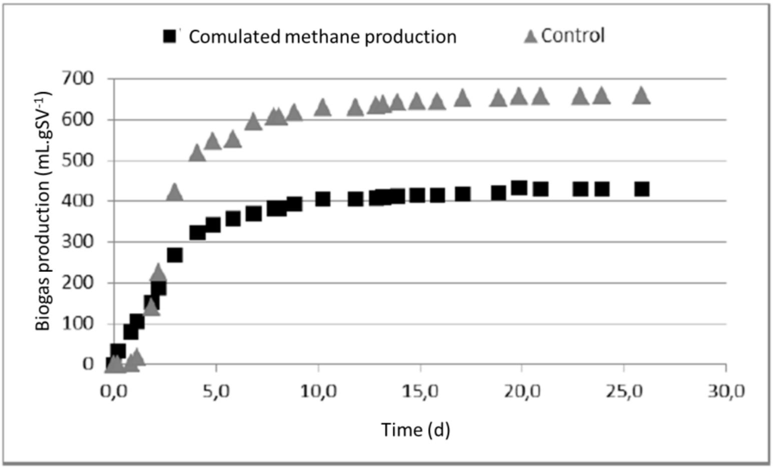

Figure 1. Graphic of specific biogas production of the studied sample (black) and control test (gray).

The pH value ranged from 7.66 ± 0.02 at the start of the assay and 7.68 ± 0.01 after completion. The VFA/TA test, performed after the end of the test, resulted in 0.143 g acetic acid/g $CaCO_3$. This indicates that the poultry litter was consumed by anaerobic digestion and that there was no inhibition to the biodigestion process due to excessive production of organic acids and/or alkalinity consumption, also evidenced by the pH remaining close to neutrality.

According to VDI 4630 (2006), biogas production is considered stabilized when the daily biogas production becomes equal to or less than 1% of the total volume produced. As a result, the stabilization of the test with the poultry litter sample occurred after the 24th day, with a value of 500 ± 7 $mL_{Nbiogas}$/gSV. The methane concentration in biogas remained at 62%. The maximum rate of biogas production was 215 $mL_{Nbiogas}$/d and occurred between 0º and 1º days of degradation.

The studied poultry litter sample presented a methanogenic potential of 312 mL_{CH4}/gSV, which corresponds to 0.219 m^3_{CH4}/kg poultry litter. The Inferior Calorific Power of methane is 8,500 kcal/m^3 (35,558 kJ/m^3), that is, in one kilogram of poultry litter was possible to recovered 1,883.2 kcal (7,879.2 kJ) of energy. Relating these data to the lower heat potential value (Table 1), was achieved 58.6% of energy recovery.

Conclusions

From the biodegradability and Inferior Calorific Power characteristics studied it is possible to conclude that poultry litter can be used as substrate for anaerobic digestion and energy recovery. It is necessary to take into account that the production of biogas per poultry litter requires dilution (due to high solids concentration).

The poultry litter presented high potential to be used in co-digestion processes, but further studies will be needed to define the level of technology to be employed in the anaerobic reactor.

Acknowledgments

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THE IMPORTANCE OF PLANNING THE SWINE PRODUCTION ACTIVITY FOR A SUSTAINABLE RURAL DEVELOPMENT

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Abstract: the growth of the population worldwide has been increasing the search for animal protein, considered fundamental for the survival of the human being. The pig production, incorporated in livestock farming and included in anthropogenic activities, is one of the main sources of production, playing an important role in the economic development of several countries, including Portugal and Brazil (specifically in the south region). It should be noted that if the agro-industry production sector do not adequately manage the water/ wastewater / waste generated along the product chain, contributing significantly to air (production of greenhouse gases and ammonia), and water and soil pollution. Thus, it is important to implement sustainable rural development programs, which, in addition to the strategies to mitigate emissions of greenhouse gases and ammonia, should promote agronomic/bioenergy valorisation, contributing with nutrients through organic fertilization (namely nitrogen, phosphorus and potassium) and minimizing the dependency of fossil energy. This work aims to motivate the various actors in the livestock industry to contribute to the establishment of an integrated vision achieved in the various projects developed in Portugal and Brazil, complementing the knowledge gaps with field studies that allow proposing technically and economically viable solutions.

Keywords: rural development, efficient water use, waste zero discharge, agronomic/bioenergy valorisation.

A IMPORTÂNCIA DO PLANEJAMENTO DA ATIVIDADE DE SUINICULTURA PARA UM DESENVOLVIMENTO RURAL SUSTENTÁVEL

Resumo: o crescimento da população em todo o mundo vem aumentando a busca por proteína animal, considerada fundamental para a sobrevivência do ser humano. A produção de suínos, incorporada na pecuária e incluída nas atividades antropogênicas, é uma das principais fontes de produção, desem-

penhando um papel importante no desenvolvimento económico de vários países, incluindo Portugal e Brasil (especificamente na região sul). Note-se que se o setor de produção agroindustrial não gerencia adequadamente os efluentes/resíduos gerados ao longo da cadeia de produtos, contribuindo significativamente para o ar (produção de gases de efeito estufa e amônia), água e poluição do solo. Assim, é importante planejar o desenvolvimento rural sustentável que, além das estratégias de mitigação das emissões de gases de efeito estufa e amônia, promova a valorização agronômica / bioenergia, contribuindo com nutrientes através da adubação orgânica (nitrogênio, fósforo e potássio) e minimizando a dependência da energia fóssil. Este trabalho visa motivar os diversos atores do sector a contribuir para o estabelecimento de uma visão integrada alcançada nos vários projetos desenvolvidos em Portugal e no Brasil, complementando as lacunas de conhecimento com estudos de campo que permitem propor soluções tecnicamente e economicamente viáveis.

Palavras-chave: desenvolvimento rural; uso eficiente da água; descarga de resíduo zero; valorização agronómica/bioenergética.

Introduction

Waste generation has rapidly increased over the past years especially the organic materials with the growth of the population and economy in the world. Due to this tendency the increase in the search and consequent demand for animal protein of high quality, but at low cost, is considered fundamental for the survival of the human being. A new paradigm appears at the beginning of the 21st century highlighting the importance of finding a balance between environmental management and livestock industry applications in order to respond to the high world demand for this valuable protein. The importance of pig production in livestock sector plays an important role in the economic development of several countries, including Portugal and Brazil (specifically in the south region). Located in different hemispheres and continents and with very different average herds of pigs, both countries currently face similar challenges in relation to the need to comply with growing legal requirements, minimizing environmental impact, without compromising their competitiveness in the global market. In fact, it should be emphasized that if the productive sector and agro- industry activities associated do not implement adequate management of the water/wastewater/wastes generated along production chain, significantly contributes to air pollution (production of greenhouse gases and ammonia), water and soil. This scenario can compromise, in the future the activity sustainability.

In this context, it is essential to adopt different strategic approaches that allow making the agro-industry units eco-efficient, leading to the resources optimization and moving towards their environmental sustainability. For the implementation of a sustainable rural development plan, in addition to mitigation strategies for greenhouse gas and ammonia e missions, it is important to introduce basic structural concepts, such as "water efficiency use" (WEU) and "waste zero discharge" (WZD). The new paradigm is to face the wastes and the solid fractions generated in the livestock units as by-products that add income to the producers due to its agronomic/ energetic value. In a framework, where the vast majority of soils, due to the intensification of agricultural practices, are mostly poor in organic matter, agronomic valorisation is one of the priority goals through organic fertilization (namely nitrogen, phosphorus and potassium).Another challenge is the bioenergy conversion of the different type wastes generated (manure, biowastes). The incorporation of these concepts in a daily management plan in a livestock unit can being implemented only with the full commitment of the farmers, throughout the adoption of the best available techniques (BAT).

Furthermore, there is a need to establish a link between the amount of manure produced and the agricultural area available to close the nutrients cycle addressing a sustainable soil management. An example is the producer's commitment to ensure the quality of the generated residues and, consequently, the quality of the correspondent separated solid fraction. Ensuring this quality, producers will ensure the viability of the synergy "wastes (slurry) application in function of the available agricultural area". Thus, regions with high pig farm density (for instance, in Portugal West region and Mesoregion Catarinense, Catarina State, Brazil), where the production is relevant according to the three pillars of sustainability: "Planet", "People" and "Profit" need to face future challenges regarding long-term food security, natural resources preservation, climate change and territorial development. The new rural development programmes aims to have a strong focus on knowledge transfer and innovation, and new forms of cooperation between different rural actors to underpin a resource efficient and productive agriculture, healthy rural ecosystems and vibrant rural communities.

Materials and methods

As a first step, it is fundamental define global consumption factors for water, energy and slurry production considering animal/day, establishing in parallel a range of values for the main parameters and physical-chemical characterization of the generated by-products. Subsequently, considering a second stage, the mapping of livestock production units and available agricultural land should be validated with the entities involved (producers, agro-industries, environmental and administrative bodies), with the objective of crossing supply and demand - for example, the Territorial Plan for Swine Production Activity (TPSPA). This plan, which was drawn up at the end of the second stage, could be a tool to support the decision-making of policies for the sector, namely in the design of the most adequate rural development plan (RDP) for each region. Figure 1 presents a Roadmap towards a sustainable pig production.

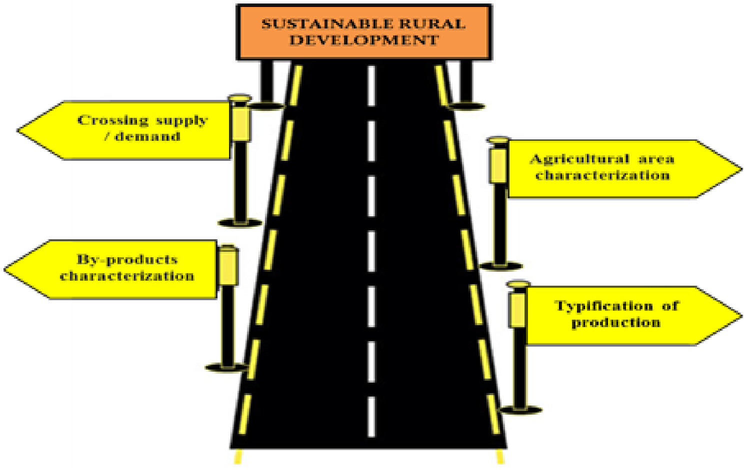

Figure 1. Roadmap towards a sustainable pig production.

Figure 2 shows how the livestock sector must be geared towards a more sustainability activity. The implementation of a pig production Plan Management is a key factor to overcome future competitiveness challenges.

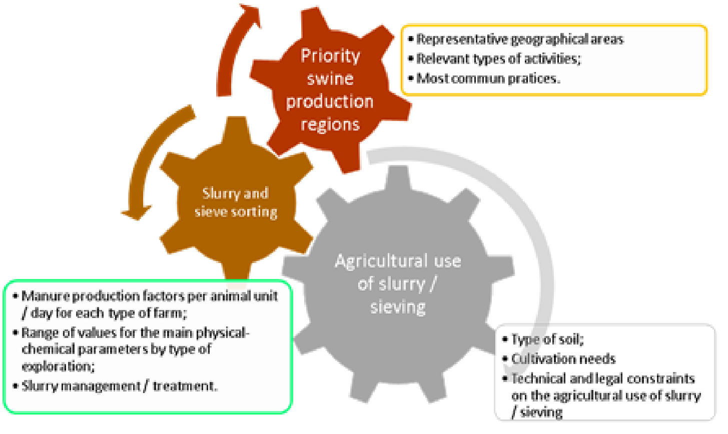

Figure 2. How pig sector can be geared to implement a TPSPA.

In Portugal and Brazil, several studies were carry out over the last few years that, with different approaches, aiming the contribution to solve problems associated with the livestock farms environmental performance, especially pig farms. Several projects of national and international scope, involving the scientific community, agro- industries, associations of producers, environmental agencies and central administration, were developed. In this context, it is important to start integrating the knowledge acquired by the working groups/stakeholders in the sector, in order to validate and enrich the current state of knowledge and support the "journey to the future". The current challenge is to motivate the various actors in the industry to contribute to establishing an integrated vision of the results achieved in the various projects developed, complementing the knowledge gaps with field studies that allow proposing solutions, technically and economically viable, which will make it possible to overcome the environmental/economic challenges to face the future with other perspective.

Figure 3 represents the "close" of the nutrient cycle transforming intensive livestock into a virtuous cycle.

Figure 3. Ideal cycle of utilization of nutrients in livestock.

Conclusions

Minimizing waste of water contributes to the reduction of the volume of slurry/wastewater to apply in agricultural areas, with savings in the cost of application. The need for investment in storage capacity decreases as well as the costs associated with the operation of treatment and/or pre-treatment and energy recovery units. In this sense, it is interesting establish a knowledge transfer network, between regions of Portugal and Brazil with the same type of specificities, which contributes to the eco-efficiency of pig production in both countries.

USE OF BIOGAS SURPLUS FOR ELECTRICAL ENERGY GENERATION IN THE PIGLETS PRODUCTION UNIT OF COOPERALFA IN THE WEST REGION OF SANTA CATARINA

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Abstract: in recent years, there has been a great increase in energy demand in all sectors of the economy and also in people's daily lives. With this increase, the search for renewable energies with sustainability is increasing, along with the discussion about the environmental impacts that some forms of production entail. One of these alternatives is the capture of methane gas produced by swine manure treatment, transforming it into electrical energy. In this study, the experience of Cooperalfa Piglets Production Unit (PPU) in Palma Sola, western Santa Catarina, Brazil, was discussed, analyzing the results achieved until now and the possibilities of increasing the time of energy production by studying the equilibrium with the local consumption load. In addition, the main difficulties that the PPU faces in order to increase its productive capacity are also discussed.

Keywords: swine, biogas, renewable energies, consumption load (kw).

UTILIZAÇÃO DO EXCEDENTE DE BIOGÁS PARA GERAÇÃO DE ENERGIA ELÉTRICA NA UNIDADE PRODUTORA DE LEITÕES DA COOPERALFA NO OESTE CATARINENSE

Resumo: observa-se nos últimos anos um grande aumento da demanda de energia em todos os setores da economia e também no cotidiano das pessoas. Com essa crescente demanda a busca por energias renováveis e sustentáveis vem aumentando, junto com a discussão sobre os impactos ambientais que algumas formas de produção acarretam. Uma dessas alternativas é a captação do gás metano produzido pelo tratamento dos dejetos suínos, transformando-o em energia elétrica. Neste trabalho, buscamos discorrer sobre a experiência da Unidade Produtora de Leitões (UPL) da Cooperalfa em Palma Sola, oeste de Santa Catarina, Brasil, analisando os resultados atingidos até o presente e as possibilidades de ampliação do aumento de tempo de produção de energia, estudando o equilíbrio com a carga de consumo do local. Além disso, debater quais as principais dificuldades que a UPL enfrenta para aumentar sua capacidade produtiva.

Palavras-chave: suinocultura, biogás, energias renováveis, carga de consumo (kw).

Introduction

Despite the small territorial area, Santa Catarina is among the six main food producers in Brazil and has high productivity indexes, which are credited to constant genetic and technological improvements. According to Associação Catarinense Criadores de Suínos (ACCS), Santa Catarina is currently the largest swine producer, the largest producer of swine breeding and the largest pork exporter in the country (Associação Catarinense Criadores SuínoS, 2009). In the year 2012, the state had a pig effective of 7,480,183 animals. The West of Santa Catarina accounted for 73% of the total stock or 5,475,274 animals (Santa Catarina, 2013). That is, even though the west region has 26% of the state territory, it concentrates 79% of the herd. With a very rugged landscape, where only 20% of the land is arable, the intensive raising of animals, both swine and birds, has been gaining strength as an economic activity, direct and indirectly involving, according to data from 2009, more than 65,000 and 140,000 people, respectively. Interesting information is the concentration of swine per inhabitant in some cities. The research of Zeni, Sehnem and Campos (2012) shows a high density in some of the studied cities, as shown in Table 1.

Table 1. Comparison of inhabitants/km² and swine in some of the cities of the west that most produce swine.

Municipality	Area (km²)	Inhabitants	Totalswine	Amount of swine/km²	Amount of swine/inhabitant
Seara	313	17,121	405,340	1,295.00	23.68
Nova Erechim	64	4,118	74,678	1,166.84	18.13
Xavantina	215	4,218	246,340	1,145.77	58.40
União do Oeste	93	3,058	98,800	1,062.37	32.31
Arvoredo	91	2,193	57,000	626.37	25.99

Source: IBGE (2010) *apud* Zeni, Sehnem and Campos (2012).

If we consider that pig herds in the west region of Santa Catarina had more than 5 million in 2012, and that a pig between 25 and 100 kg produces 7.0 L/day (oliveira, 1993, *apud* Zeni et al., 2012), more than 38 million liters of swine manure need daily appropriate destination. From these numbers, it is not difficult to see that the environmental impacts of the activity can be disastrous if there is not an adequate management. In analyzes carried out by Santa Catarina Rural Extension and Agricultural Research Enterprise in the 1980s and 1990s, more than 80% of the water sources in the west of Santa Catarina were contaminated with fecal coliforms above the limit

(Baldissera, 2002 *apud* Denardin; Sulzbach, 2005). Another problem faced is the soil saturation with excess nutrients. In the last two decades, pig farming has been looking for technologies that reduce the impacts of the activity, with a lot of success in the above-mentioned issues, but with some difficulties with regard to the methane gas produced in the decomposition of feces. Greenhouse gas emissions have risen sharply since the last century, with carbon dioxide being the main culprit in global warming. In 2013, the United Nations Intergovernmental Panel on Climate Change (IPCC) released a report in which it states that "the concentration of carbon dioxide (CO_2) in the atmosphere, a gas from fossil fuels and the most harmful one to the environment, increased by 40% since 1750 and continues to accumulate" (Netto, 2013). Agricultural activities have also contributed significantly to this increase, with the growing emission of methane gas (a silent and invisible pollution).

According to research announced, on May 9th, 2013, carbon emissions hit a historic mark with a CO_2 concentration in the atmosphere reaching 400 ppm, 43% more than at the time of the industrial revolution. This increase was mainly caused by the advance of industrialization, intensive cattle raising and use of fossil fuels in transportation.

Given the problems that the region faces with the exorbitant amount of manure produced, one of the most widely propagated alternatives that are being introduced by swine producers are the biodigesters. "Biogas production is an activity of great energetic potential through the sequestration of methane gas from the fermentation of swine manure in biodigesters" (Soares, 2013). According to the author, the production of biogas is a very old activity, but little disseminated in Brazil, mainly due to the installation costs. Although there was some newspaper articles in the 1980s that address on the use of biodigesters, it was only in the 1990s that it became more visible "[...] through the Kyoto protocol, which established targets for reduction of gases" (Dudek, 2013). Considering the need of advances in alternative energy matrices and trying to contribute to the reduction of greenhouse gas emissions effects in the atmosphere, Cooperalfa installed three biodigesters in its swine production unit.

Results and discussion

At its piglet production unit (PPU), Cooperalfa has installed three biodigesters that can be operated in series or individual. This rural property is considered a model by environmental legislation. In this place, the cooperative has 2,750 breeding sows, which produce each approximately 30 piglets/year. The installation cost of these equipment, which includes biodigesters and biogas filtration and purification systems, was R$ 731,095.96. The biodigesters have a storage capacity of 1,800 m^3 of static manure each for a period of 30 days, and can treat up to 60 m^3/day of manure each. With the surplus of biogas, after prioritizing its use directly in heating, it is used in the production of electricity, and the economy is on average 25% of the monthly bill, depending on the month, which in the case of the PPU, reduces R$ 5,102.43 of electric energy costs. Currently, the production is 65 kW/h, but the engine has the capacity to produce up to 150 kW/h. The daily production in the summer period is not higher only due to the costs of kW/h, but the PPU can be 100% self-sustaining in energy. The kW of the electric power grid had a cost of R$ 0.49 in February, 2015, and what was produced in the farm had a cost of R$ 0.64. And since the activity lives in constant crises and has a small profit margin, the increase in costs, if all the energy that could be produced on the farm were used, would certainly be passed on to the productive chain. Of course that if intangible results are considered, especially those regarding the reduction of environmental impacts, there is no discussion about the effectiveness of the system. It should also be noted that all treated manure are used by local farmers to fertilize their crops, respecting the agronomic parameters of fertilization. But with an increasingly competitive market and few government incentives, especially in the absence of a regulatory framework, it is not yet possible to rely solely on the generating potential of biodigesters in the PPU. Table 2 shows some data raised in the last months about the production of energy in the place.

In Cooperalfa, of the 16,700 associated families, 900 work with swine. Of this amount, only 1% use biodigesters in their properties (data from the technical department of Cooperalfa). The explanation is simple: high installation cost and very rigorous process management, financial return only in the long term, in addition to low government and fiscal incentives for a greater diffusion of the system. Even though swine breeding is considered a potentially degrading activity by environmental Foundation (FATMA), little has been done to encourage the use of biodigesters. The big Brazilian energy concessionaires have no interest in seeing their profits fall due to the expansion of alternative energies, and then pressure the government against possible fiscal and political incentives to other options of energy production. In addition, the IPCC, cited above, points out that there is no global government agenda that is taking data on the effects of greenhouse gas emissions, deforestation and pollution seriously.

Table 2. Data raised in the last months about the production of energy in PPU from Palma Sola.

Month/Year	Generated kW	Energy Company kW	Total Consumed kW	Produced % / demand relation kW	Average kW Period Load	Conservative Target TMA 0 80 kW/h % demand relation	Optimized Target TMA 0 100 kW/h% demand relation	Cost of kW paid to the energy company (R$)
Oct./14	8,339	41,993	50,332	16.57	60	21.23	26.60	0.4214
Nov./14	8,794	32,073	40,867	21.52	65	21.23	26.60	0.4371
Dec./14	10,874	32,745	43,619	24.93	65	21.23	26.60	0.4403
Jan./15	14,882	33,084	47,966	31.03	65	21.23	26.60	0.4469
Feb./15	13,690	30,507	44,197	30.97	70	21.23	26.60	0.4906

Economy (bill) (R$)	Economy (intended) (R$)	Cost of Conservative kW R$ 0,26/kW/h	Cost of Optimized kW R$ 0,28/kW/h	Financial Result (bill) (R$)	Financial Result (intended) (R$)	Energy Company cost (R$)	Work days	Generator engine total work hours
Oct./14	8,339	41,993	50,332	16.57	60	21.23	26.60	0.4214
Nov./14	8,794	32,073	40,867	21.52	65	21.23	26.60	0.4371
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Jan./15	14,882	33,084	47,966	31.03	65	21.23	26.60	0.4469
Feb./15	13,690	30,507	44,197	30.97	70	21.23	26.60	0.4906

Source: Cooperalfa Environmental Sector.

It is necessary that environmental technologies become more available to the producers, especially those that can adopt them, and those compensations start to be given in exchange for the use of technologies that greatly reduce the impacts of the activity. In a moment of energy crisis, projects that use biogas to generate electric power could help a lot in reducing the use of electricity or other more expensive forms of energy. Although some damages are irreversible, investments in renewable energy must be intensified. Without profound changes in the energy matrix, the possibility of environmental disasters is, unfortunately, more real every day. Dudek points out in its survey data from the American Environmental Protection Agency (USEPA) that indicates that 14% of the global methane gas emissions come from agricultural activities. “For this reason, the great challenge of regions with high concentration of animals, such as the western region of Santa Catarina, is the requirement of environmental and energy sustainability, and the reduction of greenhouse gas emissions” (Dudek, 2013).

Conclusions

In renewable energy projects with emphasis on biogas, the first steps are to study all the factors of the energy matrix, have a good project, make adjustments and set the optimized conditions for its use. People must think as producing and consuming source of this energy, seeking the sustainability of this productive matrix.

The use of biogas in renewable energy projects should be incorporated to treat effluents with biogas capture potential for the first use of this energy in its direct form, replacing other elements such as liquefied petroleum gas in heating.

In this study, in five months in which the system is adjusted, the results of consumption and production of electric energy are meeting what was predicted in the project before its implementation. The unit is generating electric power above the projected in 21.23%, however the difficulty found in this work is the load adjustment, currently in 65 kW range and the project predicts a load of 80 kW in form of conservative generation. With this, it can be predicted that the amortization period of the investment will increase, even if the current kW cost of R$0.49 is above the projected amount of R$0.33/kW. Although it is a proven effective alternative in reducing the environmental impacts of the activity, due to bureaucracy and high costs, few properties use this technology to transform the swine manure fermentation into energy. The concentration of the activity and consequent environmental impact affects all the society, so everyone involved in the use of natural resources must demand effective solutions to the problem. As long as not only producers are held accountable, but a whole society requires another model of production, there may be an effective decrease in the impacts of the activity. The solution to minimize the problem and reach a balance point must, necessarily, result from a process of involvement of producers, agroindustries, public managers and community in general, both urban and rural.

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CHALLENGES AND OPPORTUNITIES TO ENHANCE BIOENERGY COMPETITIVENESS IN AGRO-FOOD SECTOR. THE IMPORTANCE OF DIALOGUE BETWEEN PORTUGAL AND SANTA CATARINA - BRAZIL

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Abstract: agriculture generates co-products, by-products and waste streams that are currently not properly taken care of both in environmental and economic terms. In livestock production, manure, litter and other effluents management is a challenge, in particular agro industrial production units. While these effluents can be used as fertilizer, they can also be sources of bio-energy or valuable bio-products. The impacts on the environment, with emissions to the air, soil and water need to be evaluated. It is important to consider the whole effluent chain to avoid pollution swapping and health issues, due to possible transmission of pathogens. Beyond reduction and recycling of agricultural waste, co-products and by-products, there may be opportunities for new processes enabling innovative uses of these materials, also outside the agricultural sector, slaughterhouses and fruit/vegetables processing industries. The aim of this paper is to highlight the importance of the dialogue across regions with similar realities from Portugal and Brazil, towards a multisector approach for needs and options for smart use of agricultural wastes, by-and-co-products through creation of joint stakeholder's platform and other joint structures. The opportunities for the farming sector to enhance competitiveness through the incorporation of new type of biowastes from agro-food resulting in environmental and economic benefits will be exemplified.

Keywords: biowastes, anaerobic co-digestion, bio-fertilizer, sustainable bioenergy economy.

DESAFIOS E OPORTUNIDADES PARA O AUMENTO DA COMPETITIVIDADE NO SETOR AGROALIMENTAR. A IMPORTÂNCIA DAS SINERGIAS ENTRE PORTUGAL E SANTA CATARINA - BRASIL

Resumo: a agricultura gera coprodutos, subprodutos e fluxos de resíduos aos quais não é dado o devido valor e atenção em termos ambientais e económicos. Na produção animal, a gestão de estrume, resíduos e efluentes torna-se um importante desafio, em especial em unidades de produção agroindustriais. Embora estes efluentes possam ser utilizados como fertilizantes, eles também podem ser fontes de energia ou biomassa de valor acrescentado. Os impactes sobre o ambiente, nomeadamente as emissões para o ar, solo e água requerem uma avaliação mais pormenorizada, sendo de extrema importância considerar toda a cadeia de efluentes para evitar problemas de permuta de fontes de poluição e, consequentemente, de saúde, devido à possibilidade de transmissão de agentes patogénicos. Além da redução e reciclagem de resíduos agrícola, coprodutos e subprodutos, pode haver oportunidades para novos processos que permitam utilizações inovadoras destes materiais também fora do sector agrícola, nomeadamente em matadouros e indústrias de frutas/legumes de processamento. O objetivo deste artigo é destacar a importância do diálogo entre regiões de Portugal e do Brasil com realidades similares, no sentido de uma abordagem multissectorial para as necessidades e opções para uso inteligente de resíduos agrícolas e outros produtos através da criação de estruturas comuns de plataforma que possibilitem a troca de ideias e saberes ente as partes interessadas. Serão dados exemplos de trabalhos desenvolvidos que visam o aumento da competitividade no sector agroindustrial através da incorporação de um novo tipo de bioresíduos agroalimentares, resultando em benefícios ambientais e económicos.

Palavras-chave: bioresíduos, codigestão anaeróbia, biofertilizantes, economia bioenergética sustentável.

Introduction

Renewable energy and steps toward achieving more sustainable societies are the key drivers for conducting more scientific research preserving different resources. During the past decade anaerobic digestion (AD) to treat the waste organic fraction from different sources has increased their importance for both, economic and ecological reasons. It is important closing the link between biowastes/energy/bio-fertilizer towards a future circular economy (EU Comission, 2015, 2016). Therefore, the inter-linkages among these areas (biowastes, energy, agriculture, environment and economic growth) are highly encouraged taking in account an integrative approach along the product chain. In order to improve resource efficiency through biowastes minimization is crucial to implement environmental waste management plans in primary production and search for biowastes valorization opportunities into by-and co-products. Concerning the studies under development in this research area, in Portugal, the highlighted co-substrates selected to improve AD process were non-marketable apples/pears (Ferreira et al., 2012; DIAS et al., 2014), orange peel residues (paper in preparation) and canteen residues (Carvalho; Duarte, 2011) combined with livestock slurries (cow and swine manure) and mixed sludge (MS) from wastewater treatment plant (WWTP). According with National Statistical Institute (INE), during 2013, the pear, apple and orange production in Portugal was: 202,500, 287,314 and 236,800 thousand ton corresponding to an agricultural area of 12,014, 13,661 and 19,816 ha, respectively. Comparing the data from Santa Catarina – Brazil, in the same year, the amount produced of pear, apple and orange were 57,625,7,002 and 530,725 ton, respectively, (Santa Catarina, 2014) confirming the interest of this approach to construct a roadmap draft. This tool allows the evaluation of the different biowastes routes to achieve the future goals to be adapted to different realities (for example, Portugal and South of Brazil). The aim of this paper is the application of a simplified roadmap and testing the weak and strong points to promote common advances in the nexus biowastes/energy/bio-fertilizer, closing the nutrients' cycle towards a circular economy (EU Comission, 2015, 2016).

Materials and methods

It is vital to establish a common methodology to identify, quantify and characterize multisubstrates with potential use for the process of AD and anaerobic co-digestion (AcoD), in order to obtain comparable results, selecting the best route to apply the most appropriate combination between biowastes. The characterization of these biowastes includes its geographical location, production and quality. After this analysis step, it is important to assess if the substrate could be used as AD substrate, attending with such characteristics as C/N ratio, pH, volatile solids (VS) content, and chemical oxygen demand (COD) content. To enhance AD process, other biowastes could be included as co-substrates, boosting the digestion leading to better productivity of the methanogenic phase and significantly increasing the production of biogas.

The achievement of co-substrates application is based on different pre-treatments: mechanical (fractions with different particle sizes), thermal (different temperatures and operational time) and chemical (water, alkali and acids) or natural fermentation.

In High Institute of Agronomy – University of Lisbon (ISA-UL) several assays were been developed regarding AD and AcoD. Different strategies have reported the advantages of AcoD of swine and cow manure (SM and CM, respectively) and MS of wastewater treatment plant with other co-substrates to promote a feed mixture well balanced, enhancing biogas production through optimization several parameters such as macro and micronutrients, C/N ratio, pH, inhibitors/toxic compounds, biodegradable organic matter and dry matter (DIAS et al., 2014). Figure 1 shows a draft of a roadmap to be enrolled by both research teams in order to evaluate the potential of the biowastes chain value, regarding the sustainable bioenergy economy, adapting and improving with the data from Portugal and Santa Catarina – Brazil.

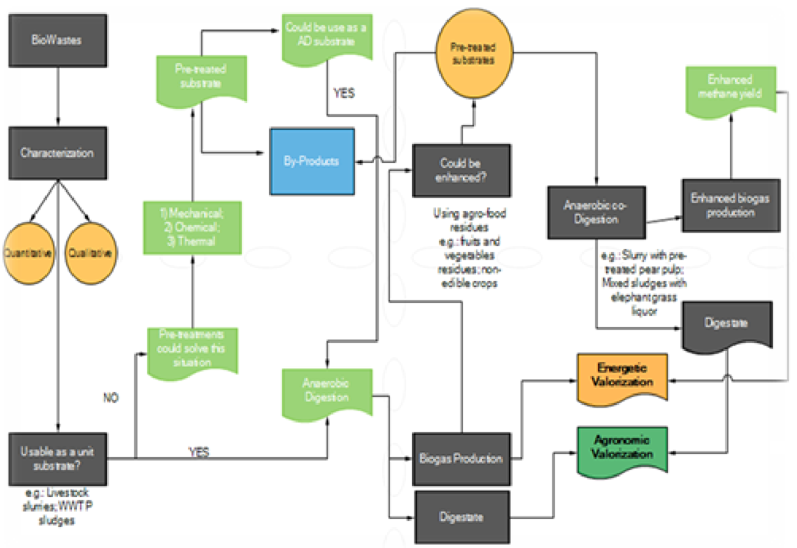

Figure 1. Roadmap to AD and AcoD processes.

Results and discussion

The results shown in Table 1 and Table 2 are an overview of different assays carried out in ISA-ULisboa, with different mono-substrates and co-substrates, following the conceptual approach of the roadmap draft (Figure 1). Both tables' compares the C/N ratio and gas production rate (GPR) obtained throughout the different assays performed by our research team.

Table 1. AD trials results using monosubstrates: LCM – liquid fraction of cow manure; SM – swine manure; SS – sewage sludge.

Substrates	C/N	GPR ($mL_{biogas}/mL_{reactor}.day$)	GPR ($mL_{biogas}/mL_{reactor}.day$)
LCM	12	200	128
SM	5	278	203
SS	6	244	146

Table 2. AcoD trials results using co-substrates: LCM – liquid fraction of cow manure; FW – pre-treated fruits waste; SM – swine manure; SS – sewage sludge.

Fee	C/N	GPR ($mL_{biogas}/mL_{reactor}.day$)	GPR ($mL_{biogas}/mL_{reactor}.day$)
LCM:FW (75:25, v:v)	35	425	301
SM+FW (85:15, v:v)	25	980	568
SS+FW (75:25, v:v)	6	534	341

The methane production enhancement achieved by the addition of different co-substrates is, respectively, 2.5 times (trial I - LCM+FW mechanical treatment and natural fermentation), 2.8 times (trial II - SM+FW mechanical treatment) and 2.4 times (trial III - MS+FW mechanical and thermal hydrolysis), comparing with AD trials (reference scenarios) (Figure 2). These results confirmed that adding an appropriate co-substrate to overcome monosubstrates drawbacks is a sustainable solution to an efficient bioconversion process.

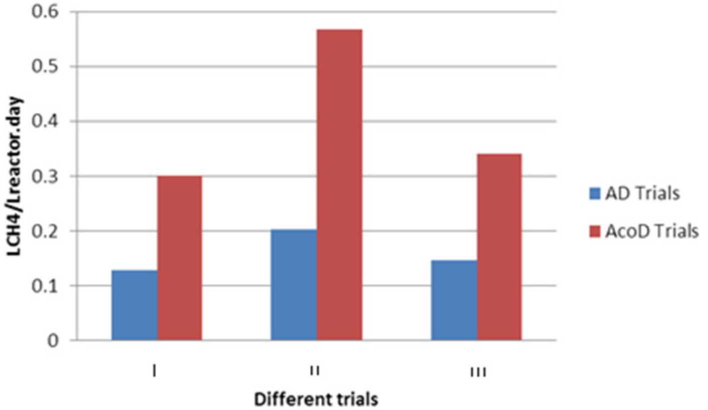

Figure 2. Enhancement of methane production with the addition of co-substrates.

Conclusions

The results show the importance of using a roadmap to select the best route according to characteristics of substrates and co-substrates, where the definition of the pre-treatment more appropriate is an important tool to enhance methane yield. At the time that the energy problem is a reality in Brazil, the consideration of the results obtained in Lisbon show great prospects and new visions for future bioenergy researches in AD and AcoD areas since Brazil has the co-products, by-products and waste streams from agriculture and agro-food industries. This approach it is an important step to share knowledge between two research teams in order to develop a strategy towards a sustainable bioenergy economy, boosting anaerobic digestion process.

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ENVIRONMENTAL ASSESSMENT OF STRATEGIES TO MITIGATE GREENHOUSE GASES THE VALUE CHAIN OF FOOD PRODUCTION

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Abstract: the aim of this paper was to evaluate the greenhouse gas (GHG) emissions of different transportation modes of grains in the chicken and swine supply chain. The life cycle assessment (LCA) methodology was used to compare the alternatives, while the GHG emissions were characterized according to the IPCC model. The baseline scenarios are described in Prudêncio da Silva (2011) for LCA of chicken and Cherubini et al. (2015) for the LCA of swine. Two different scenarios were identified in accordance with a Brazilian agroindustry: grains transportation from Center West region by lorry and train; and a hypothetical scenario which considers that the grain transportation is performed only by train. The results show that the changes in transportation modes of grains have the potential to reduce in 10% and 12% the emissions of GHG in the chicken and swine supply chain, respectively.

Keywords: GHG, animal production, transports, mitigation strategies.

AVALIAÇÃO AMBIENTAL DE ESTRATÉGIAS DE MITIGAÇÃO DE GASES DE EFEITO ESTUFA NA CADEIA DE VALOR DA PRODUÇÃO DE ALIMENTOS

Resumo: Este artigo tem como objetivo avaliar as emissões de gases de efeito estufa (GEE) por diferentes modais de transporte de grãos na cadeia produtiva de frangos e suínos. A metodologia utilizada para comparação das alternativas é a de avaliação do ciclo de vida, enquanto as emissões dos gases de efeito estufa foram caracterizadas de acordo com o modelo do IPCC. Os cenários bases são descritos nos estudos de Prudêncio da Silva (2011) para a ACV de frangos e no trabalho de Cherubini et al. (2015) para a ACV de suínos. Dois cenários alternativos foram identificados em conformidade com uma agroindústria brasileira: transporte dos grãos da região centro oeste realizada parte por caminhões e parte por trem; e, outro cenário hipotético que

considera que todo o transporte de grãos é realizado por trem. Os resultados demonstram que a alteração dos modais de transporte dos grãos possui um potencial de reduzir em 10% e 12% as emissões de GEE nas cadeias produtivas de frangos e suínos, respectivamente.

Palavras-chave: GEE, produção animal, transportes, estratégias de mitigação.

Introduction

The food production supply chain, specifically in the agricultural production phase, is one of the main responsible for the greenhouse gases (GHG) emissions. According to Steinfeld et al. (2006), the sector is responsible for 18% of the carbon dioxide (CO_2) equivalent emissions. The agricultural production in the last years has been gone through great changes, such as technological (intensification) or geographical. In Brazil, although the animal rearing expanded from the south to center west in the last years (Kunz et al., 2009; Prudêncio da Silva, 2011), a significant share of the production still occurs in the southern region with grains produced in the center west, resulting in large distances for inputs transportation.

Analyzing the environmental impacts of the chicken and swine supply chain in Brazil, (Cherubini et al. 2015; Prudêncio da Silva et al. 2014), noticed that besides the high impact of grains production, animal rearing and manure management, the long distances for grains transportation from the center west region to the southern also represents an important environmental aspect in the chain. Thus, the aim of this paper was to evaluate the GHG emissions of different transportation modes of grains in the chicken and swine supply chain.

Materials and methods

To quantify the GHG emissions and the potential to reduce these emissions we use the life cycle assessment (LCA) methodology according to the NBR ISO 14040 and 14044 standards (Associação Brasileira Normas Técnicas, 2009a; 2009b). LCA is a methodology for the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product or service throughout its life cycle (Associação Brasileira Normas Técnicas, 2009).

The defined functional unit is: tonne of frozen animal carcass (chicken and swine). The system boundaries were set from the fertilizer production for grain cultivation until the frozen animal carcass ready for cutting or further distribution. Detailed information on the LCA of chicken and swine production can be found in Prudêncio da Silva (2011), Prudêncio da Silva et al. (2014) and Cherubini et al. (2015), respectively.

The mitigation strategy defined was to change the current transportation mode of grains, exclusively by lorry, as in the following:

- **Chicken/Swine:** Chicken/Swine produced, slaughter and eviscerated in Concórdia/SC (Herval d'Oeste) with feed produced in the south, with maize and soybean from center west region. Transportation of grains from Rondonópolis/MT to Concórdia/SC (Herval d'Oeste) only by truck.
- **Chicken/Swine:** Chicken/Swine produced, slaughter and eviscerated in Concórdia/SC (Herval d'Oeste) with feed produced in the south, with maize and soybean from center west region. Transportation of grains from Rondonópolis/MT to Alto Taquari/MT by lorry; and, from this location to Ponta Grossa/PR by train, and then to Concórdia/SC (Herval d'Oeste) by lorry.
- **Chicken/Swine:** Chicken/Swine produced, slaughter and eviscerated in Concórdia/SC (Herval d'Oeste) with feed produced in the south, with maize and soybean from center west region. Transportation of grains from Rondonópolis/MT to Concórdia/SC (Herval d'Oeste) only by train.

Data regarding to the supply chain and transportation distances were collected and discussed with a Brazilian agroindustry. Data regarding to the emissions of lorry and train transportation were from ecoinvent® database (Franklin Associates, 2003; Spielmann et al., 2007).

The life cycle impact assessment (LCIA) method was the Intergovernmental Panel Climate Change (2007). The results interpretation was conducted taking into account the relative values (results) of the comparative LCA with the baseline scenario.

Results and discussion

Grains transportation used in the animal feed is responsible for 14% of the GHG emissions to produce one tonne of chicken carcass (Figure 1, scenario of lorry transportation). Meanwhile in the swine production this stage represents a higher share of total impacts with 18% of the emissions.

In the first scenario defined to reduce the GHG emissions, the grains transportation from the center west region by truck and by train, showed a potential to reduce from 2% to 8% of the CO_2 eq. emissions, for the chicken and swine supply chain, respectively.

The alternative with greater potential to reduce the emissions is the scenario where all grains are transported only by train. In this scenario, the evaluated model shows that it is possible to reduce from 10% to 12% the GHG emissions for the chicken and swine supply chain, respectively.

The use of trains in the transportation of products has the potential to reduce by 3.1 times the GHG emissions regarding to lorry usage. The product tonne emission by km (t.km) is 0.19 kg CO_2 eq. for lorry usage, while the transportation by diesel train emits 0.061 kg CO_2 eq.

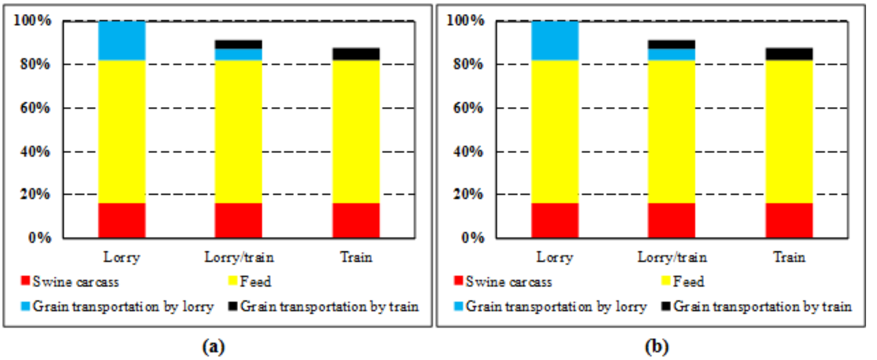

Figure 1. GHG emissions from different transportation modes in the chicken (a) and swine (b) supply chain.

The impact of grains transportation by lorry is associated with the production and combustion of the diesel used; therefore, the change of diesel for biodiesel can represent an important impacts reduction for this mode. According to Nogueira (2011), the biodiesel from soybean and palm oil has the potential to reduce in 62% and 71%, respectively, the emissions of CO_2 eq. per kg of fuel when compared to the conventional diesel.

Conclusions

The results agree with the common sense that the transportation by train has less CO_2 eq. emissions. However, in this paper it is possible to highlight through relative values the reduction potential of environmental impacts in two consolidated supply chains through changes in the transportation mode. In this sense, this paper demonstrates the importance of larger investments to increase railway lines, mainly in a country with continental dimensions such as Brazil.

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ASSESSMENT OF THE EFFECT OF DIFFERENT COMBINATIONS OF BEST AVAILABLE TECHNIQUES ON THE REDUCTION OF GAS EMISSIONS FROM PIG PRODUCTION

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Abstract: ammonia emitted by piggeries could be reduced by the implementation of Best Available Techniques (BAT) whose effectiveness has been demonstrated on husbandry, manure storage or slurry spreading. However, their implementation on one stage may affect the emission on the following stages, modifying the global effectiveness and the relative interest at the farm scale. The aim of this study was to measure the effectiveness of different BAT combinations from building to spreading for eight different pig systems during two climate conditions. Four fattening rooms with 60 pigs were studied: two rooms with frequent slurry removal (gravity and flushing, respectively), one room equipped with a bioscrubber, and the control with slurry storage underneath the pigs and no air treatment. The slurry was discharged from each room into two external tanks, one being covered. At each stage, gaseous emissions (NH_3 and N_2O) were measured and slurry mass balances were calculated. The potential of volatilization during spreading was measured in laboratory conditions. By considering the global ammonia emissions during the building and storage stages, the pig systems with BAT compared to the control led to a reduction of 8 to 62%. The effectiveness of BAT used in building was increased by 10% when coupled with a storage cover, and respectively reduced by 10% without cover. Including the spreading stage, favorable conditions to volatilization reduce the benefit of BATs between -2 to -26% compared to the control. Using BAT at each stage is useful in order to maximize the conservation of nitrogen and therefore its recycling.

Keywords: N_2O, NH_3, mitigation strategy, pig production, Best Available Techniques.

AVALIAÇÃO DO EFEITO DE DIFERENTES COMBINAÇÕES DAS MELHORES TÉCNICAS DISPONÍVEIS NA REDUÇÃO DAS EMISSÕES DE GÁS DA PRODUÇÃO DE SUÍNOS

Resumo: a amônia emitida nas suinoculturas pode ser reduzida pela implementação das melhores técnicas disponíveis (MTD), cuja eficácia foi demonstrada na criação, armazenamento ou espalhamento do dejeto. No entanto, a sua implementação em uma única etapa pode afetar a emissão nas etapas seguintes, modificando a eficácia global e o interesse relativo à escala real, na propriedade. O objetivo deste estudo foi mensurar a eficácia de diferentes combinações de MTD, do alojamento ao espalhamento, em oito sistemas diferentes de criação de suínos, durante duas condições climáticas. Foram estudadas quatro salas de terminação com 60 suínos: duas salas, com remoção frequente de dejeto (gravidade e flushing, respectivamente), uma sala equipada com biolavador e uma de controle, com armazenamento dos dejetos por baixo dos suínos e sem tratamento do ar. O dejeto foi descarregado de cada sala para dois tanques externos, sendo um deles coberto. Em cada etapa, as emissões de gás (NH_3 e N_2O) foram medidas e calculados os respectivos balanços de massa do dejeto. O potencial de volatilização durante o espalhamento foi medido em condições laboratoriais. Considerando as emissões globais de amônia durante as etapas de alojamento e armazenamento, os sistemas de criação com MTD, em comparação com o controle, conduziram a uma redução de 8 a 62%. A eficácia das MTD utilizadas no alojamento foi aumentada em 10% quando associada a uma cobertura no armazenamento e, respectivamente, reduzida em 10% na ausência dessa cobertura. Incluindo a etapa de espalhamento, as condições favoráveis à volatilização reduziram os benefícios das MTDs entre -2 a -26% em relação ao controle. Usando MTD em cada etapa é útil para maximizar a conservação do nitrogênio e, portanto, a sua reciclagem.

Palavras-chave: N_2O, NH_3, estratégia de mitigação, produção de suínos, Melhores Tecnologias Disponíveis.

Introduction

Ammonia emitted by piggeries could be reduced by the implementation of BATs whose effectiveness has been proven for housing and storage facilities or the spreading of manure. The environmental assessment of the whole manure management chain has been rarely studied. Nevertheless, the impact of BAT implemented on the housing stage may probably affect the emissions during the storage and/or spreading phases. It may modify the global effectiveness and the relative interest at the farm scale (Philippe et al., 2013). The aim of this study is to assess the global effectiveness at the farm scale of several BAT combinations.

Materials and methods

BATs combinations: eight pig systems (B: Building stage; St: Storage stage; Sp: Spreading stage) combining different BATs (bioscrubber, gravity removal, flushing, cover, anaerobic digestion) were studied during two periods (P1: September to March; P2: March to September – Table 1). For the Building stage, pigs (60/room) were fed with the same biphasic strategy in four identical fattening rooms (fully slatted floor and dynamic ventilation). Eight experimental tanks (13 m^3 volume) were used for the outdoor Storage stage. For the Spreading stage without any BAT, measurements were achieved in laboratory.

Table 1. Description of the building (B) and storage (St) stages of eight pig systems.

System name	Building (B)	External storage
Control	Room 1: removal of slurries at the end of the fattening period	Tank 1D: uncovered storage supplied with 50% of the slurries removed from room 1
Anaerobic digestion		Tank 1C: storage in mesophilic digester (37°C) with 50% of the slurries removed from room 1
Bioscrubber	Room 2: Bioscrubber + removal at the end of the fattening period	Tank 2D: uncovered storage supplied with 50% of the slurries removed from room 2 and50% of the washwater
Bioscrubber + cover		Tank 2C: covered storage supplied with 50% of the slurries removed from room 2 and50% the washwater
Gravity removal	Room 3: Gravity removal every 2	Tank 3D: uncovered storage supplied with 50% of the slurries removed from room 3
Gravity removal + cover		Tank 3C: covered storage supplied with 50% of the slurries removed from room 3
Flushing	Room 4: Flushing with removal	Tank 4D: uncovered storage supplied every 2 weeks with 50% of the slurries removed from room 4
Flushing + cover		Tank 4C: covered storage supplied every 2 weeks with 50% of the slurries removed from room 4

Gaseous emissions measurements: gaseous emissions were obtained by multiplying the difference of indoor and outdoor gas concentrations with the air flow rate. For B and St, the gas concentrations (NH_3, N_2O and H_2O) were measured with photoacoustic infrared analyzers (INNOVA 1412) coupled with a sampler dosimeter (INNOVA 1303). For B stage, air was sampled in the extraction duct. The ventilation rate was obtained with continuous measurement of speed rate at the extraction fan. For St stage, dynamically ventilated tunnels (Hassouna et al., 2010) were used for uncovered tanks. For covered tanks, the flow was measured using a tracer gas (SF6). Indoor and outdoor air temperature and relative humidity were also continuously monitored, as other outdoor climatic conditions (wind velocity on the slurry surface uncovered and rainfall). The NH_3 volatilization during Sp stage was measured in dynamic cells (Flura et al., 2013) put in controlled conditions with a conductivity analyzer (Florria). The gaseous emissions were validated by calculating N, P, K and H_2O mass balances at each stage.

Results and discussion

The cumulated ammonia losses of successive stages B+St represented between 15 and 39% of the nitrogen excreted by pigs with an average at 26%. The losses of the B+St pig systems with BAT were lower than the standard (Figure 1); the reduction comparing to standard was respectively 12% (anaerobic digestion), 23% (bioscrubbers), 43% (bioscrubbers + cover), 29% (gravity removal), 46% (gravity removal + cover), 11% (flushing) and 32% (flushing + cover). The implementation of BAT only on B stage without BAT for St showed an increase of emissions during the storage compared to the standard, especially during P2 (higher temperatures) (Table 2). This lead to a 10% reduction of the efficiency obtained for the B stage. At the opposite, the use of cover during the storage increased by 10% the reduction of BAT implemented on the B stage.

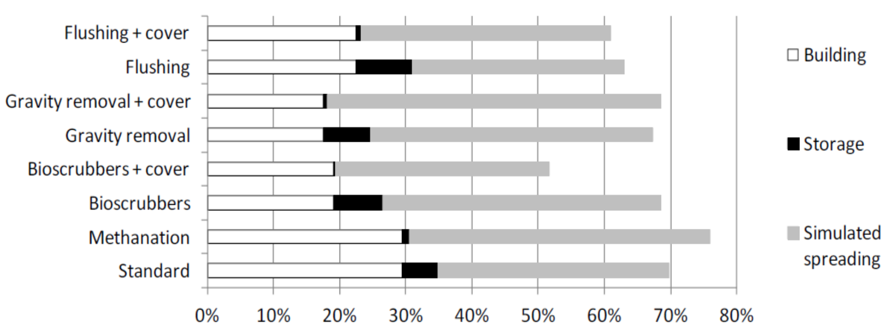

Figure 1. Average (over P1 and P2) cumulated ammonia losses (in % excreted N) during Building (B), Storage (St) and Spreading (Sp) stages of the eight pig systems.

Table 2. Average P1 and P2 gaseous emissions of each stage (in % of N at the beginning).

		Standard	Digester	Bio-scrubbers	Bio-scrubber + cover	Gravity removal	Gravity removal + cover	Flushing	Flushing + cover
B	NH_3-N	29.5	29.5	19.0	19.0	17.5	17.5	22.5	22.5
	N_2O-N	1.4	1.4	2.1	2.1	1.4	1.4	1.2	1.2
St	NH_3-N	7.7	2.0	9.2	0.6	8.5	0.9	11.0	1.0
	N_2O-N	0.04	1.96	0.03	0.01	0.08	0.01	0.07	0.01
Sp	NH_3-N	53.5	65.5	57.0	40.0	56.5	61.5	46.0	49.0

The assessment of the whole manure management chain (B+St+Sp) led to modify the relative interest of BAT in pig systems. The total cumulated ammonia emissions ranged between 36 and 80% of the excreted nitrogen with an average of 66%. For all the different systems with BAT, the reduction of ammonia emissions was observed comparing to the standard system except for the anaerobic digestion pig system. This was due to the mineralization of the slurry leading to an increase of TAN (81% of the nitrogen at the exit of the digester compared to 75% at the end of other storages). The final effectiveness of other combinations is hugely decreased of 2, 26, 3, 2, 10 and 13% compared to the control, respectively, for the following combinations: bioscrubbers, bioscrubbers + cover, gravity removal, gravity removal + cover, flushing and flushing + cover. Between B+St stages and B+St+Sp stages, the global effectiveness of BAT combinations compared to the control was reduced from 13 to 42% depending on the system. The results showed that nitrogen conserved by the implementation of BAT at the B and St stages tended to be lost during spreading, even if the conditions of ammonia volatilization during spreading were maximized in this study. This underlines the interest of the implementation of BAT for the spreading phase in order to take advantage of the BAT implemented in the previous stages as shown by Dinuccio et al. (2012).

Conclusions

This study showed that the benefit of one BAT applied in pig production at the B stage or at the St stage could be reduced (without being necessarily cancelled) at the farm scale due to the lack of BAT implementation at the following stages. At the end of the storage, the levels of nitrogen kept in the slurry varied between 61 to 85% of the excreted amounts. After the spreading, under favorable conditions for volatilization, the residual nitrogen in the slurry represented 20 to 64% of the excreted nitrogen. Those results showed the interest to combine BAT at different stages of the production to keep the nitrogen in the slurry and improve by this way its recycling as shown by Petersen et al. (2007).

Acknowledgments

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ENTERIC METHANE EMISSIONS OF COWS AT GRAZING IN TWO CONTRASTED AND LOW INPUTS DAIRY GRASSLAND-BASED SYSTEMS

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Abstract: livestock contributes to the environmental impact of agriculture with emissions of greenhouse gases (GHG). Extensive systems with low milk production per cow are often disadvantaged when emissions are expressed in g per kg of milk, as well as low input systems based on grasslands diet and using low concentrate. In this context, a study was conducted to acquire specific references on methane emissions (CH_4) during the grazing season by measuring in vivo emissions of two dairy cows herds grazing pastures within two contrasted dairy grasslands based-systems: an extensive system (Bota) managed with permanent grasslands highly diversified with no concentrate given to cows and an ecologically intensive system (Pepi) conducted with old temporary grasslands and moderate use of mineral fertilization and concentrate. In 2014 at the experimental farm of INRA located in uplands area of central France, two groups of 6 Holstein dairy cows grazing in Pepi and in Bota systems were constituted. Individual measurements of enteric CH_4 emission using the SF6 technique and milk production were performed two folds, in June (P1) and in July (P2). Simulated bites were sampled at grazing at the two periods. In P1, CH_4 emission of Bota and Pepi cows, expressed either in daily emission or per milk production, were similar (respectively 402 g/d, 16 g/kg MY). In P2, CH_4 emissions of Bota cows tended to be higher than those of Pepi (400.3 vs 330.5 g/d). These values were included in the high range of emission found in the literature. The lack of significant difference between the two systems could be related to the weak amount of concentrate given to Pepi cows, to the similarity of the botanical family composition of the cows bites and finally to the low difference of milk production between the two systems at this grazing period.

Keywords: GHG, CH_4, mitigation strategy, grasslands.

EMISSÕES DE METANO ENTÉRICO DE VACAS NO PASTO EM DOIS SISTEMAS CONTRASTANTES DE PASTAGEM E DE BAIXO CONSUMO PARA ANIMAIS LEITEIROS

Resumo: a produção pecuária contribui para os impactos ambientais da agricultura com emissões de gases de efeito estufa (GEE). Os sistemas extensivos de baixa produção de leite por vaca são desfavorecidos quando as emissões são expressas em g por kg de leite, bem como os sistemas de baixo consumo baseados em dietas de pastagem e uso limitado de concentrado. Neste contexto, foi realizado um estudo para aquisição de referências específicas de emissões de metano (CH_4) na estação de pastejo, medindo in vivo as emissões de dois rebanhos de vacas leiteiras em pasto, baseado em dois sistemas de pastagem contrastantes: um sistema extensivo (Bota), manejado com pastagens permanentes altamente diversificadas e sem oferta de concentrado às vacas e um sistema intensivo ecológico (Pepi) conduzido com pastagens temporárias velhas e uso moderado de fertilização mineral e concentrado. Em 2014, na fazenda experimental do INRA situada no planalto da região central da França, foram constituídos dois grupos de seis vacas Holstein em pastagem, em sistemas Pepi e Bota. Medições individuais da emissão entérica de CH_4 (utilizando-se a técnica SF6) e da produção de leite foram realizadas duas vezes: em Junho (P1) e em Julho (P2). Amostras das pastagens (porções das plantas normalmente ingeridas pelas vacas) foram coletadas em ambos os períodos. Em P1, as emissões de CH_4 das vacas Bota e Pepi, expressas em emissões diárias ou por produção de leite, foram semelhantes (respectivamente 402,0 g/d, 16,0 g/kg MY). Em P2, as emissões de CH_4 tenderam a ser superiores nas vacas Bota em relação às Pepi (400,3 vs 330,5 g/d). Esses valores foram incluídos na gama alta de emissões encontrada na literatura. A ausência de diferença significativa entre os dois sistemas pode estar relacionada à pequena quantidade de concentrado ofertado às vacas Pepi, à semelhança da composição botânica das famílias de amostras de forragem e, finalmente, à baixa diferença de produção de leite entre os dois sistemas de pastejo.

Palavras-chave: GEE, CH_4, estratégias de mitigação, pastagens.

Introduction

It is now well known that domestic ruminant herds contribute highly to greenhouse gases (GHG) emissions and especially to methane emissions. In this context, the National Institute for Agricultural Research (INRA) implements environmental research and experiments in conjunction with animal production. However debate still exists about emission evaluation. Extensive system with low milk production per cow are often disadvantaged when the emission is expressed in g per kg of milk, as well as low input systems based on grasslands diet and using low concentrate. Indeed it is well known that concentrate decreases methane emissions (Sauvant et al., 2011). However, recent studies showed that legumes or forbs present in grasslands may mitigate enteric CH_4 production due to the presence of secondary compounds (Martin et al., 2010; Guyader et al., 2014).

In that context, the main objective of this study was to acquire specific references on CH_4 emissions measured in vivo of two dairy cows herds grazing pastures within two contrasted dairy grasslands based-systems: an extensive system (Bota) managed with permanent grasslands with a high level of botanical diversity, no mineral fertilization and no concentrate given to cows and an ecologically intensive system (Pepi) conducted with old temporary grasslands with low level of botanical diversity but high abundance of white clover in pastures, the use of concentrate and mineral N fertilization (Farruggia et al., 2014). We hypothesised lower CH_4 emission for Pepi cows, either in g per day or in g per kg milk due to the use of concentrate, the abundance of white clover in pasture and the higher milk production per cow.

Materials and methods

The two systems, Bota and Pepi, are included in a system experiment set up at INRA's Marcenat farm in an upland area of central France (45°15'N, 2°55'E; altitude 1135-1215 a.s.l.; annual rainfall 1.100 mm). This experiment, with two herds, one in each system, (24 animals, 12 Holstein and 12 Montbélliarde) allows us to study the interaction between the grazing management, the botanical composition of grassland, milk production and CH_4 emission at the system level.

Systems: the objective of both systems is to maximise the use of grass by basing herd management on spring calving and rotational grazing. Bota is a very extensive and completely autonomous system. It has a limited stocking rate (0.6 LU/ha) on permanent grassland with a high level of botanical diversity especially forbs diversity. Pepi system is more intensive and close to farming systems in upland area. It has a higher stocking rate (1.1 LU/ha) on old leys with moderate biodiversity. Bota has more plant species (190) than Pepi (111) and the dominant species are different between the two systems. At the implementation of the system experiment in 2010, the species encountered mostly in Bota were Agrostis capillaris (23% of all identified plants), Dactylis glomerata (15%), Trifolium repens (13%), Festuca rubra (11%) and Lolium perenne (8%) and in Pepi, Dactylis glomerata (48%). Other plants such as Trifolium repens and Festuca rubra were present but in small amounts (9%).

Animals: six dairy cows of each system herd were selected for this experiment, all of the Holstein breed. These cows were selected based on milk yield (MY), rank of lactation, age and body weight (BW). The cows in Bota group consisted of 3 multiparous (MY = 31.1 kg/d, BW = 584 kg) and of 3 primiparous (MY = 24.6 kg/d; BW = 567 kg). The Pepi group has 3 multiparous (MY = 30.5 kg/d; BW = 571 kg) and 3 primiparous (MY = 23.1 kg/d, BW= 501 kg) cows. Allocation in two groups was on 12th of May 2014 and Bota cows were lactating for 37 days on average and those of Pepi for 33 days. During the experiment Pepi cows received individually 3 kg/day of production concentrate while Bota cows were fed exclusively with grass.

Measurements and analyses: all measurements were performed in two experimental two-week periods: period 1 in June 2014 (P1) and period 2 in July 2014 (P2). Each period consisted of one week of adaptation and one-week measurement. Each group of cows of Bota and Pepi grazed a pasture of their grazing area in P1 period in June and were removed on the same pasture in July in P2 period. Measurements of enteric CH_4 were performed on each system using the SF6 tracer gas technique (Johnson; Johnson, 1994). The amount of milk produced and milk fat and protein contents were measured individually at each milking time. Body weight was measured at the beginning and at the end of each period. The eating behavior of grazing cows was assessed through the method of simulated bites, applied for each of the animals in P1 and P2 for two days. The concentrations of SF6 and CH_4 in the gas samples were a determined by chromatographic analysis (GC). The composition (leaf, stem on a DM basis) of the simulated bites was obtained by sorting 100 g of fresh weight at each period.

Results and discussion

Methane Emission: CH_4 emissions were not significantly different between the two groups of cows in P1 (402.9 vs. 401.7 g/d, P=0.99), but they tended to be higher in P2 for Bota group than for Pepi group (400.3 vs. 330.5 g/d, P=0.07, respectively) (Table 1).

Simulated bites: the botanical family composition of the simulated bites was not significantly different (P>0.05) between the two groups of cows. For both periods, cows selected on average bites composed of 83% of grasses, 11.5% of forbs and 4.1% of legumes regardless of the group (P<0.05). However, although the simulated bites of Bota cows were a mixture of forbs species, Taraxacum officinale was the highly dominant forb in the bites of the Pepi cows. The average proportions of forbs and legumes evolved between P1 and P2 (P<0.05) but not for grasses (83.5%). Thus, legumes proportions increased (2.6 vs 4.9%), whereas forbs proportions decreased (13.0 vs 10.4%).

Milk yield and milk composition: there was no significant difference in milk yield between the two groups, in P1 and in P2. Average milk production of Bota cows in P1 was 24.8 kg and dropped to 21.5 kg in P2 (P<0.001) and that of Pepi cows varied from 26.2 kg to 23.3 kg (P<0.001) (Table 1). For both systems, the average milk fat and milk protein content was 42.1 g/kg and 28.1 g/kg, respectively. Milk protein content significantly decreased (P<0.002) of 1.2 g/kg between P1 and P2. The body weight of Bota cows has increased between the two periods.

Table 1. CH_4 emissions (g/d) and CH_4/Milk Yield (g/kg), Milk yield and body weight of Bota and Pepi cows at P1 and P2 period.

Period	P1		P2			P value		
	Bota	Pepi	Bota	Pepi	s.e.m.	group	period	Gr x per.
CH_4 (g/d)	402.9	401.7	400.3	330.5	27.8	0.19	0.0029	0.0053
CH_4/Milk Yield (g/kg)	15.4	16.1	17.3	15.3	1.6	0.26	0.72	0.91
Milk Yield (kg/d)	24.8	26.2	21.5	23.3	1.4	0.44	<0.001	0.57
Body Weight (kg)	578	539	593	537	16.8	0.09	0.015	0.009

Our results on CH_4 emission expressed in g/d are consistent with the results of the meta-analysis of methane data for ruminants only fed with grass forages (Archimède et al., 2011; Eugène et al., 2014) but they are in the high range values. We have not observed the expected difference in CH_4 emission between the two groups of cows in term of daily emission per cow. The lack of significant difference could be related to the low amount of concentrate given to cows in Pepi system (3.0 kg of concentrate per day, i.e. 15% concentrate in the diet) and not sufficient generate a difference in CH_4 production between the 2 systems (Sauvant et al., 2011). Another hypothesis to explain the lack of difference of these daily emissions between the two groups of cows is the similarity of the botanical composition of the selected bites in terms of botanical family. Indeed, several studies have proved that plants rich in secondary compounds (tanins, saponins, terpene, and polyphenol) are able to mitigate enteric CH_4 production (Martin et al., 2010; Guyader et al., 2014). For example, Doreau et al. (2011) have shown that the introduction of legumes in the diet tends to reduce CH_4 emissions. Other New Zealanders studies showed that it was necessary that the diet contained more than 30% of legumes to observe a significant difference between treatments and control (Waghorn et al., 2006). In our study, proportions of legumes in the simulated bites were similar in the two groups of cows and probably not high enough to impact CH_4 emissions. We expected a higher abundance of white clover in Pepi plot, but this low percentage can be partly explained because measurements were made early in the season (% of white clover progresses over the grazing season) and secondly, by the existence of large inter-annual variations in white clover abundance (Loiseau et al., 2002). Compared to legumes, proportion of forbs in the simulated bites were slightly higher but also similar between the two groups. Although forb species composition was different between Bota and Pepi groups, the effect on CH_4 emission is still difficult to highlight in such in vivo conditions. Similarly, no difference in CH_4 emission (g/kg MY) was observed due to the fact that milk production was unexpectedly similar between the two groups of cows during the two experimental periods.

Conclusions

This study provides new references on CH_4 emissions for dairy cows grazing on permanent grassland without or with low levels of concentrate and. We did not validate our hypothesis, as cows of the extensive system (Bota) have produced similar CH_4 emission than the ecologically intensive system (Pepi) either in CH_4 per day or per kg milk yields. However, other measurements of CH_4 at several periods within a year (spring, autumn and winter) would be necessary to conclude on the impact of forage management on CH_4 emission at the farm scale.

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DICYANDIAMIDE (DCD) EFFICIENCY ON REDUCING NITROUS OXIDE EMISSION DURING SWINE MANURE COMPOSTING

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Abstract: the efficiency of dicyandiamide (DCD) on reducing the emission of the greenhouse gas N_2O as well as on retaining nitrogen as NH_4 in the biomass was assessed during the composting of swine manure. Three DCD dosages plus a testimony were evaluated: 0% (C), 0.27 % (I1), 0.56% (I2) and 1.07% (I3). Results have shown that in all DCD dosages tested there was a reduction on N_2O emission and an increment on nitrogen content (NH_4) in the compost. Throughout 20 days the treatment I3 showed the lowest N_2O-N emission varying from 0.28 to 42.38 mg N_2O-N/chamber/day; at the end of this experiment, the dosage that resulted in the compost with higher NO_3-N concentration was I2 (1,282.83 mg/kg) whereas the higher NH_3-N content was observed for I3 (1,948.48 mg/kg). Although these results are promisor, more studies are needed to establish the maximum dosage and reapplication routines considering the technical and economic aspects of this practice as well as its effect on soil.

Keywords: swine slurry, composting, GHG, dicyandiamide.

EFICIÊNCIA DA DICIANODIAMIDA (DCD) NA REDUÇÃO DA EMISSÃO DE ÓXIDO NITROSO DURANTE O PROCESSO DE COMPOSTAGEM DE DEJETOS DE SUÍNOS

Resumo: avaliou-se a eficiência do uso de dicianodiamida (DCD) na redução da emissão e na retenção do nitrogênio amoniacal (N-NH_4) durante o processo de compostagem de dejetos suínos. Utilizaram-se quatro diferentes tratamentos, que consistiram no uso de três diferentes doses de DCD: 0,27% (I1), 0,56% (I2) e 1,07% (I3), mais o tratamento controle (C). Os resultados demonstraram que a DCD nas doses utilizadas possui eficiência para redução da emissão de N_2O e no aumento do nitrogênio na forma de NH_4 no composto. O tratamento que apresentou menor emissão de nitrogênio na forma de N_2O foi o I3, com as emissões variando entre 0,28 a 42,38 mg N-N_2O/câmara/dia, cada reator com 16 kg de biomassa, durante 20 dias; ao final

do experimento, o tratamento que obteve maior concentração de N-NO_3 foi o I2 (1.282,53 mg/kg) e de N-NH_4 foi o I3 (1.948,48 mg/kg). Embora os resultados sejam promissores são necessários mais estudos para estabelecer o limite máximo e o tempo de reaplicação do aditivo no sistema para redução da emissão de N_2O sem prejuízos ao processo de compostagem, considerando ainda a viabilidade técnica e econômica do seu uso em escala de campo, bem como o seu efeito no solo.

Palavras-chave: dejetos suínos, compostagem, GEE, dicianodiamida.

Introduction

Confined Animal Feeding Operations (CAFO) is a production model that is encouraged by the pork meat industry however it favours the generation of high volumes of wastewater (manure). The correct management and disposal of waste from the facilities constitute important economic, social and environmental bottlenecks. Composting is an appropriate and cost-effective alternative for the treatment and subsequent disposal of swine manure, as it transforms swine manure into a solid composted organic fertilizer which permits exporting the surplus of waste and encourage the best use of its nutrients. On the other hand, during composting, there may be emissions of acid rain-promoting gases, mainly NH_3 and greenhouse gases, such as N_2O (Angnes et al., 2013; Zhong et al., 2013). Several studies have been conducted using composting additives to mitigate greenhouse gas emissions and nitrogen losses (NH_3, N_2O, NO_x), resulting in a richer compost produced with lower environmental impact (LUO et al., 2013). Among the evaluated additives, DCD has been shown to be efficient in controlling the emission of nitrogen gases (LUO et al., 2013), by inhibiting nitrification/denitrification reactions and consequently prevent the production of NO_x and N_2O.

The objective of this study was to evaluate the efficiency of dicyandiamide (DCD) as additive in the composting of pig slurry to reduce N_2O-N emission and increase the NH_4-N and NO_3 content in the compost. Therefore, three doses of DCD were tested and the evolution of the process was monitored during 20 days.

Materials and methods

The assessment was carried out in an experimental area of Embrapa Swine & Poultry, located in Concordia/SC, Brazil. The emission of N_2O from the pig slurry composting was measured during 20 days. The composting trials were conducted in tubular PVC reactors with V = 0.035 m^3. Samples of biomass from the reactors were collected weekly and analyzed for nitrite (NO_2), nitrate (NO_3) and ammonium (NH_4), according to standard methods (APHA; AWWA; WEF, 1999). The treatments were mounted in duplicate and consisted of three treatments and the control. Treatments consisted in loads of increasingly doses of DCD: 0% (C), 0.27% (I1), 0.56% (I2) and 1.07% (I3). The composting trials were prepared by mixing 20 kg of sawdust with 111 kg of the solid fraction of pig slurry obtained from a sieve (> 1 mm mesh). The biomass was turned twice a week.

Gas emission was daily measured during 10 minutes/reactor using a static chamber connected to a photoacoustic gas analyzer (INNOVA 1412). The gas concentration in the chamber, expressed as N-N_2O, was calculated by equation (1):

$$C_2 = \frac{(C_1 \times M) \times (P \times V)}{T \times R} \qquad (1)$$

Where C_2 is the gas concentration in mg/chamber, C1 is the gas concentration in ppm, M is the molar mass of the gas (g/mol), P is the atmospheric pressure (atm), T temperature (K) and R constant of the perfect gases (atm·L/K/mol). The gas flow (mg/chamber/day) was calculated from the equation of the linear equation: y= m × x + b. Where y is C_2 and x is the time in minutes.

Results and discussion

Figure 1 shows the average daily emissions given in mg N_2O-N/chamber/day per reactor throughout 20 days. As can be seen DCD had lower N_2O emission compared to the control (C). The treatment that presents higher efficiency on mitigating N_2O was I3, which had an average emission varying from 0.28 to 42.38 mg N_2O-N.chamber-1.day-1, while in the control the emission varied from 0.96 to 165 mg N_2O-N/chamber/day. It was noticed that the effect of DCD decreased over time, since the production of nitrate and the emission of nitrous oxide increased at the end of the assessment, which point to a possible need for reapply the product. Previous study using DCD amendment in swine slurry composting showed that N_2O emission increases after 15 to 24 days possibly due to temperature decrease and nitrification reaction (LUO et al., 2013).

Table 1 shows NH_4–N and NO_3-N content in the composts given in mg/kg in dry basis. At the end of the experiment, treatment I3 presented higher concentration of ammonium nitrogen (1,948.48 mg/kg) whether I2 had higher concentration of nitrate (1,282.53 mg/kg). Indeed both I3 and I2 showed the highest NH_4–N and NO_3–N content, respectively, throughout the whole experimental period. The higher NH_4-N content in I3 was expected, since DCD inhibits the conversion of ammonium into nitrite and subsequently into nitrate, therefore the nitrate formation is inversely proportional to DCD dosage and, consequently less nitrous oxide is emitted. Possibly the NO_3-N observed in treatment I2 resulted from the inactivation of DCD at the end of the assessment due to the high temperature of composting.

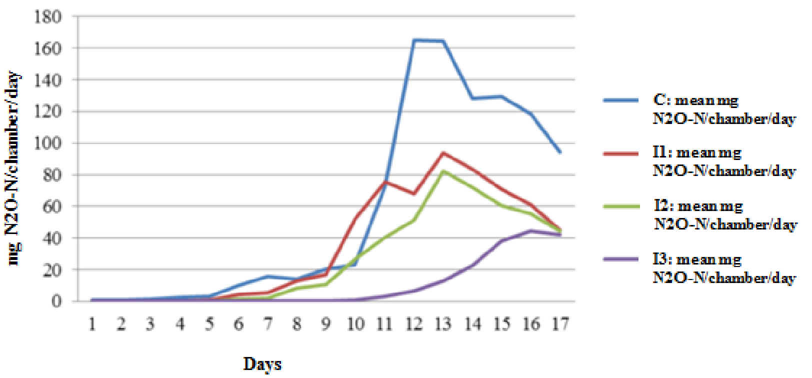

Figure 1. Average daily emission given in mg N_2O-N/chamber/day during swine slurry composting.

Table 1. NH_4 and NO_3 content in the composting materials throughout the treatment.

Time (day)	Control		I1		I2		I3	
	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N
	(mg/kg)							
1	3,671.64	0	4,288.79	0	4,523.01	0	3,993.47	0
3	5,212.08	0	5,150.10	0	5,466.28	0	5,542.10	0
5	5,722.59	106.23	5,944.43	108.28	5,767.36	66.56	5,935.65	13.41
8	1,982.14	624.36	1,833.19	502.41	2,677.69	438.18	4,047.43	199.47
11	995.79	1,016.61	1,681.44	706.21	1,885.09	607.52	2,394.39	467.66
14	389.51	966.17	2,166.24	888.49	2,058.82	1,098.78	1,982.44	741.17
17	273.61	750.95	1,525.61	1,175.65	1,806.16	1,282.53	1,948.48	660.85

Conclusions

Result showed that swine slurry composting led to N_2O emission which is a greenhouse gas with high global warming potential. DCD mitigates the emission of nitrous oxide and increases the ammonium nitrogen content in the compost. Although treatment I3 presented the best results, treatments I2 and I1 also showed some efficiency.

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Chapter IV

MEASURING METHODS

METHODOLOGY FOR DETERMINING THE EMISSIONS OF GREENHOUSE GAS AND AMMONIA IN COMPOSTING PROCESSES

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Abstract: this study presents adaptations in a methodology to calculate the emissions generated during swine slurry composting under Brazilian conditions. The method allows to quantify the loss of four important gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ammonia (NH_3). The research was carried out in the experimental field of Embrapa Swine & Poultry, located in Concórdia/SC, Brazil, where three composting piles were constructed with a volume of 2.52 m^3. The calculation method is based on two hypotheses proposed by Paillat et al. (2005): (a) significant nitrogen losses occur in the form of NH_3, N_2O and N_2 and (b) the carbon losses are mainly in the form of CO_2 and CH_4. Three ways of control were used: verification of the mass balances by sampling, verification by the balance of phosphorus and potassium and the verification of the gaseous emissions in global value by water balance. The results of the mass balance indicated an average error of 10% in the determination of the H_2O emissions as vapor form (difference between input and output), and also 10% for phosphorus, demonstrating the viability of the methodology used. The measured total flow of N in the form of gas as NH_3-N represented 78% of the emissions determined. With mass balance was possible to evaluate accurately the losses in the gaseous form of the elements C and N. Total emissions in the CO_2-C form accounted for approximately 96%.

Keywords: treatment, swine slurry, mass balance.

METODOLOGIA DE DETERMINAÇÃO DAS EMISSÕES DE GASES DE EFEITO ESTUFA E AMÔNIA EM PROCESSOS DE COMPOSTAGEM

Resumo: este trabalho apresenta adaptações de uma metodologia para cálculo das emissões geradas durante processos de compostagem de resíduos animais em condições brasileiras. O método permite quantificar a perda de quatro importantes gases: dióxido de carbono (CO_2), metano (CH_4), óxido nitroso (N_2O) e amônia (NH_3). A pesquisa foi realizada no campo experimental da Embrapa Swine & Poultry, localizada em Concórdia/SC, Brasil, onde foram construídas três leiras de compostagem para tratamento dos dejetos suínos com volume de 2,52 m^3. O método de cálculo baseia-se em duas hipóteses propostas por Paillat et al. (2005): (a) as perdas de nitrogênio importantes ocorrem sob a forma de NH_3, N_2O e N_2 e (b) as perdas de carbono são principalmente sob a forma de CO_2 e CH_4. Existem três formas de controle: verificação dos balanços de massa por amostragem, verificação por balanço de fósforo e potássio e a verificação das emissões gasosas em valor global pelo balanço de água. Os resultados do balanço de massa indicaram um erro médio de 10% na determinação das emissões de H_2O na forma de vapor (diferença entre a entrada e saída), demostrando a viabilidade da metodologia. O fluxo total medido de N na forma de gás como N-NH_3 representou 78% das emissões determinadas. Com o balanço de massa foi possível avaliar com precisão as perdas na forma gasosa dos elementos C e N. As emissões totais na forma de C-CO_2 representaram aproximadamente 96%.

Palavras-chave: dejetos suínos, tratamento, balanço de massa.

Introduction

During the composting process, as well as during the storage of the waste, nitrogen losses occur simultaneously contributing to potential gas emissions (e.g. NH_3 and N_2O) (Paillat et al., 2005; El Kader et al., 2007). Since the 1990s, research laboratories have intensified the development of measurement methods as well as the acquisition of references on the emission of gases in animal production and composting systems as well as the use of dynamic chambers (Fukumoto et al., 2003; Manios et al., 2005), and the use of static cameras (Szanto et al., 2005) or micrometeorological dispersion techniques (Lockyer, 1989). These methodologies vary in complexity, costs and analytical precision. In Brazil, the quantification of emissions or rates of greenhouse gas emissions in animal waste treatment systems has been intensively researched, recently. In addition, there are no standardized methods for collecting, measuring, and calculating such components resulting in significant variability. Discussions promoted by scientific forums on analytical methodologies for gaseous emissions showed consensus that there is an ideal method that should allow the automation of analyzes, with the measurements being taken continuously in situ. This last condition is essential for a better understanding of complex environmental/management/emissions interactions, which is fundamental for predicting emission, transport and destination (modeling) mechanisms. Sampling, in this case, is usually obtained through so-called dynamic systems, in which time monitoring of the gas emission rate is carried out, and it is possible to measure the influence of factors such as time of day, temperature, humidity and the type of management applied, among others. The main advantages of dynamic systems are the minimization of interference caused by high concentration and pressure. The objective of this work was to evaluate the applicability of the methodology proposed by Paillat et al. (2005) to determine carbon dioxide, methane, nitrous oxide, and ammonia in swine slurry composting pile.

Materials and methods

The swine slurry composting experiments were conducted for 35 days inside a polyethylene greenhouse located at Embrapa Swine & Poultry (Concordia/SC, Brazil: 27 180 4600 S, 54 590 1600 W). Triplicates of composting piles were prepared inside wood boxes with the following dimensions: 2.1 1.5 0.8 m (L W H). To achieve a final ratio of 7.9 L of slurry (SL) for kg of wood shavings (WS), fresh SL was mixed with 300 kg of WS in a total of six applications distributed over time (days): 727 L (1), 724 L (8), 217 L (16), 215 L (17), 247 L(22), 252 L (30). To promote aeration, the compost pile was manually mixed on days 4, 11, 14, 18, 21, 24, 28, and 32. The leachate produced during the process was collected and reintroduced onto the piles. A transparent PVC chamber measuring 12 m^3 was built over each composting pile to collect CO_2, CH_4, N_2O, NH_3 and water vapor emissions.

Mass balance: samples of SL, WS and compost material (approximately 1.0 kg) were collected on days 4, 8, 18, 21, 28, and 35 for physical–chemical characterization. Non-volatile P inputs (WS + SL) and recovery on compost samples was used to check the mass balance within the piles.

Calculating water losses: in order to perform this calculation it was necessary to know the concentrations of water that entered and left the chamber where the composting piles were located. Thus for the water was calculated its loss from the mass of substrate (sub) and swine slurry (dej) and their respective concentrations of water and the quantity percolated. In Equation 1 an example of the calculation performed to predict the water loss of the biomass during the composting process is presented.

$$H_2O\ loss = H_2O_{in}\ \Sigma((H_2O_{sub} x M_{sub}) + (H_2O_{dej}\ x\ M_{dej})) - H_2O_{out}\ \Sigma(H_2O_{comp} x M_{comp}) + H_2O_{perc}) \quad (1)$$

Calculation of the mass concentration of the emitted gases: the gases (CO_2, CH_4, N_2O, and NH_3) were measured using the INNOVA 1412 photoacoustic meter. These gas concentrations were recorded by the equipment in parts per million-volume (ppm-v). It is necessary to use the perfect gas law considering the air temperature of 20 °C to convert the volume of gas measured by mass of gas per kg of moist air using the Equation (2).

$$C_i^m = C_i^v \times \frac{M_{mol}}{V_m} \times \frac{M_m}{M_{mol}} \quad (2)$$

Where C_{mi} is the equivalent concentration of C or N of the gases (mg/m^3), measured at time t (CH_4-C, CO_2-C, NH_3-N, N_2O-N); C_{vi} is the ppm-v concentration of the gas in question (equivalent to ml/m^3 being m^{-3} adopted per unit time as a function of gas flow (m^{-3}/h^1)); M_m is the equivalent molecular mass of nitrogen and carbon of the considered gas (Ex: CO_2 = 12 CH_4 = 12, NH_3 = 14, N_2O = 28 g of N/mol^1); M_{mol} is the molar mass of each gas molecule (Ex: CO_2 = 44, CH_4 = 16, NH_3 = 17, N_2O = 44). V_m is the molar volume in L/mol^1, corresponding to the molecular mass of a gas perfect for a pressure (P) and air temperature 20 °C (T).

Calculation of air flow and gas concentration differences: in the calculation of emissions, gaseous emissions are deducted from the flow of air exiting the chamber, the volumetric mass of the air and the mass concentration in N or C. To determine the emission flow, was utilized the calculation recommended by Robin et al. (2006):

$$\emptyset = Q_{air} \times \rho_i \times (C_i^m - C_e^m) \tag{3}$$

Where Ø is the emission of gas in g/h of dry air estimated from the air flow, gas concentration and volumetric mass of dry air; Q_{air} is the flow, ie the volume of air in m^3/h taken from the composting environment, according to the formula Q = A x V, where A is the area and V the velocity of the air in the PVC pipe at the exit of the composting line; ρ_i is the volumetric mass of air leaving the installation in kg dry air/m^3.

Results and discussion

The mass balance was determined from the quantities of the elements that entered in the composting system in the form of N, C and P, and the quantities of these elements that were retained in the biomass. After default calculation, the value was compared to the amounts of the loss element in the gas form, allowing the verification of the gas monitoring method accuracy, besides identifying the representation of each gaseous form in the total amount of the lost element. In this work we find nitrogen element loss of about 4.7 kg (Table 1). From the amount of lost N sampled by the analyzer, N_2O represented 6.60% and NH_3, 93.4%. The water balance showed a reduction of 54.75% in the total amount of water between the entrance and the exit in the biomass in the composting system. The water vapor measured in the form of gas represents 89.77% of the total water loss that entered the biomass. The difference between the observed water loss and the water emission measured was 10.22%. For phosphorus, used as an element to verify the balance error, the difference between the mass that entered the process and the concentration in the final compound was 8%.

Table 1. Total emissions of carbon and nitrogen and validation of data by mass balance.

Element	Measured emission (kg)	Mass balance (default, kg)
Carbon	80.96	90.95
Nitrogen	1.21	4.75[1]
Water	1,221.55	1,360.67

[1]40-80% of this value corresponds to molecular nitrogen (N_2).

Conclusions

The measured total flow of N in the form of gas as NH_3-N represented 78% of emissions determined. With mass balance was possible to evaluate accurately the losses in the gaseous form of the elements C and N. Total emissions in the CO_2-C form accounted for approximately 96%.

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PECUS Network and Embrapa Swine & Poultry.

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ELECTRONIC NOSE: AN ALTERNATIVE FOR MEASURING AND ASSESSING LIVESTOCK AND POULTRY FARM ODORS

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Abstract: high odorants concentrations from animal husbandry could affect the animals and workers health and cause nuisance to neighbors. This paper presents some electronic systems for odorant measurements, which can be used to assess the impact of livestock and poultry farm odors. Moreover, in this work is described the development of an electronic nose prototype, which allows to perform some measurements of odors patterns in swine or chicken facilities. This system can also be applied to specific gaseous compounds, like ammonia (NH_3) and carbon dioxide (CO_2), commons in these animal husbandry scenarios. The prototype is based on MOS gas sensors and a free hardware/software Arduino platform, allowing the system to be reconfigurable and low cost. Odor profiles for quantitative and qualitative analyses of gaseous compounds were obtained by the automatic gas delivery system and sensor array. Correlations of output data linked to dynamic olfactometry, gases detectors or gas chromatography technique provide broad and robust results for odors analyses.

Keywords: electronic nose, gases and odors measurement, swine odors, chicken odors.

O NARIZ ELETRÔNICO: UMA ALTERNATIVA PARA A MEDIÇÃO E AVALIAÇÃO DE ODORES NA AGROINDÚSTRIA

Resumo: os odorantes produzidos pela criação de animais, quando atingir elevados níveis de concentração podem prejudicar a saúde dos animais e trabalhadores, além de causar desconforto à vizinhança. Neste contexto, o atual trabalho apresenta alguns sistemas para medição de gases que podem ser usados na avaliação do impacto odorante na agroindústria. Dentro desses instrumentos, se descreve com maior ênfase o desenvolvimento de um protótipo de nariz eletrônico, que pode ser projetado para realizar medições e avaliações de padrões odorantes no processo de criação suína e avícola. Com este sistema, também podem ser medidos compostos como amônia (NH_3) e dióxido de carbono (CO_2), predominantes nesse ambiente. O protótipo está baseado em sensores MOS para gases e uma plataforma de hardware/software livre com um microcontrolador Arduino Mega 2560, o que permite que o sistema seja reconfigurável e de um custo moderado. Através de uma linha de transporte automática de fluidos e das medições com os sensores, se obtém os pulsos odorantes, ricos em informação transitória e estacionária, para as análises quantitativas e qualitativas dos compostos gasosos. O protótipo apresentado também pode ser útil quando se correlacionam seus resultados com outras técnicas analíticas como a olfatometria dinâmica e cromatografia gasosa.

Palavras-chave: nariz eletrônico, medição de gases e odores, odores na agroindústria.

Introduction

Meat production is an important activity for Brazilian economy and more specifically for Santa Catarina State. Treatment of farm waste and manure from chicken and swine facilities influences directly in the animal's quality of life, and consequently in the quality of meat. It can be note that emissions of certain chemical compounds, like ammonia or hydrogen sulfide, can be toxics and these could injure both animals and employees. In addition, odors emission from livestock cause nuisance in the neighbors and frequent complaints. Malodors from these sources can also generate stress, anger and others psychological disturbs (Liu et al., 2014).

There are some typical instruments to quantify gases and odors concentration as gases detectors and gases analysers. The more complex gas chromatograph coupled to mass spectrometers (GC-MS) to identify gaseous compounds and the traditional olfactometer for odor concentrations, are others instruments useful for these tasks (Powers, 2004). Modern devices, so called electronic noses (e-nose), are a new kind of instrument for odorants assessment that could be employed. The e-nose, in a simple way, mimics the mammalian olfactory system in terms of sensory response and information processing (Arshak et al., 2004). These instruments mainly contain an array of sensors with cross sensitivities, and an appropriate patterns recognition system capable of recognising simple or complex odors (Gardner; Bartlett, 1994). It should be remarked that e-noses involve gases and odors analyses, feature that distinguish this instrument regarding the rest of devices. E-noses allow in-situ and real-time monitoring simultaneously, as well as trend analyses from odorant samples. In addition, the measurement process can be automated and reconfigurable. Moreover, the e-nose can operates under aggressive environments for long time periods and it is non-samples destructive instrument (Stetter; Penrose, 2002). These devices are based on chemical sensors and computational tools, thus, they have low maintenance costs. There are different e-noses for multiple applications, however, some of these options are restricted to use in laboratory tests, designed to specific applications and also some of these are commercially available with high costs (Moreno et al., 2009).

To select or to develop an instrument for gases/odors measurements it is taking to account the specific application, odorants features, researcher experience, device performance, research budget. Even so, in some cases it is also relevant to correlate outputs from different instruments. This integration usually provides more detailed and encompassed outcomes (Sohn et al., 2008; de Melo Lisboa et al., 2009; Abdullah et al., 2012).

This study presents an e-nose prototype as feasible and embraced option, which can be applied to assess gaseous compounds from livestock. The system is based on a gas sensor array and a free reconfigurable hardware/software platform, which also has low costs regarding to GC-MS, olfactometers, and commercial e-noses. This approach allows performing qualitative and quantitative analyses to specifics gases and odors. In addition, the results by the e-nose prototype could be correlated with others instruments.

Materials and methods

Typically, the measurement process by an e-nose comprises some stages or functional blocks, Figure 1.

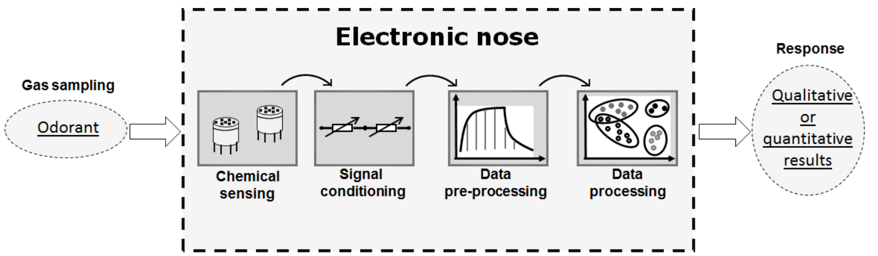

Figure 1. Typical funcional blocks of an e-nose.

At the first stage, chemical sensing, the odorants or reference gas are led through fluid transportation line to the measuring chamber, which comprises the sensor array. Therefore, the odorants molecules cause changes in physical or/and chemical properties of sensing material, like conductivity (Arshak et al., 2004). Consequently, electrical signals which correspond to the gas concentrations variations can be obtained. The fluid transportation line could be manual or automatic, although the second option generally is more fast and accurate. In this case, the system usually contains valves and a vacuum pump. By this support, the so-called odorant pulses are performed. These profiles are electrical signals, voltage or electric conductance vs time, associated to qualitative and quantitative chemical information about compound under analysis. Then, to achieve the pulses, a sequence in four stages should be executed: baseline (to conduct the reference gas through the system), rising transient (to conduct the odorant), steady state (to maintain the odorant inside the measuring chamber) and recovery transient (to conduct the reference gas again). Afterward, by the signal conditioning stage, the odorant pulse can be amplified or filtered. Usually, an analog-to-digital converter (ADC), that capture and codify the electrical signals to the corresponding binary numbers is used. This conversion to the digital domain allows the data management and results representation in a simple way. Through the data pre-processing stage, several mathematical tools are applied in order to improve the signals quality and to extract relevant information. For this purpose baseline correction, filtering, scaling normalization, among others methods can be employed. Moreover, the use of several techniques for feature extraction and feature selection is also required. At the last stage, data are processed to achieve qualitative or quantitative results from odorants samples. More specifically, pattern recognition algorithms and regression models could be performed, for instance, Artificial Neural Network (ANN), Principal Component Analysis (PCA), Clustering Analysis (CA), Fuzzy Logic, and others. Hence, certain odor patterns could be established and concentrations levels of gaseous compounds can be measured.

E-noses to assess livestock odors: there are different electronic noses projects to assess livestock and poultry farm gases/odors (Sohn et al., 2008; Pan; Simon, 2009; Elazari-Volcani; Yanai, 2010; Abdullah et al., 2012; Yanai; Elazari-Volcani, 2012; Romain et al., 2013; Muresan; Muresan, 2013). Romain et al. (2013), for example, reports an e-nose coupled to an olfactometer to study odorants emissions from swine farms. This system provides extended results by the correlations between human sense and an array of non-specific gas sensors. Sohn et al. (2008) also relates an e-nose with interesting features, which includes gases analyses of samples from chicken facilities. Nevertheless, the instrument uses three measuring chambers and a complex delivery system, which increases the costs and cause poor reproducibility. At the same time, the e-nose developed by Pan and Simon (2009) is flexible, with high components integration and also it presents small dimensions. Furthermore, odor data collected from different sample points are transmitted via wireless network to a computer server. The system developed by Elazari-Volcani and Yunai (2010) so-called "vitality meter for health monitoring of anonymous animals in livestock groups" and another reported by Yanai and Elazari-Volcani (2012) are instruments with wide scope. These devices can estimate animals health by odors measurements, visual and acoustic signals, and handling others information that called vitality. Although, regarding to gaseous compounds, these systems only use a NH_3 detector and this procedure do not support odors patterns recognition. The instrument proposed by Muresan and Muresan (2013) also presents high integration of hardware components.

Typically, the instruments used to gases analyses from swine or chicken facilities in Brazil, only perform measurements of specific gases that not provide information about odors emissions. It is known, that from concentration of individual compounds it not possible to estimate, with acceptable fitting, the global odor concentration (Guoliang et al, 2008). Besides, several devices employed in Brazilian scenario, use commercial platforms with high costs and low flexibility.

E-nose prototype: Figure 2 shows the e-nose block diagram. It includes: (1) a charcoal filter to obtain the baseline from ambient air; (2, 4, 7) three solenoid valves; (3) a measuring chamber, that contains three MOS sensors from Figaro manufacturer and a temperature sensor LM-335; (5) a Fisatom vacuum pump; (6) a sampling chamber; (8) a control card for handling the valves and the pump; (9) an electronic conditioning board with a voltage divider circuit for each gas sensor; (10) a board based on Arduino Mega 2560 to acquire, processing and to send the data to the Personal Computer, it also manages the control card; and (11) a Personal Computer commanded by a Virtual Instrument (VI) application software.

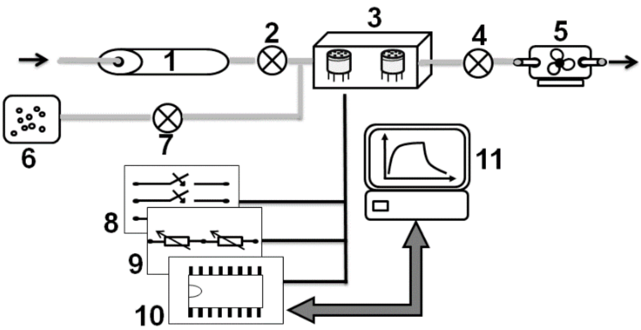

Figura 2. Block diagram of the e-nose prototype.

Conclusions

E-nose prototype presented in this study can be applied to identify livestock and poultry farm odors. The use of commercial sensors and a free hardware/software platform leads to moderate costs of development and maintenance, regarding to traditional instruments. Reconfigurable features as well as high flexibility allow adjusting the system to new scenarios and upgrade procedures, for example to NH_3 and CO_2 measurements. Odor profiles for quantitative and qualitative analyses of gases/odors can be obtained. To achieve more robust results, the e-nose output can be correlated to gases detectors, GC-MS, dynamic olfactometry, and other devices. Therefore, this e-nose prototype could be an interesting choice to assess gases and odors from swine and poultry facilities.

Acknowledgments

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ESTIMATED EMISSIONS FROM MANURE MANAGEMENT: WHICH CALCULATION METHOD SHOULD WE CHOOSE?

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Abstract: the aim of this paper was to perform a sensitivity analysis of the different calculation methods to estimate the emissions of CH_4 and N_2O applied to a case study of manure management in swine production. We evaluate the emissions from biodigester, composting and slurry tanks. The calculation models used to estimate the emissions were: GES'TIM; static mass flow model; three variations of the IPCC guide; and the proposed model by Cherubini et al. (2015). Our paper shows that the results are highly sensitive to the chosen calculation model in a way that the uncertainty overlaps the results of each scenario.

Keywords: emissions, calculation methods, manure management, CH_4, N_2O.

ESTIMATIVA DE EMISSÕES NO MANEJO DE DEJETOS: QUAL MÉTODO DE CÁLCULO ESCOLHER?

Resumo: o objetivo deste artigo foi realizar uma análise de sensibilidade de diferentes métodos de cálculos para estimar as emissões de CH_4 e N_2O, usando como estudo de caso o manejo de dejetos suínos. Os sistemas avaliados foram biodigestor, compostagem e o cenário de esterqueiras. Os modelos de cálculo usados para as estimativas de emissões foram: GES'TIM; Modelo de fluxo de massa estático; três variações do guia do IPCC; e modelo proposto por Cherubini et al (2015). O artigo demonstra que os resultados são altamente sensíveis ao modelo de cálculo utilizado, sendo que a incerteza acaba por sobrepor os resultados de cada cenário.

Palavras-chave: emissões, métodos de cálculos, manejo de dejetos, CH_4, N_2O.

Introduction

The growing concern of societies and governments with the sustainability of anthropogenic activities is pressing the industries to quantify and reduce their impacts on climate change. On the other hand, the disclosure of the greenhouse gas inventory emissions becomes an opportunity to companies to increase their competitiveness by demonstrating transparency and environmental and social commitment.

Life cycle assessment (LCA) is one the environmental tools used by companies to quantity their emissions and has been becoming a common practice in the industrial sector. LCA projects are based on a detailed quantification of inputs and outputs of a product's life cycle, which allows a strict control of environmental aspects identifying inefficiencies through the value chain. Therefore, besides being used to build a life cycle inventory, LCA is also used to scenario evaluation and to indicate alternatives to reduce product's emissions.

The life cycle inventory phase of an LCA project it is not always an easy task and may requires the need of calculation methods, mainly to quantify the output emissions. Thus, methods to estimate (or calculation guides) are fundamental in LCA, specially, to evaluate agricultural products, in which the lack of knowledge about methane and nitrous oxide emissions represent a major difficulty; for these cases the use of IPCC guide is very common practice. However, the use of different calculation methods and different emission factors can generate different results (Cherubini et al., 2014; 2015). Recent studies showed that the use of various methods to estimate the emissions from slurry tanks can lead to an amplitude of 1,331 kg CO_2 eq. (Cherubini et al., 2014), and that the variation of the emission factors in the same calculation model for the comparison of manure management of swine production (emission factors of the composting model) can show a difference up to 700 kg CO_2 eq. (Cherubini et al., 2015).

In this sense, the aim of this paper was to perform a sensitivity analysis of the different calculation methods to estimate the emissions of methane (CH_4) and nitrous oxide (N_2O) applied to a case study of manure management in swine production.

Materials and methods

The comparison was performed using the LCA methodology. The manure management systems evaluated were: biodigestor, composting and slurry tanks from Cherubini et al. (2014).

The functional unit (FU) was the manure management generated to produce 1 ton of swine live weight. The system boundaries were set from the manure ex-house until its application on field as organic fertilizer. The characterization factor for CH_4 and N_2O was according to the Intergovernmental Panel Climate Change (2007), of 25 and 298 kg of CO_2 eq. respectively.

The calculation models used to estimate the emissions were: (i) GES'TIM (Deltour et al. 2009); (ii) static mass flow model of Hutchings et al. (2013); three variations of the IPCC guide (Intergovernmental Panel on Climate Change, 2006): (iii) IPCC with European default parameters, IPCC (DF-EU); (iv) IPCC with Latin American default parameters, IPCC (DF-LA); (v) IPCC with parameters adjustments to represent Brazilian reality, IPCC (BR); and (vi) the proposed model by Cherubini et al. (2015), which is based on the equations of the model from Hutchings et al. (2013), Hamelin et al. (2011) and from Intergovernmental Panel Climate Change (2006), called Baseline. The input parameters of the calculation methods related to the amount and manure composition are described in Cherubini et al. (2014).

Results and discussion

Table 1 presents the results comparison for the biodigestor and composting scenarios.

The results showed that, regardless of the manure management scenario, the IPCC (DF-LA) calculation model presents the highest CO_2 eq. emissions, while the lowest emissions were obtained using the model described by Hutchings et al. (2013).

Analyzing the values from Table 1 for biodigester emissions, the contributions by emission type and the stage when they occur, it can be noticed that the calculations models with default parameters of IPCC (e.g IPCC (DF-EU) and IPCC (DF-LA)) has a high influence in the emissions of N_2O (27.9%-67.8% of the total).

The main responsible for the emissions of CO_2 eq. in biodigester is the CH_4 in all models, although in IPCC (DF-LA) the participation of methane is significantly lower when compared with the other calculation options.

Highest emissions of N_2O in the IPCC guideline occur due to the high values considered for excreted N, mainly for the model that uses the default input parameters to Latin America. The high emission of indirect N_2O (volatilization of NH_3+NO_x) occurs due to the emission factors considered by IPCC (i.e. 48%). Meanwhile the high emission of CH_4 in IPCC (DF-EU) when compared to the others IPCC scenarios can be explained by the high methane producing capacity per m^3 of manure (Intergovernmental Panel on Climate Change, 2006).

Table 1. Results per FU (percentage of the contribution per column are given in the parentheses).

Emissions by source/model	GES'TIM	Hutchings et al (2013)	IPCC (DF-EU)	IPCC (DF-LA)	IPCC (BR)	Baseline
Slurry tanks see Cherubini et al. (2014)						
Biodigester						
Emissions in storage (kg CO_2 eq.)						
CH_4	288.4 (61.4)	278.1 (96.2)	937.1 (72.1)	517.9 (32.2)	278.1 (71.2)	300.8 (93.4)
Direct N_2O	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Indirect N_2O (NH_3-N+NO_x-N)	n.c[1]	n.c	142.6 (11.0)	429.2 (26.7)	4.9 (1.3)	1.7 (0.5)
Emissions in field (kg CO_2 eq.)						
CH_4	0.1 (0.0)	n.c	n.c	n.c	n.c	n.c
Direct N_2O	181.6 (38.6)	11.1 (3.8)	154.5 (11.9)	465.0 (28.9)	72.7 (18.6)	11.1 (3.4)
Indirect N_2O (NH_3+NO_x)	n.c	n.c	30.9 (2.4)	93.0 (5.8)	13.9 (3.6)	4.6 (1.4)
Indirect N_2O (NO_3 leaching)	n.c	n.c	34.8 (2.7)	104.6 (6.5)	21.0 (5.4)	3.9 (1.2)
Total	470.1 (100.0)	289.2 (100.0)	1,299.7 (100.0)	1,609.7 (100.0)	390.7 (100.0)	322.1 (100.0)
Composting						
Emissions in storage (kg CO_2 eq.)						
CH_4	72.9 (18.2)	39.5 (37.8)	133.2 (17.2)	73.6 (3.7)	39.5 (2.6)	39.5 (35.0)
Direct N_2O	260.5 (64.9)	46.2 (44.1)	297.1 (38.3)	864.2 (44.5)	953.2 (62.6)	45.9 (40.6)
Indirect N_2O (NH_3-N+NO_x-N)	n.c[1]	n.c	133.7 (17.2)	402.4 (20.0)	28.4 (1.9)	2.8 (2.5)
Emissions in field (kg CO_2 eq.)						
CH_4	0.0 (0.0)	n.c	n.c	n.c	n.c	n.c
Direct N_2O	67.9 (16.9)	18.9 (18.1)	148.6 (19.2)	447.1 (22.3)	423.1 (27.8)	19.0 (16.8)
Indirect N_2O (NH_3+NO_x)	n.c	n.c	29.7 (3.8)	89.4 (4.5)	29.0 (1.9)	3.7 (3.2)
Indirect N_2O (NO_3 leaching)	n.c	n.c	33.4 (4.3)	100.6 (5.0)	49.4 (3.2)	2.1 (1.9)
Total	401.3 (100.0)	104.7 (100.0)	775.7 (100.0)	2,007.3 (100.0)	1,522.6 (100.0)	113.0 (100.0)

[1]Not considered.

Analyzing the models to estimate the emission in manure composting, the values show the same trend in which the emissions of N_2O in the manure storage is the main responsible by the CO_2 eq. emissions. However, the models showed a high variability between the scenario with the lowest emission 104.7 kg of CO_2 eq. (i.e. Hutchings et al. 2013) and the one with the highest emission 2007.3 kg of CO_2 eq. (IPCC (DF-LA)). These outcomes were also influenced by the highest amount of excreted N considered in the IPCC models.

Comparing the outcomes from different models to estimate the emissions from biodigester and composting to the ones for slurry tanks (CherubinI et al. 2014), it can be noticed that the results uncertainty due to the chosen calculation model overlaps the results of each scenario (Figure 1).

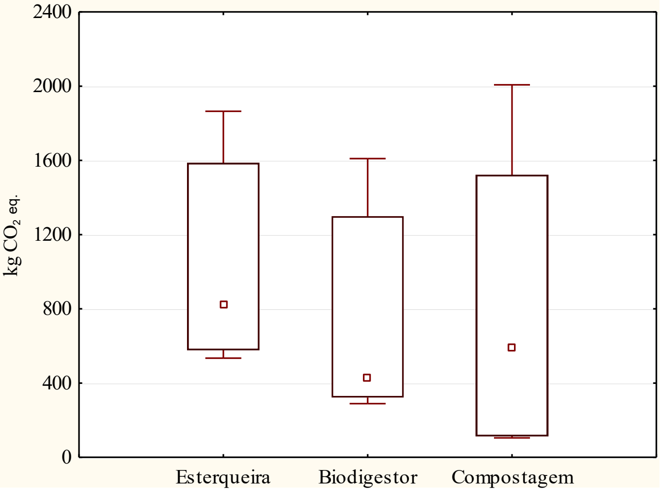

Figure 1. Models comparison to estimate the CH_4 and N_2O emissions in manure management.

Conclusions

This article shows that the results are highly sensitivity to the chosen calculation model. The methods used to estimate the emissions for manure management by composting were the ones that showed the highest range between the values with lowest and highest emission of CO_2 eq.

Analyzing the models and based on our judgment, the calculation procedure used in Hutchings et al. (2013) seemed to be preferable because it allows to considerate the biodigestion effects in the manure composition (mineralization of organic N). The results of this paper also showed the importance of increase the studies in this field due to the uncertainty in the results comparison.

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QUANTIFICATION OF AMMONIA VOLATILIZATION IN OPEN BROILER HOUSES USING METHODOLOGY OF STATIC SEMI-OPEN CHAMBER COLLECTOR

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Abstract: ammonia (NH_3) is considered the most important toxic pollutant found inside poultry farms. The aim of this research was to adapt and validate a simple technique to determine the flow of ammonia in poultry deep-litter, commonly used in broiler production. The experiment was carried in ESALQ's experimental aviary and assessed the NH_3 emissions of (i) shavings + excreta, (ii) excreta, (iii) clean shavings and (iv) poultry reared on concrete floor as control. The losses of nitrogen in the form of ammonia were quantified according to the methodology developed by Araújo et al. (2009) and Jantalia et al. (2012) called SALE collector, a simple and viable method, widely used in soil and fertilizer research, adapted for poultry housing. The loss of nitrogen in the form of ammonia was increasing for treatments with excreta throughout the rearing period. The adaptation was practical and the SALE collector was consistent with the results.

Keywords: NH_3 collector, poultry, ambience, animal waste, shavings.

QUANTIFICAÇÃO DA VOLATILIZAÇÃO DE AMÔNIA NA PRODUÇÃO DE FRANGO DE CORTE USANDO A METODOLOGIA DE CÂMARA SEMIABERTA ESTÁTICA

Resumo: a ammonia (NH_3) é considerada o poluente tóxico mais importante encontrado dentro das granjas avícolas. O objetivo desta pesquisa foi adaptar e validar uma técnica simples para determinar o fluxo de amônia em cama sobreposta de aves, comumente utilizada na produção de aves. O experimento foi realizado no aviário experimental da ESALQ e avaliou as emissões de NH_3 de (i) aparas + excreta, (ii) excreta, (iii) aparas limpas e (iv) aves criadas em piso de concreto como controle. As perdas de nitrogênio na forma de amônia foram quantificadas de acordo com a metodologia desenvolvida por Araújo et al. (2009) e Jantalia et al. (2012) – designada coletor SALE, sendo um método simples e viável amplamente utilizado em solos e pesquisas de fertilização, adaptado para o alojamento de aves. As perdas de nitrogênio na forma de amônia aumentaram para os tratamentos com excreta ao longo do seu ciclo de produção. A adaptação foi prática e o coletor SALE foi consistente com os resultados.

Palavras-chave: NH_3, coletor, aves, ambiência, resíduo animal, aparas.

Introduction

The demands of the consumer market, both external and internal, about production and quality of product of animal origin has led producers around the world to adopt increasingly sustainable and environmentally accepted techniques from the point of view of constant climate change.

Studies that quantify the gas emissions in the poultry production chain are still very limited (Calvet et al., 2011). In addition to uncertainties related to the methodology to be adopted, there is no consensus on the operational limits of inventories and specific emission factors for different climatic conditions and animal handling.

Of all the emission sources of broiler chicken farming, those from the use of litter (mixture of excreta, feathers of chickens, feed and material used on the floor of the sheds to serve as a poultry litter) are the least information. Some authors identify poultry as a major producer of ammonia (Guiziou; Béline, 2005; Singh et al., 2009), its intensity depends on the moisture, pH and/or compaction of the litter and its volatilization is related to the future deposition of N on the soil surface and by nitrification to form nitrous oxide (N_2O). The most gas measurement methodologies in production systems of broilers are in closed facilities, however, the challenge of this work was to adapt a simple technique to open environments.

The aim of this research was to adapt and validate a simple technique to determine the flow of ammonia in poultry deep-litter, commonly used in broiler production.

Materials and methods

The present research was carried in the experimental poultry facility of the Department of Animal Sciences – Non-ruminant sector, at the College of Agriculture “Luiz de Queiroz” (ESALQ-USP), Piracicaba-SP, Brazil. The experiment was conducted during the period from May to June 2014 (winter), a total of 42 days of rearing. But in this paper are the results of up to 21 days of creation.

Features of the facility: the shed used has northwest-southeast orientation, which is 15 meters long and 8 meters wide, with 3 meters of ceilings, being completely screened and provided with side curtains, covered with clay tiles, floor covered in concrete and masonry side walls with 0.6 meters in height. The shed has little thermal insulation, which is commonly observed in Brazil and South America, therefore only natural ventilation was available during the experimental phase.

Description of the study (experimental): the treatments evaluated were: (i) shavings + excreta, (ii) excreta, (iii) clean shavings and (iii) poultry reared on concrete floors as control. For evaluating the treatments (i) and (ii) the broilers were raised in 0.5 m cages (Figure 1a), whose density was 4 chickens per cage (mixed lot). In the control group, 25 birds were used in 3 m^2 (Figure 1b).

Volatilization of ammonia: the losses of nitrogen in the form of ammonia were quantified according to the methodology developed by Araújo et al. (2009) and Jantalia et al. (2012) called SALE collector, a simple and viable method, widely used in soil and fertilizer research. The necessary adaptation to perform this study in poultry litter was the preparation of a support of zinc plate (Figure 1).

Figure 1. Addapted collectors of ammonia (SALE) in the cage (a) and on the floor of the shed (b).

For this technique, the NH_3 is captured by a semi-open chamber made from a plastic bottle (PET) with a capacity of 2.0 L and an area of 0.008 m^2. To retain the NH_3, sheets of polyurethane foams (0.017 g/cm^3) 0.3 cm thick, 2.5 cm wide and 25 cm long were used, which are soaked in 10 ml of H_2SO_4 solution, 1 mol/dm^3 + glycerin (2% v/v) and suspended vertically with the aid of a rigid wire inside the pet.

The foam samples were collected at three-day intervals and the loss of N-NH_3 was determined by the technique of flow injection analysis (FIA). Temperature, moisture and pH were evaluated over the experiment.

Results and discussion

The average temperature observed inside the shed during the rearing period was 22.7 ºC, with a minimum of 18.6 ºC and a maximum of 27.7 ºC. The mean moisture content was 65%, ranging from 51 to 78%.

The values of moisture and pH of the poultry litter [(i) shavings + excreta, (ii) excreta, (iii) shavings and (iv) control (chicken raised on the concrete floor)] during 21 days of broiler chicken farming are presented, respectively, in the Figures 2 and 3. The moisture content was increasing for all the treatments studied, although for shavings this content remained constant over the period of rearing.

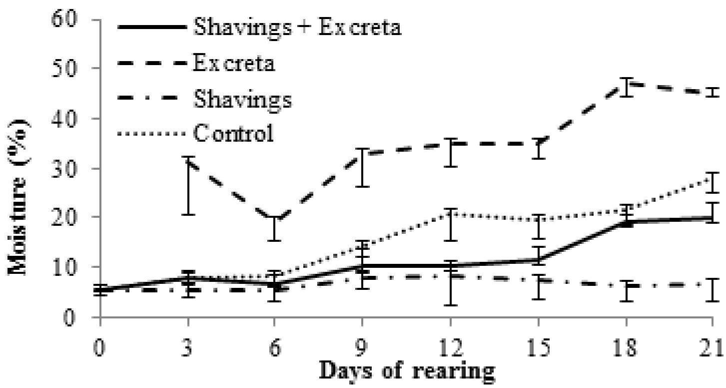

Figure 2. Moisture of the treatments under study during the rearing period.

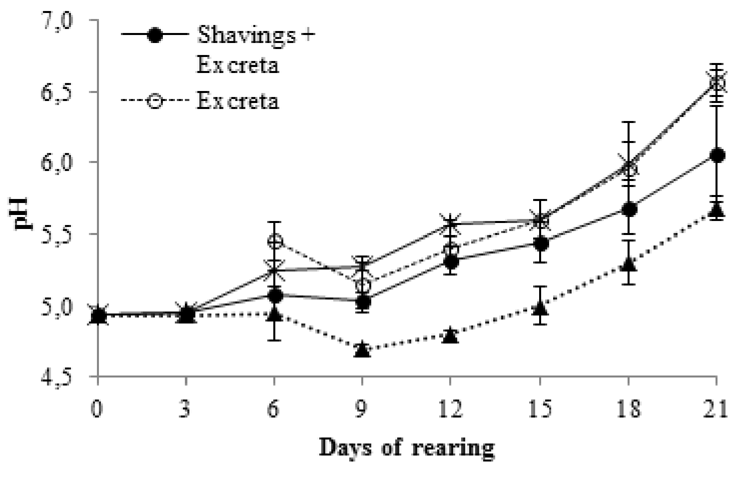

Figure 3. N-NH_3 volatilization rate and standard error of the average in 21 days of broiler breading estimated b the adapted SALE collector.

For the chickens reared on the concrete floor (control) the moisture was higher than in the cages, probably due to higher water waste and feed in the litter.

The mean values of shavings + excreta pH varied from 4.9 to 6.7 over the rearing period. In excreta treatment the pH values initially were 5.5 to 6.6 in the last week of creation, as represented in Figure 3.

N-NH_3 loss of nitrogen was increased for excreta treatments over the rearing period (Figure 4).

The accumulated emissions of N-NH_3 observed in Figure 4 corresponded to an ammonia loss of 0.86 and 0.84 g/m^2 for shavings + excreta and excreta, respectively. In control treatment the ammonia loss was 0.42 g/m^2 and 0.083 g/m^2 for shavings.

As indicated in the literature, the increase in the rate of ammonia emissions over time was probably due to the accumulation of broilers' excrements and microbial growth in poultry litter (Groot Koerkamp; Ueng, 1997). Miles et al. (2008) observed that as a consequence of the greater amount of NH_4+ in the litter, also losses of NH_3 by volatilization to the underlying air increase with the age of the poultries.

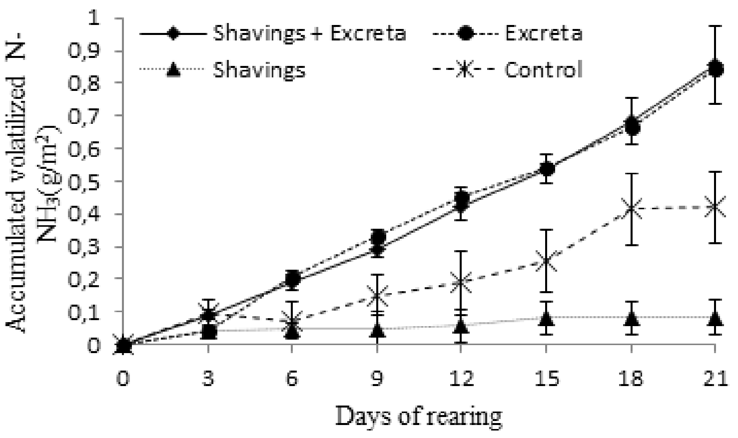

Figure 4. Cumulative volatilized N-NH_3 and standard error of the average in 21 days of broiler chicken farming, estimated by the adapted SALE collector.

The results for the treatment with litter (shavings + excreta) or without litter (excreta) were similar, although excreta presented higher moisture. The loss of N-NH_3 in the control was lower compared to the treatments of the cages, even presenting higher moisture in the litter. Ammonia when formed in the litter can be found in two ways: as NH_3 (no charge) or as ammonium (NH_4+) depending on the pH of the bed. The higher the pH, the lower the conversion of NH_3 (volatile) to NH_4+ (non-volatile). As the accumulation of fecal material occurs in deep-litter the microbial population responsible for the mineralization of organic matter and uric acid transformation increases, increasing its NH_4+ content.

Conclusions

The preliminary results, using the adapted SALE collector, indicated a growing of NH_3 emission throughout the farming of chicken. The reported method seems to be efficient and low cost for ammonia volatilization in studies in open poultry houses. Other investigations are necessary to confirm this result.

Acknowledgments

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Chapter V

INVENTORIES
ENVIRONMENTAL EVALUATION

PERFORMANCE EVALUATION OF AN ODOR CONTROL DEVICE ON THE REDUCTION OF A RENDERING PLANT IMPACT

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Abstract: the odorant impact is one of the main environmental complaints to public authorities. Among odor-producing sources, animal rendering plants are known for their high degree of impact. To avoid the occurrence of odorant nuisance events, pollution control equipment's are commonly employed in these industries. However, a reduction in odorant emission rate does not necessarily mean the full resolution of this type of impact. In the case of odors, perception governs the occurrence or not of impact due to a series of factors: topography, meteorology, emission temperature, among others. From the odorant impact assessment tools, dispersion modeling is an interesting option because it allows estimation of spatial amplitude, frequency and intensity of impact. This work aimed to evaluate the influence of an odor treatment system (gas scrubber and biofilter) in reducing the impact caused by the emission of odors from an animal rendering plant. For this, odor dispersion modeling through the model AERMOD was used.

Keywords: dispersion modeling, odors, rendering plants, AERMOD.

AVALIAÇÃO DO DESEMPENHO DE UM SISTEMA DE TRATAMENTO DE GASES NA REDUÇÃO DO IMPACTO ODORANTE DE UMA FÁBRICA DE RAÇÃO

Resumo: o impacto odorante constitui umas das principais reclamações ambientais perante o poder público. Dentre as fontes emissoras de odores, as indústrias produtoras de ração animal são conhecidas por seu elevado grau de impacto. Para evitar a ocorrência de eventos de incômodo odorante, equipamentos de controle de poluição são comumente empregados nessas indústrias. Entretanto, uma redução na taxa de emissão odorante não necessariamente significa a resolução plena desse tipo de impacto. No caso dos odores, a percepção rege a ocorrência ou não de impacto em função de uma série de fatores: topografia, meteorologia, temperatura de emissão, dentre outros. Das ferramentas de avaliação de impacto odorante, a modelagem de dispersão é uma opção interessante por possibilitar a estimativa da amplitude espacial, frequência e intensidade do impacto. Esse trabalho visou avaliar a influência de um sistema de tratamento de odores (lavador de gases e biofiltro) na redução do impacto ocasionado pela emissão de odores de uma fábrica de ração. Para isto utilizou-se a modelagem de dispersão de odores através do modelo AERMOD.

Palavras-chave: modelagem de dispersão, odores, indústria de ração, AERMOD.

Introduction

Odorant pollution has been gaining importance in industry and agriculture (Defoer et al., 2002). Odor impacts caused by animal food production, through the processing of by-products of the agro-food industry, are one of the main problems of the sector, being considered among the most intense and least tolerated by the population (Fukuyama et al., 1986; European Union, 2005; Anet et al. 2013). The production process of this industry consists in subjecting the raw materials (carcasses, bones, feathers, among others) to high temperatures and pressure, to eliminate microorganisms and remove moisture. Afterwards, the fat and protein are separated, and then processed to obtain the final characteristics of the product (European Union, 2005; Shareefdeen et al., 2005). The emission of odors occurs mainly by the degradation and fermentation of the raw material (through its storage), and by the thermal deterioration and drying (during the production). Volatile organic compounds are the main atmospheric contaminants emitted and include organic sulfides, disulfides, aldehydes of 4 to 7 carbons, trimethylamine, 4-carbon amines, ammonia, quinoline, dimethylpyrazine, organic acids of 3 to 6 carbons, mercaptans and hydrogen sulfide (Fukuyama et al., 1986; United States Environmental Protection Agency, 1995; Anet et al., 2013). Some of these substances are insoluble in water and others become volatile when in contact with water vapor. They are perceptible at low concentrations, causing impacts even far away from the producing unit (Fukuyama et al, 1986).

Minimizing the annoyance caused by odors can be achieved by changing design parameters or by using end of pipe devices. The efficiency of these interventions can be evaluated by techniques such as physicochemical analysis and sensory analysis using a jury panel (olfactometry) (Defoer et al., 2002). Olfactometry is the standard method for measuring odors in a number of countries, but it has the limitation of being financially and temporally expensive. In addition, the measurement of odor in ambient air can reach the same noise levels as the measuring equipment (olfactometer). The most common way to evaluate the odorant impact is by calculating the dispersion using a mathematical model.

The mathematic dispersion model is basically a set of equations programmed in a computer for the purpose of estimating the concentrations of pollutants emitted by sources at a receiving site. In other words, it simulates the physics and chemistry that govern the transport, dispersion and transformation of pollutants in the atmosphere (New Zealand, 2004). Therefore, it is possible to predict the concentrations of a pollutant in a given point or region during a desired period (Melo Lisboa et al., 1997; Kawano, 2003). In order to be able to use this technique, it is necessary to have meteorological, topographic and measurement data of odor emission rate (O.U./h). This rate is obtained by multiplying the concentration, in O.U./m^3, by the gas flow of an odorant source. The results of dispersion modeling can provide important information about the perception of odors and also allow comparison with legislation standards (Nicell, 2009).

The proposed work is to evaluate the influence of a gas treatment system, consisting of a gas scrubber and a biofilter, in the odorant impact caused by a rendering plant.

Materials and methods

Dynamic olfactometry was used to determine emission odorant concentration. Samples were collected through direct and superficial sampling - before and after the odor treatment system. Direct sampling was used at a point located before the treatment system, using a stainless steel diaphragm pump to avoid adsorbing odors. A cooling system was used to condense the excess of moisture (Melo Lisboa et al., 2010). To collect samples after the biofilter, a superficial sampling hood was used, which respected the parameters established by the German standard VDI 3477/2004. Flow velocity in the hood was determined by the use of a thermo-anemometer. The emission concentration was then determined according to Equation 1.

$$c_t = \frac{C_1 \times v_1 + C_2 \times v_2 + \ldots + C_n \times v_n}{n + v_m} \qquad (1)$$

Where: Ct is the average emission concentration (O.U./m^3); Cn is the odor concentration found in the subarea n (O.U./m^3); vn is the flow velocity found in subarea n (m/s); n is the number of subareas.

The samples were collected in duplicate, two for the upstream point and six for the downstream point (the biofilter was divided into three subareas). To determine the emission rate, the flow was measured at the upstream point according to the USEPA Method 2 (Determination of stack gas velocity and volumetric flow rate), and Brazilian standards ABNT NBR 11.967 and NBR 10.701.

Regarding the dispersion modeling, USEPA's recommended software, AERMOD, was used. Five years of meteorological data from Brazilian National Institute of Meteorology (INMET) were used. For relief input data, SRTM mission of the United States National Aeronautics and Space Administration (NASA) information were used. Land cover data were obtained from the United States Geological Survey (USGS), LANDSAT satellite images. A square grid of receptors measuring 5 km each side, centered in the emitting plant and with spacing of 100 meters was used.

As impact assessment methodology, the Good practices guide for odors assessment and management in New Zealand (New Zealand, 2003) was considered. A value of u equal to 0.25 was used for the peak-to-mean calculation (Schauberger et al., 2012).

Results and discussion

The evaluation of odor removal efficiency of the control system resulted in a value of 89%. In the modeling, the maximum concentration registered in the receptors dropped from 1,320 O.U/m^3 to 20 O.U/m^3, a reduction of 98.5% in the highest concentration observed. Figure 1 shows the impact reduction by comparing the plumes of the maximum concentrations obtained in modeling the scenarios considering or not the removal of odors and the frequency of the impacting events (odor concentration greater than 5 O.U/m^3).

As it can be seen in the figures on the right, even with the treatment system implementation, the odors emitted by the factory would continue to have significant impacts, but at lower intensities and frequencies than the other scenario.

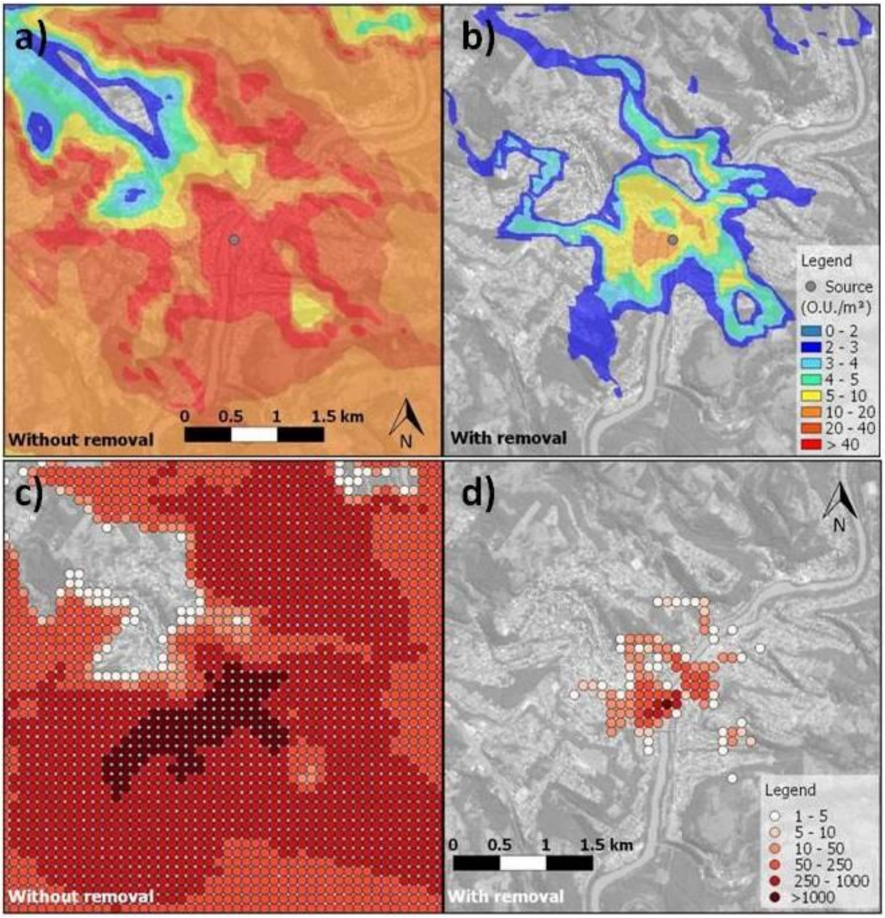

Figure 1. Comparison of maximum concentration plumes (in O.U/m^3) and frequency of impacting events (in number of events). (a) maximum concentrations not considering treatment; (b) maximum concentrations considering odor removal system; (c) frequency (in five years) of events above 5 O.U/m^3 not considering odor abatement (d) frequency (in five years) of events above 5 U.O./m^3 considering odor removal.

Conclusions

This article showed that the gas treatment system significantly reduced the impact caused by odors emitted by the evaluated industry. There was a considerable reduction in the maximum concentrations, as well as the amplitude of the impacted area and the frequency on which the odors would be perceived. In addition, the utility of dispersion modeling of pollutants as a tool for strategy and management of environmental impacts related to odorant activities was exemplified. Modeling facilitates the verification of impact reduction even before the implementation of control measures and emission reduction of pollutants. Through it, it is also possible to verify the rate of abatement required so that there would be no significant impact on the receptors. In this case, an odor removal of more than 89% would be required, since the impact of the industry was still evident in the vicinity of the rendering plant.

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RETORDED SHALE ADDITION IN AUTOMATED PIG SLURRY COMPOSTING TO MITIGATE AMMONIA VOLATILIZATION

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Abstract: the pig farming in southern Brazil generates large amount of slurry (DLS), which cause strong environmental problems with its incorrect use. The alternative for solving this problem is the composting of DLS, transforming this slurry in a solid matrix that can be more easily managed. On the other hand the disadvantage of composting is a large loss of nitrogen (N) by ammonia (NH_3) volatilization which causes loss of agronomic value. The alternative to mitigate this problem is to use retorted shale (XR) which has characteristics like high porosity and low pH, factors that can reduce the losses by NH_3 volatilization. Therefore, is being realized in an automated composting platform, an experiment that aims to evaluate the efficiency of the use of XR in mitigating such problems. Until this date, 90 days of experiment, the XR was reduced by approximately 40% the emissions of NH_3, being efficient in reducing losses by volatilization of NH_3.

Keywords: NH_3, mitigate strategy, slurry treatment, pig farming.

ADIÇÃO DE XISTO RETORTADO PARA MITIGAÇÃO DA VOLATILIZAÇÃO DE AMÔNIA EM COMPOSTAGEM AUTOMATIZADA DE DEJETOS LÍQUIDOS DE SUÍNOS

Resumo: a suinocultura na região sul do Brasil gera grande volume de dejetos líquidos (DLS), que acabam causando grandes problemas ambientais quando usados incorretamente. Uma alternativa para a solução deste problema é a compostagem de DLS, transformando este dejeto em uma matriz sólida que pode ser mais facilmente manejada. No entanto, o inconveniente da compostagem é a grande perda de nitrogênio (N) por volatilização de amônia (NH_3), fazendo com que este composto perca valor agronômico. Uma alternativa para mitigar este problema é a utilização Xisto Retortado (XR), que possui características como alta porosidade e baixo pH, fatores que podem diminuir as perdas de N por volatilização de NH_3. Para tanto, está sendo realizado, em plataforma de compostagem automatizada, um experimento que tem como principal objetivo avaliar a eficiência da utilização do XR na mitigação de tais problemas. Até o momento, 90 dias de experimento, o XR reduziu em, aproximadamente, 40% as emissões de NH_3, mostrando-se eficiente na redução das perdas de N por volatilização de NH_3.

Palavras-chave: NH_3, estratégia de mitigação, tratamento de dejetos, suinocultura.

ENVIRONMENTAL IMPACTS AT AGRICULTURAL BIOGAS PLANTS AND ITS CONTROL MEASURES

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Abstract: teffluents and wastes from agricultural activities are known for their high environmental impact potential in water, soil and air contamination. An important alternative treatment for those is the biodigestion system, which can provide value to the waste through the generation of by-products such biogas and fertilizers. It is outlined in Brazil the necessity of renewable energy sources diversification to promote the sustainable development. Along with the incentive of insertion of biogas plants, there is the necessity to identify the environmental impacts from this activity to reach a good and fitted operation to the environmental legislation. In this article are introduced typical environmental impacts of biogas plant as well its mitigation measures.

Keywords: biogas, agricultural activities, environmental impact, control measures.

IMPACTOS AMBIENTAIS EM PLANTAS DE BIOGÁS DE ATIVIDADES AGROPECUÁRIAS E MEDIDAS DE CONTROLE

Resumo: os efluentes e dejetos gerados em atividades agropecuárias são conhecidos por seu elevado potencial de impacto ambiental, seja na contaminação das águas, solo ou ar. Uma alternativa importante de tratamento desse material é o sistema de biodigestão, que pode agregar valor ao rejeito através da geração de subprodutos como o biogás e fertilizantes. Destaca-se no país a necessidade da diversificação de fontes renováveis de energia para subsidiar o desenvolvimento sustentável. Junto ao incentivo da inserção de plantas de aproveitamento de biogás, existe a necessidade de identificar os impactos ambientais decorrentes dessa atividade de forma a permitir uma operação segura e adequada à legislação ambiental. Nesse artigo são apresentados impactos ambientais típicos de plantas de biogás, bem como as medidas mitigadoras associadas.

Palavras-chave: biogás, atividades agropecuárias, impacto ambiental, medidas de controle.

Introduction

Biogas generation systems are known for their efficient and strategic potential in combating several environmental problems in agriculture. The implantation of these systems could lead not only to the reduction of greenhouse emissions by the replacement of fossil fuels, but also to indirect benefits derived from the change in the handling of manure and crop wastes (Michel et al., 2010). Nevertheless, the biogas plant operation requires a set of procedures and by-products monitoring to assure it not becoming a pollution source. This article highlights and reviews environmental impacts in biogas plants linked to agricultural activities, theirs sources and control measures indicated in the literature.

Literature references

Impacts classification: in the process of biogas production, environmental impacts from plant operation or from its by-products can be grouped in (Seganfredo, 1999; Ministry for the Environment of New Zeland, 2003):

a) **Atmospheric impacts:** at impacts related to the air pollution, the more common is linked to the odour emissions. It can be originated from feedstock transport, storage and reception (in case of bad packing), or in anaerobic digestion processes when there are leakages in the biogas generation structure.
b) **Surface and groundwater impacts:** inappropriate digestate disposal (fertilizers) on soil can lead to surface and groundwater quality deterioration because to the high levels of nutrients. When it is not controlled and assimilated by the cultivation, they can reach water resources.
c) **Soil impacts:** they are related to the nutrient saturation when there is excessive and uncontrolled digestate disposal from biogas plant.

Biogas and plant operation: the appropriate operation is a crucial point to ensure its efficiency as in the biogas generation quality as in the environmental impacts prevention. The biogas plants malfunction and, accordingly, bigger probability to trigger impacts could be related to the following factors (Bensah; Brew-Hammond, 2010):

a) Feedstock unavailability/insufficiency (manure, remnants of agricultural production, organic effluents, etc.);
b) Failure of storage biogas compartments;
c) Lack of maintenance;
d) Lack of technical operational knowledge;
e) Gas leakage.

These factors should be foreseen and combated through: a good implementation plant project; proper planning to assure inputs and biogas and digestate consumers; constant monitoring and qualified operation of the unit.

Environmental impact control: it is directly connected to the correct plant operation. According with Djatkov et al. (2012), an efficient biogas plant holds the following pattern:

a) **Optimized energy consumes:** plants that operate with maximum energy use from biogas (in gas, electrical or thermal form) show good operational structure and process control.
b) **Proper chemical, technical and biological conditions to the maximum biogas generation:** the operational control is essential to ensure a satisfactory biogas and its by-products generation. The more environmental controls are applied in the operation plant, more environmental impacts are avoided.
c) **Environmental programs:** periodic system maintenance along with an operation control made by qualified labour and impacts monitoring through environmental programs are items that aim the impact mitigation at processes occurring in biogas plants.
d) **Financial feedback to the plant owner:** the capital generation from a biogas plant activity is an incentive to its implantation, maintenance and continuous improvement.

A plant that meets the previous requirements, which are directly linked it selves, certainly holds a good operational and control structure, decreasing the probability of air, soil and water pollution. A proper unit operation with control process, the fidelity to the environmental programs and the equipment's maintenance are guidelines to reach environmental impacts prevention of biogas plants activities.

Biogas use incentive: this is seen like a tool for controlling environmental impacts from biogas plants. When the government is interested for the technology, it looks for technical capacitation of strategic institutions in the energy and environmental domains besides the regulation of biogas production and use, leaving the process less vulnerable to bad designed projects without the proper environmental controls.

A study done in 2010 at biogas plants installed in Ghana concluded that digestate is not used like fertilizer and most of the plants discharge their effluents near green areas or in rainwater drainage network. There is expectancy in the country that the incentive with ranchers and farmers aiming biogas plants implantation will encourage the correct digestate disposal, using it in agriculture and then reducing environmental concerns and the dependency of imported organic fertilizers.

Similarly, in Brazil actions of incentive for the biogas technology incorporation in organic waste and effluent treatment has begun. The Ministry of Cities along with Germany government within the German Agency for International Cooperation – GIZ had been developed the project called "Brazil-Germany Project to Promote the Use of Biogas in Brazil – PROBIOGÁS (acronym in Portuguese)" that aims to amplify the biogas use in Brazil. The cooperation acts mainly in two areas: the protection and sustainable use of natural resources and the energy efficiency adding renewable resource in the energetic Brazilian matrix. This initiative covers the study, development and dissemination of actions directed related to basic sanitation and agriculture (Brasil, 2015).

In addition to the question of the generation of energy by biogas, the incentive to reuse the wastes generated in agricultural activities meets the requirements of federal Brazilian law nº 12.305/2010 (establishes the Brazilian policy of solid wastes), which restricts that it should only be sent to the landfill the wastes that cannot be reused or recycled in any way, the so-called "rejects". This restriction makes it fundamental to search for new treatment alternatives that guarantee a better use of waste considering the technical, social, economic and environmental aspects (Brasil, 2010).

Conclusions

Biogas technology should be increasingly used in agricultural activities due to its generation potential and the government incentive. Plants need to be well planned, implemented and operated to ensure maximum prevention of environmental impacts. It is in the interest of both government and entrepreneurs that technology establishes itself as an alternative source of energy generation. In addition, the system is configured as a solution for the treatment of highly polluting effluents and waste generated in agricultural activities. Since well-operated and controlled, biogas plants are a great alternative to combine energy, economic, social and environmental gain.

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Chapter VI

POSTERS

STUDIES APPLIED ON EVALUATION OF ODOURS EMITTED FROM LIVESTOCK ACTIVITIES

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Abstract: livestock activities have characteristic biological odours. In the case that these odours emissions are uncontrolled or/and very close to a community, it may result in complaints of the enterprise. This article presents some methodologies that help detect, diagnose and scale out odourant impacts of livestock activities in order to control and mitigate the negative effects of these emissions.

Keywords: odours, livestock activities, impact.

ESTUDOS APLICADOS NA AVALIAÇÃO DE ODORES EM ATIVIDADES AGROPECUÁRIAS

Resumo: as atividades agropecuárias possuem odores biológicos característicos. As emissões desses odores, quando não controladas ou quando muito próximas a uma comunidade, podem resultar em reclamações e denúncias ao empreendimento. Nesse artigo são apresentadas algumas metodologias que auxiliam a detectar, diagnosticar e dimensionar os impactos odorantes advindos de atividades agropecuárias com o objetivo de controlar e mitigar os efeitos negativos dessas emissões.

Palavras-chave: odores, atividades agropecuárias, impacto.

Introduction

One of the most well-known impacts of livestock activities is the emission of odours. Typical sources of emission are: animal husbandry, fertirrigation, slaughterhouses, rendering plants and composting. Usually the problems are associated to (Department for Environment Food and Rural Affairs – UK, 2010):

a) Proximity of sensitive development, e.g. housing;
b) Material exposed during loading and unloading vehicles, e.g. not operating in an odour controlled area;
c) Poor dispersion of odours during early morning and evening;
d) Waste management on-site, building & odour control system design, ancillary operations;

e) Inadequate maintenance of odour control systems.

In this context, knowledge of tools that help prevent, contain and mitigate adverse effects of odourant emissions is important for the agricultural sector. In the article, parameters that influence the perception of the odours and the methodologies and evaluations to diagnose and control these emissions are discussed.

Revision

The evaluation and control methodologies that can be applied to estimate and scale out odourant impact depend on the primary identification of influence factors of odour perception. Following, the way that odours are perceived and studies applied to determine the extent and importance of impacts are presented.

Perception of odours: according to Nicell (2009) the level of nuisance associated to an odour depends on its frequency of occurrence, intensity, duration, offensiveness (character) and location of the odourant event. These parameters are known as the FIDOL parameters (Table 1).

Table 1. Description of FIDOL parameters.

Parameter	Meaning
Frequency	The amount of time that individuals are exposed to the odour
Intensity	How strong the odour is
Duration	How long a particular event last
Offensiveness	Is related to the odours hedonic tone, which can be pleasant, neutral or unpleasant
Location	Land use and the nature of anthropic activities on the vicinities of the odour source

Different combinations of these factors may result in adverse effects. For example, odourant events may occur at a particular site in a rare or frequent manner, over short or long periods. The way that people are exposed to odour defines the importance of impact. Depending on the severity of the odourant event, a single occurrence may be enough to consider that a significant adverse effect happened. However, there may be situations where the duration of the event is greater and the impact on the neighborhood is significantly lower, so that to be considered an adverse effect, the frequency of events would need to be greater. (New Zealand Ministry of the Environment, 2003).

High levels of background odour present in an area can make people insensible to a specific odour, and the addition of other similar odours may not be noticeable. However, there are occurrences where cumulative effects of an additional odour may turn the odour unacceptable. The effect depends primarily on the nature of the odours and where they are occurring. In rural areas, for example, odours originated from agricultural activities tend to have greater acceptance than odours from chemical industries or other sources less characteristic of the environment (Gostelow et al., 2001).

Odour evaluation: as stated by Nicell (2009), there are two possible approaches to perform odourant impact assessment at a receptor. The first is through direct measurement of the nuisance in the impacted site. The second is to characterize the source and then predict the impact caused by it in its surroundings, through mathematical dispersion models. The flow chart in Figure 1 shows the possible ways to measure odours.

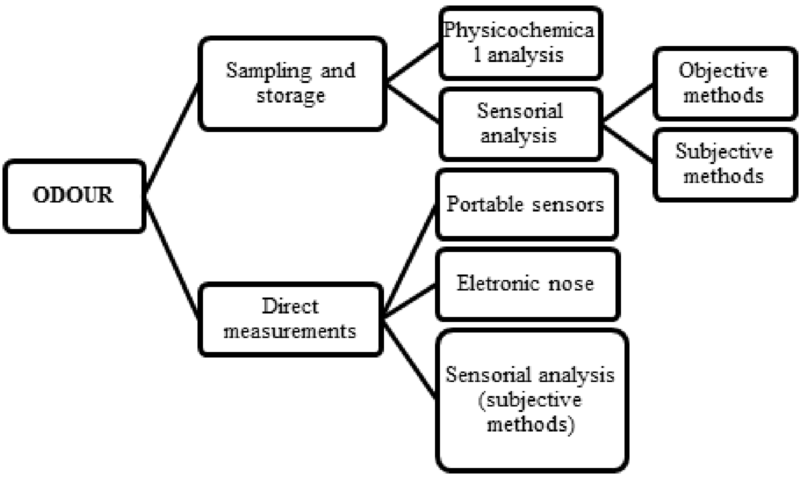

Figure 1. Methods to quantify and qualify odours on the environment.

The following methodologies are usually applied to identify odourant impacts (Mcginley; Mgginley, 1998; New Zealand Ministry of the Environment, 2003).

Surveys: allow to identify sources that, according to the community, contribute to the impact on the neighborhood. They are indicated only in areas where there is sufficient population density to generate statistically significant results. In areas with low population density, odour diaries and modeling studies are preferred methods for assessing odour impacts. This instrument directly measures the extent of recurrent adverse effects of odours in a neighborhood.

Odour dispersion modeling: is a tool used to predict the concentration of an odour downwind of its source using a computer software. Modeling input data include emission characteristics, terrain height, local weather conditions, receptor locations, and odour emission rates. It is one of the only assessing tools that can predict the potential effects of a new odour-emitting activity.

Odor diaries: is a tool used by people in affected communities to record the daily odour exposure. It may be useful to determine the particular conditions in which people are affected by odour from a single source or from various sources. The resulting data can be used to calculate the percentage of time (hours/year) in which people are exposed to odours of a specific source, as well as the intensity and typical character of the impacts.

Odour impact control measures: design and operating practices can prevent and minimize odour problems in livestock activities. There are technologies that can be used to reduce odour throughout the production process.

Table 2 presents the most common pollution control equipment's with a brief description of their application on odour abatement (Mcginley; Mcginley, 1998; New Zealand Ministry of the Environment, 2003; Nicell, 2009).

Table 2. Equipment's for odor control.

Parameter	Meaning
Incinerators	Incineration performs the degradation of odourant compounds through thermal oxidation of these into carbon dioxide (CO_2) and water. It is best applied to emissions containing organic compounds
Biofilters	Biofiltration occurs when organic contaminants in a gas stream pass through a bed of adsorbent material. In this procedure the odourant compounds are adsorbed on the surface of the material, where they are degraded by the microorganisms. It is a great alternative for emissions with livestock activities characteristics
Gas scrubbers	Gas scrubbers designed for a specific activity can achieve a removal efficiency of 99% for certain contaminants. A disadvantage of these systems is the production of liquid waste, which requires treatment for reuse or disposal
Adsorbing systems	Well-designed adsorption equipment can achieve 95-98% efficiency for VOC in concentrations ranging from 500 to 2,000 ppm
Dilution and dispersion	Ideal dilution and dispersion are usually achieved through stack height and emission parameters. The stack should be designed to ensure adequate height in relation to neighboring buildings, and this requires a dispersion modeling study
Neutralizing compounds and masking agents	It consists in the addition of compounds, to the gas stream, that transform or neutralize the odour character of the emission

In addition of control technologies, preventive measures should be considered to avoid odourant impact. In some cases, such measures avoid or reduce the need of end of pipe controls. Process monitoring allows preventive actions to be taken. Hereafter are some key steps (New Zealand Ministry of the Environment, 2003):

a) Select or change raw materials to reduce odours (e.g. improve raw material quality for rendering);
b) Ensure that odour sources are properly sealed and control equipment is accessible for cleaning;
c) Monitor the operating conditions of the processes that interfere on odour emissions and adopt the conditions in which the lowest rate is observed. The monitoring parameters are those observed in the control of the control device efficiency (e.g. dissolved oxygen in aerobic ponds or humidity and temperature in biofilters);
d) Implement a preventive maintenance program to minimize equipment failures and the need to interrupt processes;
e) Guiding employees on the importance of compliance with good management practices to achieve enterprise environmental compliance;
f) Operations that may have odourant impacts should be conducted on days when the weather has favorable dispersion conditions (avoid emissions at night and early in the morning, consider wind direction in sensitive areas, avoid emissions on hot days).

Conclusions

In studies of odourant impact derived from livestock activities it is necessary to identify the nature of the odour, its frequency, duration, location and intensity in which it occurs. From this characterization it is possible to choose the best study alternative to be applied in determining the extent and forms of containment of the odourant impact.

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ODOR IMPACT ASSESSMENT ON THE SURRONDINGS OF A MEAT RENDERING PLANT THROUGH SURVEY

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Abstract: although odors are often not considered as a health issue, this type of pollution can be taken as an environmental problem that affects the quality of life and causes property depreciation around animal breeding sites and other related activities, resulting in social and economic conflicts. In this work, an evaluation of the impact caused by odors, on the surrounding population of a meat rendering industry, is presented through the application of questionnaires. The results show that the odors emitted by the respective enterprise caused annoying odors in the environment. A survey is an appropriate and inexpensive way to assess the amplitude and magnitude as well as control the impacts of installed odor-emitting enterprises.

Keywords: odor, odor impact assessment, survey.

AVALIAÇÃO DO IMPACTO ODORANTE NO ENTORNO DE UMA FÁBRICA DE RAÇÃO ATRAVÉS DE ENQUETE

Resumo: embora muitas vezes os odores não sejam tratados como uma questão de saúde, este tipo de poluição pode ser considerado um problema ambiental que afeta a qualidade de vida e causa depreciação dos imóveis no entorno de criadouros de animais e outras atividades relacionadas, resultando em conflitos sociais e econômicos. Neste trabalho, é apresentada uma avaliação do impacto causado por odores, junto à população circunvizinha a uma fábrica de ração, através da aplicação de questionário. Os resultados mostram que os odores emitidos pelo respectivo empreendimento causam incômodos olfativos no entorno. A metodologia de enquete é uma forma adequada e pouco onerosa para avaliar a amplitude e magnitude, bem como controlar os impactos de empreendimento já instalados e emissores de odores.

Palavras-chave: odor, avaliação de impacto odorante, enquete.

Introduction

Even though the effects of odor nuisance on human health are not yet completely known, these annoyances can cause serious social, environmental and economic conflicts due to the deterioration of the quality of life and depreciation of real estate around animal breeding grounds, meat rendering plants and slaughterhouses. Given the increasing intolerance of the inhabitants to environmental issues and the expansion of residential areas that are getting closer to odor sources, it is important to control such impact (Kabir; Kim, 2010).

The present study aims to verify the impact caused by odors emitted by a meat rendering industry on its surrounding neighborhood through the application of questionnaires. The methodology and results obtained in the survey are presented, as well as data statistical analysis. The applied questionnaires are divided in two parts; the first stage is carried out in order to characterize the target population. Secondly, possible sources of odors, most affected places, period of occurrence and other aspects of discomfort caused by odorant emissions are identified.

Materials and methods

To study the potentially affected region, a circumference with a diameter of approximately 3 km, centered on the industry was delineated. Such area covered 17 neighborhoods of the municipality where the enterprise is located (either partially or in total). The number of questionnaires applied was determined in order to obtain a statistical representativeness. A tolerable error of 5% was established. According to Barbetta (2010), Equation 1 was used to determine this number.

$$\mathrm{n} = \frac{\mathrm{N} \times n_0}{\mathrm{N} + n_0} \quad \text{where,} \quad n_0 = \frac{1}{E_0^2} \qquad (1)$$

Where: n is the number of questionnaires, E02 is the tolerable sample error, N is the population size.

The resulting value of Equation 1 was 393 questionnaires, for a population of 17,702 people. The number of questionnaires applied in each neighborhood was arbitrated taking into account the number of inhabitants, population density of each neighborhood and also the estimated area of the neighborhood covered by the 3 km circumference. Neighborhoods' population data were taken from the 2010 Brazilian Census, (Brasil, 2010). The number of questionnaires calculated to be applied in each neighborhood is shown in Table 1. Population density and estimated area covered by the circumference can also be observed in this table.

Table 1. Data for questionnaires calculation.

Neighborhood	Inhabitants	Area covered by the circumference (%)	Percentage of total affected population (%)	Number of questionnaires
1	5,084	100	28.7	113
2	2,046	100	11.6	46
3	1,848	93	9.7	39
4	1,813	100	10.2	41
5	1,663	100	9.4	37
6	1,500	50	4.2	17
7	1,423	45	3.7	15
8	1,349	46	3.5	14
9	918	100	5.2	21
10	762	100	4.3	17
11	683	56	2.2	9
12	681	100	3.8	16
13	407	100	2.3	10

The questionnaire used was of the closed-end type, with the first two questions related to the link of the interviewed person with the region where the questionnaire was applied. These are eliminatory questions: If the person does not remain in the studied neighborhood for more than four hours a day, or has been living/working for less than 3 months in the locality, subsequent questions are not asked, and it is not counted as an interviewed person. If the interviewee is fit, the questionnaire is continued, with 3 questions about the person's profile (gender, age, and smoker). The next four questions were aimed to ascertain the perception and annoyance caused by odors.

It should be noted that there was no mechanism of exclusion of the interviewee or presumption of any impediment regarding their sensitivity to odors (for example, having the flu, being allergic, among others). This is assumed because the poll is based on the interviewee's odor memory and not on their condition at the time of the interview. The odors questions addressed in this questionnaire were based on the German standard VDI 3883 part 2 (VDI, 1993). The questions were elaborated in order to evaluate the odorant impact according to their frequency of occurrence, character and offensiveness, as recommended by Nicell (2009). The calculation of the offensive index (OI) caused by the odors on the interviewed population was also performed according to Equation 2 (Vdi, 1993; Nicollas et al., 2010).

$$IO = \frac{1}{N}\sum_{i=0}^{5} W_i N_i \qquad (2)$$

Where: N is the number of questionnaires, i is the answer category, Wi is i's category's coefficient; Ni is the number of answers of the category i.

The value of the olfactory discomfort index is zero at times when people say they are not bothered, 25 for little bothered, 50 for bothered, 75 for very upset and 100 for that situation in which all respondents feel extremely uncomfortable. This question values the sensitivity of individuals, attributing a greater weight to the responses of the most troubled population. This index also allows to determine the evolution of odors offensiveness year after year.

Results and discussion

Among the interviewees, the majority lives or work more than 5 years (> 70%) and spend from 8 to 24 hours a day in the affected location (> 75%). The others live or work between 1 to 5 years and spend from 4 to 8 hours a day in the region under investigation. The age range of the interviewees was between 18 and 70 years, with individuals between 20 and 50 years old (> 60%) as the predominant group. This range was adequate to evaluate the odors, since people with age in this range are sensitive to the perception of odors (Nimmermark, 2004), olfactory functions are less acute in the elderly. Almost all (90%) of the interviewees are non-smokers, and this is another important factor to the perception of the odors that were taken care of in this study. A balance between male and female respondents was verified, allowing a consistent impact assessment, since women tend to have the most accurate sense of smell (Nimmermark, 2004).

The graphs in Figure 1 present the results of the questionnaires regarding the perception of odors by the interviewees.

According to Figure 1, most of the interviewees feel some kind of odor, with approximately 55% of them feeling animal food odors. These odors are rarely felt for most individuals. However, for almost 40% of them, the perception is periodic or frequent. As for the degree of discomfort caused by the perception of odors, most of them feel very uncomfortable (> 30%), followed by medium (> 25%) and little (> 15%). A small portion of respondents claimed to feel extremely troubled, accounting for approximately 12%.

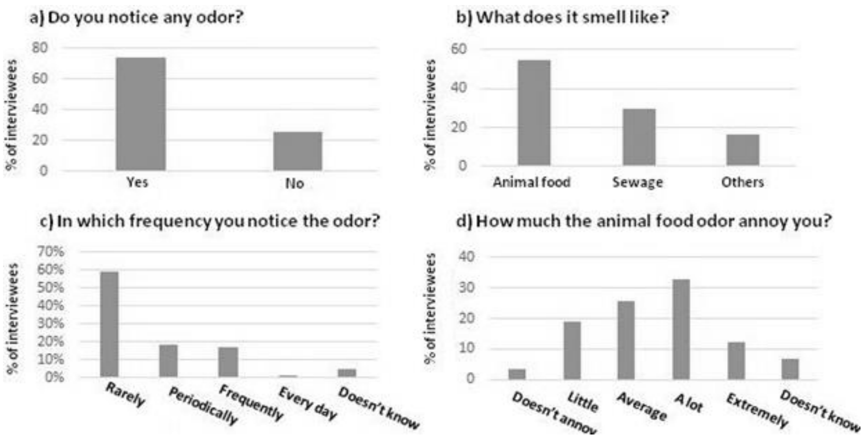

Figure 1. Graphs regarding the perception of odors in the surroundings of the meat rendering plant. a) Number of people that notice odors. b) Determination of odor character. c) Frequency of perception. d) Offensiveness.

Figure 2 shows the percentage of interviewees who feel the odor and the index of offense segregated by the neighborhoods in which the interviews were conducted. According to Figure 2 (a), there are more people who perceive the odor in places closer to the enterprise. However, the highest levels of nuisance [Figure 2 (b)] were identified in the most distant neighborhoods. This may be attributed to prolonged exposure of individuals to odors, reducing their perception and discomfort to it. Another factor that may have influenced the results is the presence or absence of background odors and other sources of odor emission in each neighborhood, which in turn exert a large effect on the magnitude of the odorant impact.

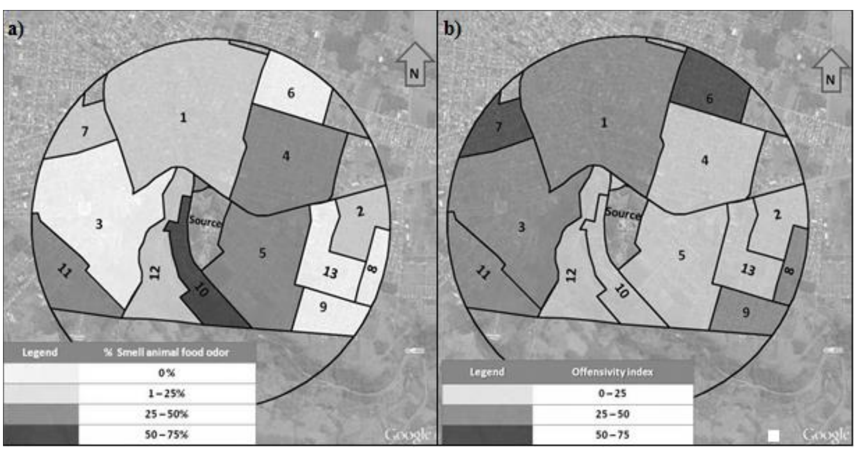

Figure 2. Neighborhood data; a) Meat rendering plant odor perception b) Offensiveness index.

Conclusions

Offensiveness index indicated that the population of most of the neighborhoods investigated is uncomfortable with the odor the meet rendering plant. The frequency with which animal food odors are perceived is rare to periodic, and is especially rare. The population of most of the neighborhoods within the studied perimeter is uncomfortable due to the industry emission of odors.

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EVALUATION OF PIG SLURRY COMPOSTING TECHNOLOGY

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Abstract: the south region of Brazil, especially the west region of Santa Catarina, has the swine industry as one of the main economic activities. The high concentration of animals in the region has intensified the need to implement alternative systems to treat and mitigate the pollutant potential of pig slurry. In this sense, the composting technology of pig farming wastes has become a growing practice among pig farmers in south of Brazil. The treatment of pig slurry via composting process is indicated as an alternative to minimize environmental impact and nutrient recycling. The objective of this study was to evaluate the pig slurry management using composting technology for a cooperative located in the west region of Santa Catarina. During two years were evaluated two complete cycles of pig production. The study was carried out on a farm with a composting system for the slurry treatment produced by 3.500 pigs in fattening phase. The physical-chemical characteristics of pig slurries were evaluated weekly, as well as the biomass characteristics. The results showed that composting technology was strongly influenced by the low concentration of total solids present in pig slurry, showed by a higher final C/N ratio, demanding a longer time for compost maturation.

Keywords: pig slurry, fattening phase, management, treatment.

AVALIAÇÃO DA TECNOLOGIA DE COMPOSTAGEM DE DEJETOS SUÍNOS

Resumo: a região sul do Brasil, especialmente a região Oeste de Santa Catarina, tem como uma das principais atividades econômicas a suinocultura. A alta concentração de animais nessas regiões intensificou a necessidade de implantação de sistemas alternativos para tratamento e mitigação do potencial poluidor dos dejetos suínos. Nesse contexto, a tecnologia de compostagem dos resíduos da suinocultura tornou-se uma prática crescente entre os criadores de suínos da região sul do brasil. O tratamento dos dejetos de suínos via processo de compostagem é apontado como alternativa para minimizar o impacto ambiental e reciclagem de nutrientes. O objetivo deste trabalho foi avaliar o manejo dos dejetos suínos de uma cooperativa localizada na região oeste de Santa Catarina através do uso da tecnologia de compostagem. Durante dois anos foram avaliados dois ciclos completos de produção de suínos. O trabalho foi realizado em uma granja comercial com sistema de compostagem para tratamento dos dejetos gerados por 3.500 animais em fase de engorda. As características físico-químicas dos dejetos suínos foram avaliadas semanalmente, bem como as características da biomassa resultante do processo de compostagem. Os resultados mostraram que a tecnologia de compostagem foi fortemente influenciada pela baixa concentração de sólidos totais presente nos dejetos suínos, o que resultou em uma relação C/N final acima da recomendação para uso do composto orgânico, necessitando assim de maior tempo para maturação do composto.

Palavras-chave: dejetos suínos, suínos em crescimento, gestão, tratamento.

Introduction

Pig farming is one of the main economic activities in the southern region of Brazil, especially in the west region of Santa Catarina where 75% of production is concentrated (Brasil, 2012). In the region, the increase in pig production led to a consequent accumulation of pig slurry resulting in environmental impacts, as global emissions of greenhouse gases (GHG) and accumulation of nutrients in the water and soil. These impacts have affected the development of pig production systems and the composting technology has been pointed out as an alternative capable to minimize the environmental impacts, allowing also the recycling of nutrients. The development of alternative technologies allows the producers to manage the pig slurry properly (Angnes, 2012). The composting process has been very widespread among producers in the west region of Santa Catarina (Oliveira, 2004). Composting process consists on the decomposition of pig slurry by biological via, under controlled conditions, until the biomass reaches a maturation stage that can be handled, transported, stored or applied as an organic fertilizer without affecting adversely the environment (Mazé et al., 1996; Angnes, 2012). The objective of this study was to evaluate the pig slurry management using composting technology for a cooperative located in the west region of Santa Catarina.

Materials and methods

Generalities: the study was developed in a commercial pig farm during a period of two years, divided in two phases. The first phase began in November 2012 and the second phase in November 2013, totalizing 120 days in each phase. The farm located in the municipality of Ponte Serrada had a composting system for the treatment of the pig slurry produced by 3.500 pigs. The composting unit was a masonry barn covered by tiles of red clay. The pile dimensions were: 12.0 m width, 100.0 m length and 1.10 m height. The farm evaluated had as automated and mechanized composting unit to inversion of biomass through a rotation system equipped with helical screw, a hydraulic/electric pump to distribute pig slurry on the biomass. During the composting process the biomass temperatures were measured at 3 different points.

Physical-chemical analyses: total solids (TS), volatile solids (VS), fixed solids (FS), total nitrogen (NTK), ammonia (NH_3-N), total phosphorus (TP), total potassium (TK) and total organic carbon (TOC). In each composting unit three biomass samples were collected from the pile with 25 cm depth (approximately) and one of pig slurry. The physical-chemical parameters were performed at Embrapa Swine & Poultry Lab, according to Standard Methods (Apha et al., 2012) and AOAC (2005). From the analyzes of compost were observed DM content, Total Organic Carbon (TOC) and Total Nitrogen (NTK), to evaluate characteristic as an organic compost for application in agriculture.

Results and discussion

Table 1 presents the characteristics of the pig slurry added to the composting system during both monitored phases.

Table 1. Characteristics of pig slurry added to composting piles.

Phases	TS	VS	NH_3-N	NTK	TP	TK
	Mean±Standard deviation (g/L)					
1	36.4 ±18.5	29.5±16.9	1.08±0.25	2.19±0.52	0.56±0.32	0.87±0.22
4	36.5 ±18.7	36.4 ±24.0	1.75 ±0.51	3.53±0.90	0.87±0.56	1.08±0.28

Total solids is an important parameter for the composting processes, since the volatile solids presented in the slurry is basically a fraction which promote the development of microorganisms in the biomass (Mazé et al., 1996; Oliveira et al., 2003; Oliveira; Higarashi, 2006). The recommended value of volatile solids concentration in pig slurry should be, on average, higher than 40 g/L, for a better development of the composting process (Oliveira et al., 2003; Oliveira; Higarashi, 2006). The results indicated that TS and VS had values below those recommended for composting processes. The low concentration of TS in pig slurry indicated the excessive use of water in the farm evaluated.

Table 2 shows the temperature of biomass recorded during the phases monitored. The average biomass temperature in the compost was 46.18 and 51.56 °C, respectively for phase 1 and 2. It was observed that both phases presented temperatures in the range of 46 to 52 °C, which is recommended by, several authors (Dai Prá et al., 2009). Nevertheless, phase 1 presented in the pile a maximum temperature 15 °C lower than the phase 2. This difference indicates that there was a greater loss of water during the process in the phase 2 due to evaporation.

Table 2. Temperature of biomass recorded during the phases monitored.

Phases	Biomass Temperature (ºC)		
	Mean±σ	Max.	Min.
1	46.18±4.45	52.28	39.55
2	51.56±6.88	65.54	39.25

One of the recommended indicators for monitoring the development of composting process is the biomass temperature since it may indicate: the evaporation capacity of the water contained in the biomass, the rate of organic matter degraded and the total humidity of biomass in the pile. In the composting the temperature exerts a strong influence on the development of microorganisms thus affecting the efficiency of organic matter degradation during the process.

Table 3 presents the characteristics of the biomass presented in the compost during both monitored phases.

Table 3. Characteristics of biomass presented in the compost.

Phases	DM	NTK	TP	TK	TC	C/N
	Mean±Standard deviation (g/kg)					
1	31.6 ±9.5	1.7±0.7	0.4±0.2	0.9±0.2	1.0 ±0.01	32.9±3.4
4	28.5 ±6.5	2.8±1.2	1.5±1.4	1.8±0.2	0.5 ±0.04	32.2±7.5

The NTK, TP, and TK contents in the second phase were higher than the observed in the first (which was to be expected) since parameters were also higher in biomass in the second phase. The DM obtained in the compost at first phase was higher than that observed in the second phase which indicates bigger moisture content in the final compost. Considering the values recommend for commercialization, the DM values determinate were above. Nevertheless, the compost can be used in the farm (Brasil, 2009). Although the biomass moisture content during the composting process should not exceed 65% (Dai Prá; 2009; Oliveira; Higarashi, 2006), in this study it was observed a higher value (more than 65%), mainly in the first phase, which can be attributed to the low temperature observed in the biomass in this phase. Recommendations in literature give a C/N ratio in final compost below 20 (Dai Prá, 2009; Brasil, 2009). The results obtained show that the C/N ratio of the biomass in the two phases was above the recommended 32:1 (the biomass needs to remain a longer time in the composting unit to finalize the compost maturation).

In the current legislation and regarding the IN-25 recommendation for organic composts commercialization, it is necessary a minimum of 0.5% of NTK (Mapa, 2009). The results exhibited at Table 3 demonstrate that the average of NTK is above the value quoted and C/N ratio is above 20.

Another important issue is the moisture in the compost (should not exceed 50%). Values obtained in the study where higher than 50%; under the need to reduce the moisture at the compost, this must pass through a pre-drying process.

Conclusions

Both phases did not present satisfactory results regarding the C/N ratio. It is possible to conclude that the process was strongly affected by the low amount of TS, resulting in a possible lack of OM for a better development of the composting process. The solid-liquid separation of pig slurry can be an interesting alternative to increase TS concentration in effluent, since these values are lower in the piglet's production units in comparison to other types of production systems.

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EVALUATION OF THE ECONOMIC FEASIBILITY OF COMPOSTING TECHNOLOGY FOR THE TREATMENT OF PIG SLURRY

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Abstract: the development of confined intensive pig farms resulted in the production of a large amount of slurry that is applied to the soil, most of the time without criteria and without previous treatment. Brazilian pig breeding has been showing a high growth rate in the in recent decades and some alternatives to the solution of environmental problems of pig farms have emerged from Embrapa Swine & Poultry, among them the composting technology. This technology aims the transformation of liquid pig slurry into solid organic compost. The composting of pig slurry is an alternative that has helped many producers mainly in the aspects related to the management of wastes, allowing the expansion and environmental feasibility of the activity in small areas and equating the issues related to pollution and environmental impacts. This study was carried in west of Santa Catarina, complaining four pig farmers integrated into an agroindustry, where the economic feasibility of composting technology for the treatment of pig slurry was evaluated.

Keywords: pigs, slurry treatment, composting technology, economic feasibility.

AVALIAÇÃO DA VIABILIDADE ECONÔMICA DO USO DA TECNOLOGIA DE COMPOSTAGEM PARA O TRATAMENTO DOS DEJETOS SUÍNOS

Resumo: o desenvolvimento dos sistemas de produção de suínos confinados e o crescente aumento da produção resultaram na geração de uma grande quantidade de dejetos que são lançados ao solo, na maioria das vezes, sem critério e sem tratamento prévio. A suinocultura brasileira vem demonstrando um elevado índice de crescimento nas últimas décadas e algumas alternativas para solução dos problemas ambientais da suinocultura têm surgido de pesquisas da Embrapa Swine & Poultry, destacando-se entre elas a tecnologia de compostagem. Esta tecnologia visa a transformação do dejeto líquido de suíno em composto orgânico sólido. A compostagem dos dejetos suínos é uma alternativa que vem auxiliando muitos produtores, principalmente nos aspectos relacionados ao manejo dos dejetos, possibilitando a expansão e a viabilidade ambiental da atividade em pequenas áreas e equacionando as questões relacionadas com a poluição e os impactos ambientais. Este trabalho foi desenvolvido no Oeste de Santa Catarina, contemplando quatro produtores de suínos integrados a uma agroindústria, onde a viabilidade econômica da tecnologia de compostagem para o tratamento dos dejetos suínos foi avaliada.

Palavras-chave: suínos, tratamento de dejetos, tecnologia de compostagem, viabilidade econômica.

Introduction

Pig farming is one of the main economic activities in the southern region of Brazil, especially in the west region of Santa Catarina where 75% of production is concentrated (Brasil, 2012). The increase in pig production resulted in some concerns for society, per example, the correct disposal for the amount of effluents produced (pig slurry). The major concern of the society related to the environmental sustainability is also increasing since some properties do not contain enough agricultural areas for the recycling of the slurry as fertilizer in the farm (Oliveira, 2004; Oliveira; Higarashi; 2006). In this sense, it is necessary the implementation of a treatment system for pig slurry in order to mitigate its potential to pollute. The development of a new alternative technology is allowing producers to adequate the management of pig slurry, promoting its own use in the system and decreasing the pollution liberated for the environment (Oliveira, 2004). Among the technologies available there is the composting of pig slurry, which has been an alternative widely used by pig producers in the west region of Santa Catarina (Oliveira, 2004). The volume of pig slurry generated on the pig farms and the number of areas for its application in the soil, indicates that approximately 65% of the properties have insufficient area for its recycling (Miranda, 2005). Composting process can be used to reduce the slurry volume and at same time to increase its efficiency as fertilizer, eliminating odors and generating a final product with easy handling and use. Another important aspect for improving composting is the C/N ratio (Dai Prá, 2009). When adequate C/N is obtained, the compost can be applied in soil to crops and pasture having a great efficiency as organic fertilizer. The investment to implement the composting technology in the first year not brings significant profits to the producers, but it will allow environmental improvement and its feasibility for pig activity. The aim of this study was to evaluate the economic feasibility of composting technology for the treatment of pig slurry.

Materials and methods

Generalities: this research was classified as exploratory and quantitative. Considering the experimental design it was characterized as a case study, taking as base composting units and evaluating the economic and environmental feasibility. Six pig units were monitored weekly, located in the west region of Santa Catarina, during one year and seven months (2013/2014), but only four production units were used for economic evaluation of the composting unit. During the monitoring period, biomass temperatures of the compost bed were measure, and samples were collected for physical-chemical analysis of the compost and pig slurry. The production units were divided according to production system: one Weaning-to-Finishing Unit (WF), two Piglets Production Units (PPU), and one Termination Unit (TU).

Physical-chemical analyses: total solids (TS), volatile solids (VS), fixed solids (FS), total nitrogen (NTK), ammonia (NH_3-N), total phosphorus (TP), total potassium (TK) and total organic carbon (TOC). In each composting unit three biomass samples were collected from the pile with 25 cm depth (approximately) and one of pig slurry. The physical-chemical parameters were performed at Embrapa Swine & Poultry Lab, according to Standard Methods (APHA; AWWA; WEF, 2012) and AOAC (2005). From the analyzes of compost were observed DM content, Total Organic Carbon (TOC) and Total Nitrogen (NTK), to evaluate characteristic as an organic compost for application in agriculture.

Economic feasibility of farms: all composting units evaluated were automated, with mechanical revolving machines, electric motors and recorder of the electric energy consumption used, which facilitated the economic feasibility analysis, considering production/operation costs and the value of the organic compost. In order to carry out the analyzes of the viability of the compost, it was necessary to verify the amount of pigs, costs of the construction of the composting barn, machine value, engine power (electric power), substrate quantity m^3/pile (sawdust), number of piles per year, number of piles in composting barn, number of hours worked by in the process, employee, amount in kg of the material composted per pile, time needed for the producer to obtain the initial investment profit, final destination of composted material and the value of material sold per ton or kilo.

Results and discussion

Table 1 exhibits the characteristics of productive systems, number of animals, compost pile volume and agricultural area available in pig units.

Table 1. Characteristics of productive systems, number of animals, compost pile volume and agricultural area available in pig units.

Farm	Prod. System	N. Pig/Sows	Pile Volume (m^3)	Available Area (ha)
1	WF	4.400	1.568	8
2	PPU	920	1.320	3
3	TU	1.400	564	6
4	PPU	4.200	1.287	45

The units evaluated have different production systems according to physiological phase, the management of pig slurry, but have in common the automated and mechanized composting unit to inversion of biomass through a rotation system equipped with helical screw.

Table 2 presents the characteristics of pig slurry added to composting system during the evaluation period.

Table 2. Characteristics of pig slurry added to composting piles.

Farm	TS	VS	NH_3-N	NTK	TP	TK
	Mean (g/L)					
1	33.3	23.6	2.2	3.5	0.9	1.7
2	22.3	14.6	1.3	2.1	0.6	0.6
3	76.9	56.8	2.9	4.7	2.3	1.8
4	30.3	21.6	2.3	3.5	0.9	1.3

The mean for TS (g/L) observed in slurry added to the composting piles varied between 22.3 and 76.9. Since the recommendation for ST, on composting process, is above 40 g/L (Dai Pra et al., 2009), only farm 3 obtained a mean value higher. In this sense, it is possible to identify the excessive use of water in the farms evaluated (except farm 3).

Table 3 shows the temperature of biomass, C/N ratio and dry matter content (DM) in the composting piles during the evaluation period.

Table 3. Temperature of biomass, C/N ratio and DM content in the composting piles.

Farm	Biomass Temperature (°C)			C/N ratio	DM
	Mean±σ	Max.	Min.		(%)
1	51.9±6.7	67.2	37.4	24.5	28.6±2.9
2	54.7±7.4	72.6	39.7	34.3	27.2±4.2
3	49.9±5.2	59.1	37.9	27.4	24.1±3.5
4	45.1±6.5	58.1	34.2	54.6	26.6±1.6

σ – standard deviation.

The average temperature observed in the composting units varied between 45 ºC and 56 ºC, so that the temperatures are in the optimal range for maintenance of the microbial population according to several authors (Oliveira; Higarashi; 2006; Dai Prá, 2009). These temperatures stimulate competition between species and increase the rate of decomposition of organic matter and the elimination of pathogenic microorganisms, resulting in a safe product from the bacteriological view (Paillat et al., 2005). The DM obtained in the final compost was below 30%; this result is important since reflects the need to review the management of producers, since it is recommended that when applying to soil, the final compost presents DM content between 40% and 60%. Recommendations in literature give a C/N ratio in final compost below 20 (Dai Prá, 2009; Brasil, 2009). Observing the results presented in Table 3, it is possible to verify that the final compost from farm 1 and 3 are closer of IN-25 recommendation (C/N ratio of 24.5 and 27.4, respectively) (Brasil, 2009). The compost can be used in the farm.

Table 4 shows the net income by farm obtained from selling compost.

Table 4. Net income from selling compost by farm.

Farm	Cost (ton)	Sales value (ton)	Profit/Loss (ton)	%
1	R$ 160.91	R$ 200.00	R$ 39.09	24
2	R$ 172.27	R$ 200.00	R$ 27.73	16
3	R$ 205.29	R$ 208.50	R$ 3.21	1
4	R$ 202.79	R$ 89.79	-R$ 113.00	56

From Table 4 it is possible to observe that producers 1, 2 and 3 have profit in each compost batch. For farm 4, it was performed an estimation since producer do not sell the compost. It was assumed that the equilibrium value is the cost to produce the compost (wood shaving, price per hour for employee, and electric energy). The organic compost generated shows a very wide price range, which depended on system production. In these cases, the economic viability is related to the final sale value of the compost. However, it should be emphasized that composting can also be used only as a way to make the activity in the property viable in relation the animal housing number.

Conclusions

The composting technology is economically feasible as long as producers adequate the management of the process. Composting can enable the treatment of pig slurry, especially in small areas of agriculture or pasture. Considering the environmental impacts associated to slurry production, the technology minimizes the risks of liquid pollution, making possible increase the number of animals in the properties.

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ADDITIVE EFFECT ON GHG EMISSION FROM SWINE MANURE COMPOSTING

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Abstract: three doses of additive ($MgCl_2$ + H_3PO_4) were tested on composting of swine manure and their effect on the emissions of greenhouse gases (CO_2, CH_4 and N_2O) were assessed during 30 days – doses given in moles of Mg:P /kg of manure: (1) 0.08/0.02; (2) 0.18/0.04 e (3) 0.35/0.08. No inhibition on organic matter degradation was noticed in the concentration range studied and the cumulated emissions of CO_2-C for all assays, including the testimony, were 121 ± 7 g. Nevertheless emissions of CH_4 have significant decrease (>45%) in all treatments compared to the testimony. The cumulated emissions of N_2O increased 16% for dose 2, however it decreased 4% and 57% for doses 1 and 3, respectively. Additional studies are required to better understand how the additive interferes on the biochemical of this system and establish an optimum dose in order to minimize N_2O e CH_4 emissions without any damage to composting process. Also, economic and technical aspects must be considered to evaluate the viability of this technology on real scale.

Keywords: swine production, manure treatment, global warming, struvite.

EFEITO DA UTILIZAÇÃO DE ADITIVO NA EMISSÃO DE GEE DURANTE O PROCESSO DE COMPOSTAGEM DE DEJETOS DE SUÍNOS

Resumo: avaliou-se por 30 dias o efeito de três doses do aditivo ($MgCl_2$+ H_3PO_4) na emissão dos gases de efeito estufa CO_2, CH_4 e N_2O da compostagem de dejetos suínos - dose dada em moles Mg:P /kg de dejeto: (1) 0,08/0,02; (2) 0,18/0,04 e (3) 0,35/0,08. Nas faixas estudadas, o aditivo não inibiu a degradação aeróbia da matéria orgânica, sendo que a emissão acumulada média de C-CO_2 para todos os ensaios, incluso o branco, foi de 121 ± 7 g. Por outro lado, ocorreram reduções significativas (>45%) na emissão de CH_4 em todos os tratamentos frente ao branco. A emissão acumulada de N_2O aumentou 16% na dose 2 e diminuiu 4% e 57% nas dose 1 e 3, respectivamente. Embora esses dados preliminares sejam promissores, são necessários estudos mais

aprofundados para a melhor compreensão do efeito do aditivo na bioquímica do sistema, a fim de estabelecer a dose ideal capaz de reduzir a emissão de N_2O e CH_4 sem prejuízos ao processo de compostagem, considerando ainda a viabilidade técnica e econômica do seu uso em escala real.

Palavras-chave: suinocultura, tratamento de dejetos, aquecimento global, estruvita.

Introduction

The proper management and disposal of the wastes originated from swine facilities constitute important obstacle for the increase of this production in the regions of high animal density. Among the available treatment alternatives, composting stands out as one of the most promising because it allows exporting the surplus of manure and promoting the better utilization of its nutrients content by the production of composted organic fertilizer (Angnes et al., 2013). Nevertheless some hazardous gases can be emitted during composting such as NH_3 (acid rain) and the greenhouse gases N_2O, CO_2 and CH_4 (Zhong et al., 2013).

Some recent studies have been conducted using composting additives to mitigate GHG emissions and nitrogen loss (NH_3, N_2O, NO_x) to produce a richer compost with lower environmental impact (Luo et al., 2013). Among these additives, (Mg + PO_4) has demonstrated to be efficient in reducing the emission of nitrogenous gases (Fukumoto et al., 2011) due to the crystallization of NH_3-N as magnesium ammonium phosphate ($NH_4MgPO_4.6H_2O$ - struvite). Struvite crystallization decreases the amount of free ammonia available to be emitted by volatilization [$NH_{3(g)}$] or by its oxidation to $NO_x/N_2O_{(g)}$ during the nitrification/denitrification. The objective of this work was to assess the effect of adding three doses of $MgCl_2$ + H_3PO_4 on cumulate emission of GHG during 30 days of co-composting of swine slurry with sawdust in the typical conditions met in Brazil.

Materials and methods

The composting experiment was carried out in an experimental area of Embrapa Swine & Poultry, located in Concordia/SC in Southern Brazil (27° 18' 46" S, 54° 59' 16" W). Emission of gases (CO_2, CH_4 and N_2O) from swine slurry co-composting was measured from tubular PVC reactors ($V=0.035\ m^3$) during 30 days. The assay was conducted in duplicate with three treatments that consisted in increasingly doses of $MgCl_2$ + H_3PO_4 beside the control, as shown in Table 1.

Table 1. Doses of $MgCl_2 + H_3PO_4$.

Treatment	Mol Mg /kg of swine slurry	Mol P /kg of swine slurry
Control	0.00	0.00
Dose 1	0.08	0.02
Dose 2	0.18	0.04
Dose 3	0.35	0.08

Gas emission was daily measured during 10 min/reactor using a static chamber connected to a photoacoustic infrared analyzer INNOVA 1412 (Lumasense Tech, Denmark). Gas concentration in reactors was calculated with Equation 1 and expressed as CO_2-C, CH_4-C and N_2O-N.

$$C_2 = \frac{(C_1 \times M) \times (P \times V)}{T \times R} \qquad (1)$$

Where C_2 is the gas concentration given in mg/chamber, C1 is the gas concentration in ppm, M is the molar mass of the gas (g/mol), P is the atmospheric pressure (atm), T is the temperature (K) and R is the ideal gas constant (atm/L/K/mol).

Gas flow (mg/chamber/day) was calculated with the Equation 2.

$$y = mx + b \qquad (2)$$

Where y is C_2 and x is the time in minutes.

Results and discussion

Figure 1 shows the cumulate emission of C-CO_2-C, CH_4–C and N_2O-N in 30 days. Results showed that there was no significant inhibition in the aerobic degradation of organic matter (CO_2-C) in any treatment compared to control (T). The average cumulate emission was 121 ± 7 g of CO_2-C. This behavior was unexpected once previous work has reported that the inhibition of aerobic biodegradation of organic matter by $MgCl_2 : H_3PO_4$ would be the limiting factor for using higher doses of this additive (Lee et al., 2009). Possibly the dose range tested were below the concentration needed to inhibit aerobic activities although dose 3 was two times higher than the concentration met in literature (Fukumoto et al., 2011).

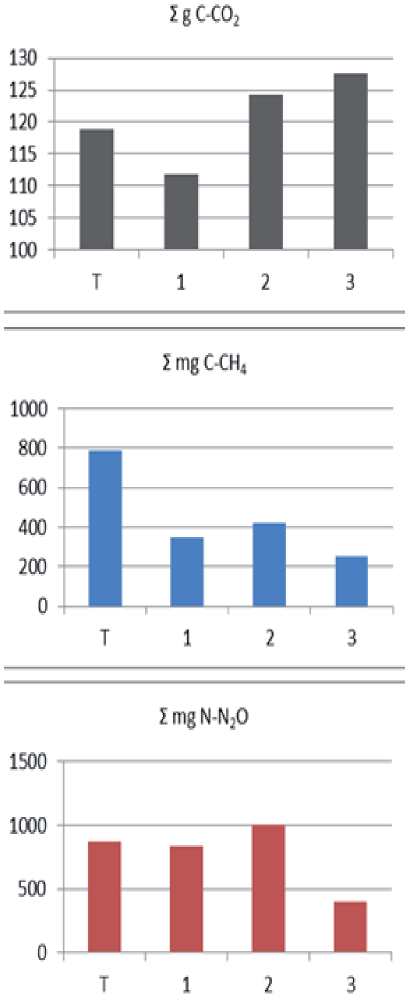

Figure 1. Cumulate emission of CO_2-C (g), CH_4-C (mg) and N_2O-N (mg) during 30 days of swine slurry co-composting.

Doses 1 and 2 emitted similar cumulate mass of CH_4-C and both have no efficiency on the reduction of N_2O-N emission compared to the control, with an emission decrease of only 4% for dose 1 and an increase of 16% for dose 2. According to Fukumoto et al. (2011), the struvite precipitation results in the mitigation of NH_3 and others nitrogenous gases, except N_2O. Nevertheless at dose 3, which corresponds to a concentration two times higher than this cited report, there was a sudden reduction of approximately 57% of N_2O-N emission.

Concerning CH_4-C emission, all treatments showed reductions of up to 45% compared to the control, possibly due to the inhibition of methanogenic microorganisms that are sensitive to any environmental modification, such as a pH decrease by the addition of H_3PO_4.

The treatment that showed the higher efficiency on mitigating CH_4-C and N_2O-N emissions was the dose 3 with reduction of 68% and 57% of cumulate emission, respectively, without prejudice the aerobic biodegradation of organic matter, which is essential to ensure the stabilization and maturation of the composted fertilizer.

Conclusions

Greenhouse gases such as CH_4 and N_2O are emitted from swine slurry composting, furthermore, the massive nitrogen loss during this process led to a resulting composted fertilizer poor in this nutrient that is very important for the plants to growth. Mg and P can be used to mitigate methane and nitrous oxide. Results have shown that dose 3 presents the best results although lower doses was also effective on mitigating methane emission. Therefore more studies related to scale-up, additive reapplication and efficiency of the resulting composts as a source of nutrients for the development of plants.

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Chapter VII

INVITED PAPERS

PERFORMANCE EVALUATION OF AN ODOR CONTROL DEVICE ON THE REDUCTION OF A RENDERING PLANT IMPACT

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Abstract: this article provides a review of US livestock and poultry systems, methods of measurement of dust and gas emissions including ventilation rate, some recent findings and a review of some lessons learned.

Keywords: ventilation, GHG, NH_3, H_2S, PM_{10}, uncertainty.

EMISSÃO DE GASES E POEIRAS NOS EDIFÍCIOS DE PRODUÇÃOANIMAL E AVES NOS ESTADOS UNIDOS DA AMÉRICA

Resumo: este artigo apresenta uma revisão dos sistemas de produção de suínos e aves nos EUA, métodos de medição de gases e poeiras incluindo taxas de ventilação, algumas descobertas recentes e a revisão de algumas lições aprendidas.

Palavras-chave: ventilação, GEE, NH_3, H_2S, PM_{10}, análise de incertezas.

Introduction

Inventories of select species for US systems are provided in Table 1, based on 2012 inventories from the United States Department of Agriculture's National Agricultural Statistics Service (USDA NASS, 2012).

Table 1. Key animal inventory and Sales Data for USA.

Species	2012 Inventory (x 1000)	2012 Sales (x 1000)	Value (x $\$10^6$)
Poultry: Layers	350,716	204,942	(n/a)
Poultry: Pullets	110,297	176,802	(n/a)
Poultry: Broilers	1,506,277	8,463,195	(n/a)
Swine	66,026	199,115	$22,493
Cattle: Beef	53,652	31,457	$74,730
Cattle: Dairy	17,515	6,968	$4,461
Milk Sales			$35,277

Livestock and poultry are large contributors to the agricultural economy of the USA, providing a stable market for grain producers and a reliable, low-cost and safe protein supply for the country. On a volume basis, the broiler (meat poultry) sector dominates other species with nearly 8.5 billion head sold, followed by layers (205 million hens), market pigs (199 million head), and replacement pullets for egg production (177 million birds). USDA tracks sales/value of swine and cattle, with beef cattle valued at nearly $74 billion, milk production at $35 billion, swine valued at over $22 billion, and broilers in excess of $29 billion wholesale. Clearly, animal agriculture in the USA is a significant economic driver.

Ongoing interest in environmental regulations related to air quality concerns have resulted in a series of studies in the past decade, some of which are being published now. The US Environmental Protection Agency (US-EPA) has not yet adopted these findings into their regulatory framework. In this article, a brief review of common livestock and poultry productions systems are reviewed, followed by a review of air quality measurement methods with a focus on obtaining direct emissions estimates from facilities. Information related to quantifying uncertainty into the published results is also provided.

Materials and methods

US production systems:

- **For beef cattle:** common systems include cow-calf operations generally on pasture, backgrounding or "stocker" animals that are post-wean and raised to near finish, and finishing systems. The stocker systems can be either pasture, dry-lot or a combination. Finishing systems are predominantly large-scale feed lots, however there is a recent growth in naturally ventilated buildings with either bedding or slotted flooring.
- **For naturally ventilated facilities:** species housed include dairy cattle, poultry and swine. However, most poultry and swine are raised in either mechanically ventilated or mixed "hybrid" natural/mechanical ventilation buildings. There is a rapid transformation in the egg industry away from cages, and nearly 100% of large-scale egg production barns are mechanically ventilated.

Measurements needed for emissions estimates:

Unique measurements for both concentration and ventilation rates are required depending on whether a barn is naturally or mechanically ventilated, especially with respect to measuring ventilation rate, although gas and particulate matter measurements methods are somewhat different also. Naturally ventilated buildings impose great uncertainty in emissions measurement owing to the difficulty of getting accurate ventilation rates, with tracer gas methods the predominant technique used.

- **Open path techniques:** these include "tunable diode laser arrays"

(TDLA) which attempt to measure mass flux of a gas passing across the laser path. One comparison of 3 methods (Casey et al. 2010) clearly showed the limitations of the method especially with respect to ventilation rate component.

- **Closed Building:** in principle a closed, in mechanically ventilated buildings it should be straightforward to measure emissions, since all ventilation air leaves through exhaust fans. Emission is effectively the product of concentration difference and ventilation rate, and errors in the measurements related to either of these quantities propagate (and often magnify) into the emissions estimate. It is important to note that emission rate is not measured, it is computed from these other measurements. Neglecting the many sources of error in these measurements reduces the quality of emissions data that are collected.
- **Emissions Rate (ER):** we commonly collects building static pressure, station pressure, concentration difference between exhaust and background air, and air temperature. These measurements are used directly, or indirectly, in the components of the emissions rate equation:

$$ER = Q_e \left(\frac{[G]_e}{T_e} - \frac{\upsilon_i}{\upsilon_e} \times \frac{[G]_i}{T_i} \right) \times 10^{-6} \times T_{std} \times \frac{P_a}{P_{std}} \times \frac{w_m}{V_m} \quad (1)$$

Where:

ER: gas emission rate for the house (g/h/house);

Qi,, Qe: incoming and exhaust ventilation rate of the house at field temperature and barometric pressure, respectively (m^3/h/house);

[G]i,[G]e: gas concentration of incoming and exhaust house ventilation air, respectively, parts per million by volume (ppm_v);

wm: molar weight of the gas (g/mole) (e.g., 17.031 for NH_3);

Vm: molar volume of gas at standard temperature (0 °C) and pressure (101.325 kPa) or STP (0.022414 m^3/mole);

Tstd: standard temperature (273.15 °K);

Ti, Te: absolute temperature of incoming and exhaust air, respectively (°K);

Pstd: standard barometric pressure (101.325 kPa);

Pa: atmospheric barometric pressure at the monitoring site (kPa).

- **Ventilation rate:** mechanical ventilation is challenging to measure. This is critical to address, since seemingly similar fans perform very differently. One method utilizes the Fan Assessment Numeration System (FANS), which is used to build a unique fan performance curve for each fan in a building (Gates et al., 2005). Then, measurements of fan run-time and concurrent static pressure can be used to determine reasonably accurate airflow rates for each fan, and their sum is the building ventilation rate. Our previous work has clearly shown that neglecting to account for building ventilation by means of direct measurement results in substantial loss in accuracy of estimates for ER, owing to the variation among fans (Figure 1).

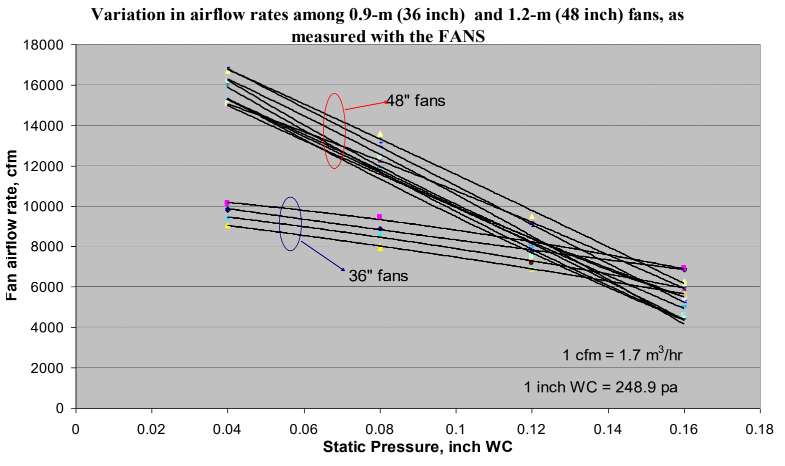

Figure 1. Variation in the fan airflow rates among the 36“ and 48“ fans in a Tyson broiler house.

Source: from author, copied from Moody et al. (2008).

- **Concentration measurement:** for gases, wet chemistry, electrochemical and/or spectroscopic techniques have been employed, and for particulates measurement studies have used both mass-based and particle-based technologies. For the broiler study done by the author and colleagues, Table 2 lists the equipment selected.

Table 1. Project measurement equipment and personnel requirements for maintenance.

Project Measurements*	Method	Data Type	Equipment Requirement**	Personnel Requirement
NH_3	Automated	Digital	INNOVA 1412	Unit Calibration & Maintenance, Data Transfer, & Data Review
CO_2	Automated	Digital	INNOVA 1412	Unit Calibration & Maintenance, Data Transfer, & Data Review
TSP	Automated	Digital	TEOM 1400	Unit Calibration & Maintenance, Mid-Flock Unit Move, Data Transfer, & Data Review
PM_{10}	Automated	Digital	TEOM 1400	Unit Calibration & Maintenance, Mid-Flock Unit Move, Data Transfer, & Data Review
$PM_{2.5}$	Automated	Digital	TEOM 1400	Unit Calibration & Maintenance, Mid-Flock Unit Move, Data Transfer, & Data Review
H_2S	Automated	Digital	API 101 E	Unit Calibration & Maintenance, Data Transfer, & Data Review
NMHC	Automated	Digital	VIG 200	Unit Calibration & Maintenance, Data Transfer, & Data Review
Barometric Pressure	Automated	Digital	WE 100	Unit Calibration, Data Transfer, & Data Review
Temperature	Automated	Digital	Type T Thermocouple	Unit Calibration, Data Transfer, & Data Review
Static Pressure	Automated	Digital	Setra 264	Unit Calibration, Data Transfer, & Data Review
Ventilation Fan Operation	Automated	Analog Signal	Current Switch	Data Transfer & Data Review
Relative Humidity	Automated	Digital	HMW 61U	Unit Calibration, Data Transfer, & Data Review
Litter N Content	Manual	Numeric	Rapid Still II and Digester	Sample Collection & Laboratory Analysis

Source: Moody et al. (2008).

- **Measurement system:** given the large size of modern facilities, it is generally necessary to use sample pumps and bring sample gas to analyzers located in a common point. For some equipment, such as particulate matter samplers and lower-cost Portable Monitoring Units that have been used (e.g. Gates et al., 2005; Liang et al., 2005; Wheeler et al., 2006) this is not possible. However, for ammonia and other gases a sampling-and-centralized-analysis system is predominant. One example method (Moody et al., 2008) utilizes positive pressure gas sampling system (PG-GSS) with minim connections on the vacuum side of the sampling pump, and all instrumentation downstream of the pump in the positive pressure zone. A schematic is in Figure 2.

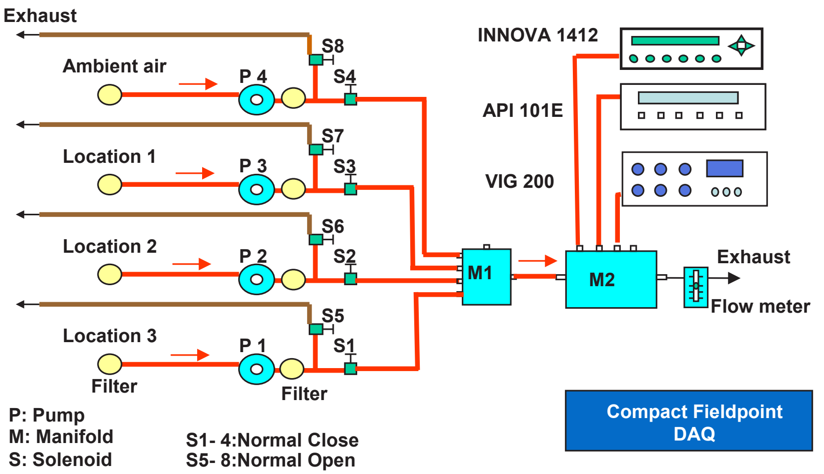

Figure 2. Positive Pressure Gas Sampling System. Note location of Pumps P1-P4 and minimal connections on their vacuum side.

Source: Moody et al. (2008).

Results and discussion

Recent projects: a list of recent US projects includes the following:

Laying hen and broiler chicken facilities:

1. Gates, Xin and Wheeler (2001-2005) $870,000. Used PMU+FANS system, “many” poultry houses. Multiple publications, NH_3 only.
2. Burns, Xin and Gates (2005-2008) $1,047,756. Used MAEMU+FANS system, two broiler houses. Conference papers. NH_3, GHG, PM.

Poultry, dairy, swine, layers, broilers:

1. National Air Emissions Monitoring System, or "NAEMS", project by Heber et al. (2006 – 2011) >$14M. US-EPA directed. Used system similar to MAEMU+FANS, local subcontractors. Conference papers–none with results at time of this conference speech. NH_3, H_2S, PM. Mechanical and natural ventilation systems. No open lots.
2. Several "add-on" projects for GHG.

A list of useful publications is provided in the References section.

Lessons learned: this is a compilation by the author, based on observations and two decades of emissions measurement experience.

- **Lesson 1:** characterizing emissions, including their uncertainty, is extremely challenging even for the simplest closed systems (Gates et al., 2008; Calvet et al., 2013). Figure 3 shows the standard uncertainty in ER as a function of building ventilation rate QT. A 10% standard uncertainty in ventilation rate is remarkably small, and with the Innova gas sampler yields an ER standard uncertainty of about 5-13%. A more realistic ventilation rate uncertainty of 25% raises the ER standard uncertainty to a range of 10 to 30%. A grand challenge to our research community is to develop and enforce measurement and reporting protocols this could allow for better comparisons (for example, between species, systems, countries, climates, etc.).

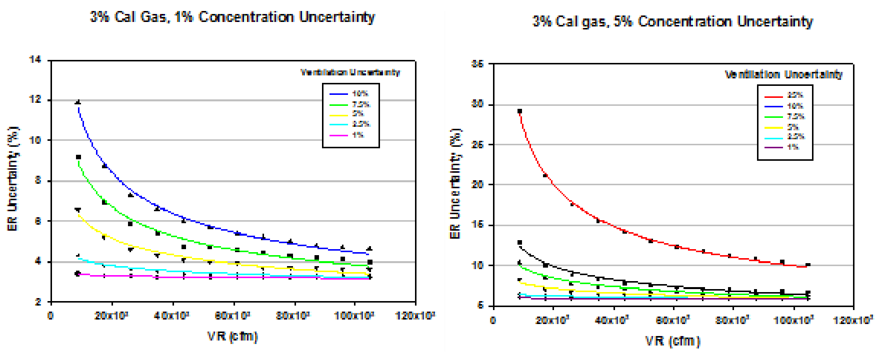

Figure 3. Example of ER standard uncertainty value for different uncertainties in ventilation rate and ventilation rate standard uncertainty.

- **Lesson 2:** if the goal is to characterize emissions from a type of livestock or poultry system, the question of statistical validity must be addressed in the planning phase. One must consider, and decide: Is it better to get extensive data from a few replicate sites, or less intensive sampling from many replicates of the system? A corollary to this is the issue of determining a suitable number of replicates to have confidence that the resultant ER is representative of the type of system being measured.
- **Lesson 3:** a well-executed plan to characterize emissions for a segment of industry, or a country, is expensive. It is critical to answer these questions during the planning phase: what are the objectives? Are there sufficient resources? Are researchers provided with support? As of this writing, over $15M of direct funding was spent on emissions measurements, and no US emissions data from these projects had been published, nor adopted by the US-EPA.

Conclusions

A brief review of US systems, measurement equipment and protocols, and a few of the major projects aimed to measure emissions of gas and particulate matter has been provided. The author's thoughts on lessons learned from these experiences are provided. ER determination is expensive, requires standardization, and must include assessment of statistical validity and employ uncertainty analysis as part of the project deliverables.

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BIOENERGY PRODUCTION FROM AGRICULTURAL BIOMASS: A CANADIAN PERSPECTIVE

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Abstract: Canada and the United States have much greater electricity energy consumption per capita (15.54 and 12.96 MWh per capita per year) than all other G8 countries (6.4 MWh per capita per year on average) based in 2014 data (EIA, 2014). Nearly all of the energy consumed in Canada comes from fossil fuels, namely refined petroleum products (35%), natural gas (29%) and coal (11%). Other energy sources come from nuclear (9%), hydroelectricity (12%) and other renewable sources (4.4%). The province of Quebec is unique in its consumption of hydroelectric power. Primary electric energy's share, essentially hydroelectricity, was 39% in 2003, compared with only 14% for the whole of Canada [Quebec's energy sources: hydroelectricity (39%), oil (38%), natural gas (12%), renewable sources (9%) and coal (1%)]. According to Villeneuve et al. (2012) the biomass heating industry is far from mature in North America which can be seen as a paradox based on the quantities of available biomass fuels. Canada already has a large and growing fuel ethanol industry, producing about 175 million litres of ethanol each year, mainly from corn and wheat. The direct combustion of biomass as thermal process for energy production presents an interesting and effective avenue under certain circumstances. However, there are some concerns about emissions from direct combustion. Both chemical composition and physical properties are very different among biomass, especially agricultural biomass in relation to woody biomass; hence emitted substances are different and often closely related to biomass origin. Furthermore, biomass combustion process is complex and emissions are not only influenced by the chemical components of the biomass. Godbout et al. (2010) showed the wide ranges of gaseous and particulate emissions from comparable biomass using combustion equipment with similar output capacity (<3 MW). Other variables related to the culture and conditioning practices of four biomass fuels in relation to their combustion properties have also recently been studied (Morissette et al., 2010). Additionally the current air quality regulations in Quebec render the combustion of agricultural biomass complicated and costly. The regulations oblige users of agriculture biomass to install an incinerator type combustion chamber (MDDEP, 2011). The limitations are mainly based on a lack of information regarding emissions from the combustion of these types of biomass. In fact, although many studies have been conducted to measure emissions from biomass combustion, a wide proportion of this scientific research is performed on woody biomass while research in agricultural biomass is less intensive (Godbout et al., 2010). The impact on air quality is the major issue related to biomass combustion. In order to comply with actual regulations, a framework must be set to define a range of specific parameters and characteristics of biomass used for combustion. This framework will provide practical tools to develop innovative combustion devices and a more uniform "fuel" resulting in better flue gas control.

Keywords: agricultural biomass, bioenergy, combustion, emissions, manure, agricultural waste management.

PRODUÇÃO DE BIOENERGIA A PARTIR DE BIOMASSA AGRÍCOLA: UMA PERSPECTIVA CANADENSE

Resumo: o Canadá e os EUA têm um consumo de energia *per capita* muito superior (15,54 e 12,96 MWh per capita por ano) aos restantes países do G8 (6,4 MWh per capita por ano, em média), com base em dados de 2014 (EIA, 2014). Quase toda a energia consumida no Canadá é proveniente dos combustíveis fósseis, nomeadamente produtos petrolíferos refinados (35%), gás natural (29%) e carvão (11%). Outras fontes de energia são a nuclear (9%), e hidroelétrica (12%) e outras fontes renováveis (4,4%). A província do Quebec é única no consumo de energia hidroelétrica. A participação da energia elétrica primária, essencialmente hidroelétrica, foi de 39% em 2003, contra apenas 14% em todo o Canadá [fontes de energia do Quebec: hidroelétrica (39%), petróleo (38%), gás natural (12%), fontes renováveis (9%) e carvão (1%)]. De acordo com Villeneuve et al. (2012) a indústria de aquecimento de biomassa está longe de ser madura na América do Norte, o que pode ser visto como um paradoxo baseado nas quantidades de combustíveis de biomassa disponíveis. O Canadá já tem uma indústria grande e crescida de combustível de etanol, produzindo cerca de 175 milhões de litros de etanol por ano, principalmente a partir das culturas do milho e trigo. A combustão direta de biomassa como processo térmico para a produção de energia apresenta-se como uma via interessante e eficaz em determinadas circunstâncias. No entanto, existem algumas preocupações sobre as emissões a partir da combustão direta. Tanto a composição química quanto as propriedades físicas são muito diferentes entre as biomassas, especialmente a biomassa agrícola em relação à biomassa lenhosa; assim, as substâncias emitidas são diferentes e muitas vezes estreitamente relacionadas com a sua origem. Além disso, o proces-

so de combustão da biomassa é complexo e as emissões não são apenas influenciadas pelos componentes químicos da biomassa. Godbout et al. (2010) mostraram as amplas gamas de emissões de gases e material particulado de biomassa comparável usando equipamentos de combustão com capacidade de saída similar (<3 MW). Outras variáveis relacionadas com a cultura e práticas de condicionamento de quatro combustíveis de biomassa em relação às suas propriedades de combustão também têm sido recentemente estudadas (Morissette et al., 2010). Adicionalmente, as atuais normas de qualidade do ar no Quebec tornam a combustão da biomassa agrícola complicada e onerosa. Os regulamentos obrigam os usuários de biomassa agrícola a instalar uma câmara de combustão do tipo incinerador (MDDEP, 2011). As limitações baseiam-se, principalmente, no vazio de informação sobre as emissões resultantes da combustão destes tipos de biomassa. De fato, apesar de muitos estudos terem sido conduzidos para medir as emissões da combustão de biomassa, uma grande parte desta pesquisa científica é realizada sobre biomassa lenhosa, enquanto a pesquisa em biomassa agrícola é menor (Godbout et al., 2010). O impacto na qualidade do ar é a principal questão relacionada à combustão da biomassa. Para cumprir com os regulamentos atuais, deve assim ser definido um quadro para definir uma gama de parâmetros específicos e características para a biomassa utilizada na combustão. Este quadro fornecerá ferramentas práticas para desenvolver dispositivos de combustão inovadores e um "combustível" mais uniforme, resultando em um melhor controle de gases de combustão.

Palavras-chave: biomassa agrícola, bioenergia, combustão, emissões, dejeto, gestão de resíduos agrícolas.

Introduction

The growing demand for energy in the world has driven the development of technologies from renewable sources to reduce the emission of greenhouse gas. However, petroleum, natural gas and coal currently represent 81.7% of primary energy (EIA, 2014) for its transformation and consumption around the world. In Canada primary energy sources used varies geographically throughout the territory e.g. petroleum and natural gas in the Maritimes, hydroelectricity in Quebec and Manitoba, refined petroleum products in Ontario (nevertheless, natural gas and production of steam and electricity by cogeneration is increasing in the industrial sector), natural gas in Alberta, and refined products from petroleum in British Columbia (Ménard, 2005).

Canada and the United States have much greater electricity energy consumption per capita (15.54 and 12.96 MWh per capita per year) than all other G8 countries (6.4 MWh per capita per year on average) based 2014 data (EIA, 2014). Mainly, energy consumed in Canada comes from fossil fuels, such as refined petroleum products (35%), natural gas (29%) and coal (11%).

Remaining energy sources include nuclear (9%), hydroelectricity (12%) and other renewable sources (4.4%).

Biomass is an alternative to feedstock for energy production. Canada's potential for producing biofuels and energy from biomass (crop residues, grasses, sawdust, woodchips, sludge, livestock manure) is huge. According to Champagne (2007) such potential is underutilized. Villeneuve et al. (2012) points out that the biomass heating industry is yet at intermediate state in North America and can be seen as a paradox based on the quantities of available biomass fuels. The biomass inventory carried out by Wood and Layzell (2003) illustrates Canada's major potential to utilize its vast forestry and agricultural resources to provide a sustainable supply of bio-based energy. These authors estimated that the potential for the conversion of the carbon from available unused biomass is equivalent to 27% of the total energy that Canada obtains from fossil fuels, from which 14% could be provided from designated crop production including residues, 3% from livestock manure, 70% from forestry and 13% from municipal waste.

Much biomass-to-energy conversion processes are well established and in development in Canada such as direct combustion and pyrolysis. According to Industry Canada (2005) cited by Champagne (2007), biofuel production is expected to rise in the near future, particularly in the physical, chemical and thermal conversion of primary and residual biomass to bio-based energy and industrial products because of the abundance of biomass in Canada. The present paper aims to review such opportunities, more specifically from biomass produced by agricultural activities in Canada. The focus will be on the thermal conversion by direct combustion. Additionally, a critical review of the legal and environmental issues is also discussed.

Available agricultural biomass in Canada

In the last few years: Canada has put in place different programs to promote environmental responsibilities and to reduce GHG emissions resulting in a positive growth (30% over 1995 production) of biofuel production over the country. The total biomass produced in Canada by 2001 represented approximately 5,142 PJ, in which 60.3% was provided by the forestry, 36.9% by the agricultural activities and 2.8% by livestock manure (Figure 1). However, due to the different uses of biomass, only 43% of total biomass (i.e. 2,212 PJ/yr) is available for energy purposes. Thus unused Canadian biomass both from agricultural and forestry activities represent a huge potential as feedstock to produce renewable energy. However, in 2006, biofuel production from Canadian biomass was estimated to 531.8 PJ in which 96% were provided by solid biomass (raw material for combustion), 2.3% by biogasoline and 1.8% by biogas. This production represents only 24% of the total available energy that Canadian biomass could supply (Food Agriculture Organization United Nations, 2007) (Figure 1). The present situation can be seen as an example of the paradox cited by Villeneuve et al. (2012) about underestimation of the Canadian biomass potential. In addition, Canada presents an undeveloped biomass supply chain. For instance, from the 1.34 million tonnes of pellets produced from biomass in 2008, only 22% was used in Canada [78% was exported principally to Europe (Bradley, 2011)].

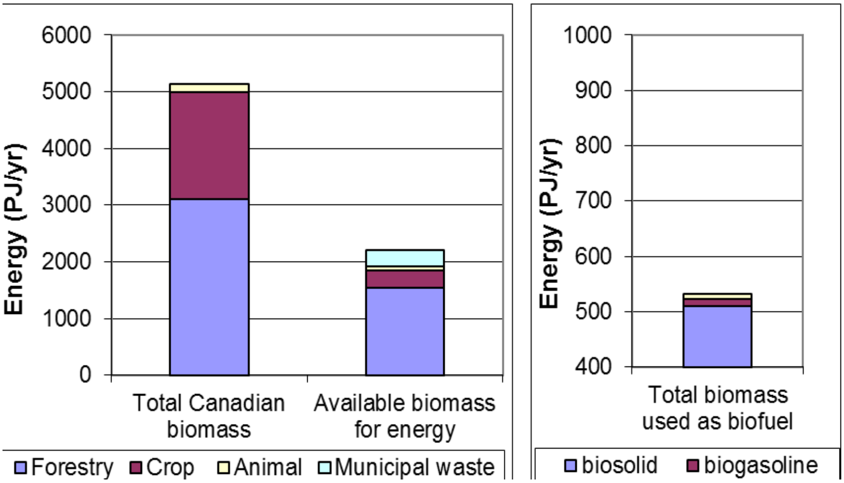

Figure 1. Total and available energy from Canadian biomass (left) and biofuels produced (right).

Major crop residues: in Canada assessed for potential biomass residues as sources for energy generation includes wheat, corn for grain, barley, canola and tame hay. The total sustainable [in all crop systems, a portion of the crop residue must be returned to the soil in order to ensure the maintenance of the soil tilth, humic content and fertility (Wood; Layzell, 2003)] removal biomass potential from crop residues in Canada has been estimated to 43.9 million tonnes of oven-dried biomass (M ODT/yr) (Wood; Layzell, 2003). However a fraction of these residues must remain in the field to ensure soil fertility, while another fraction is lost during collection or used for animal bedding and mulching reducing availability to 17.8 M ODT/yr, equivalent to a potential of 0.3 EJ (Wood; Layzell, 2003).

Livestock manure production: accounted up to approximately 181 Mt by 2006. Major volume of manure comes from beef cows (38%), milk cows (12%), calve (12%), heifer (12%) and pig (9%) production (Hoffman, 2008). Livestock manures are generally used directly as soil amendments and opportunities for deriving energy are often overlooked (Champagne, 2007). However the Department of Agriculture and Agri-Food Canada recognizes that animal manure management presents disposal problems and contributes about 3.4% of Canada's GHG emissions. Used as an energy source, livestock manure could produce over 3 Gm^3/yr of biogas through anaerobic digestion

(Wood; Layzell, 2003), which could provide 0.065 EJ/year of energy [calorific value (CV) ranging from 14 to 18 GJ/t], an amount equal to 0.8% of the fossil fuel energy use in Canada in 2001. However, according to Chen et al. (2004) cited by Champagne (2007), due to the specific characteristics of animal manures and their high protein content, utilization of energy production is more complicated than other lignocellulosic biomass.

Energy crops: perennial grasses and trees grown through traditional agricultural practices are increasingly being produced as renewable feedstock for bio-based products, fibre and energy sources (Tolbert et al., 2002). Energy may be generated through direct combustion or gasification to produce electricity and heat, or by converting to liquid fuels such as ethanol. The most common dedicated energy crops in Canada are willow, hybrid poplars, switchgrass, Miscanthus giganteus and pearl millet. Canada has over 20 million hectares of available land suitable to produce energy crops. The most attractive benefit of producing energy crops is to give added value to the low potential agricultural lands. The province of Quebec has approximately 300,000 ha of marginal lands available to produce energy crops. This land could allow an annual production of 3 Mt of biomass, which is the equivalent of more than 9 million barrels of oil (Mesli, 2010). Major benefits of energy crops include increased rural economic development, energy security and environmental benefits. However, there are some barriers that limit the use of energy crops on a large scale such as the high initial establishment cost and the waiting period prior to the first revenue generating harvest. The Michigan Energy Program (2002) points out that there is a chicken and egg syndrome when it comes to growing and utilizing energy crops (i.e. what should come first). Farmers are reluctant to adopt new crops that have uncertain markets as well as uncertain yields and paybacks. They want a reliable demand for crops before they invest their money to establish them. Conversely, users want a guaranteed supply of an energy source before making the capital investments to build new facilities. Other barriers include the high ash content in biomass (particularly in switchgrass and sorghum), the relatively high overall cost production (particularly in Miscanthus, willow and hybrid poplar), the added expenses associated with harvesting and processing, the lack of funding for research and the lack of energy crop establishment policies and incentives (Michigan Energy Program, 2002). Such policy-related issues were identified by the Department of Energy (DOE) as the major non-technical barrier for increased biomass energy development.

Current canadian context of biomass products and transformation processes

Direct combustion: is the most common energy production process from solid fuel biomass in Canada. In fact, as regards renewable bioenergy sources, combustion of biomass ranks second to hydropower in Canada's primary energy production. Major biomass feedstock includes woody product, particularly residues from forest activity (sawdust, planer shavings, bark, logging waste from sawmills, and diseased and insect-killed trees). Technology regarding combustion of woody biomass is well developed and commercially available (e.g. pellets stoves and large-scale biomass-fed-boilers). Consequently there is a significant increase of commercial installations and homes for converting their traditional heating system based in gas or fossil fuel into a biomass heat system. In addition, pelletizing process of wood has grown exponentially in Canada last years. Canadian pellet producers increased the number of plants from 33 in 2010 to 39 in 2017. This increased capacity per year by almost 1.3 MT to reach 3.7 MT by 2017. Also there are 7 proposed plants for 2017 with a capacity of up to 0.9 MT per year.

New products in pellet form are being developed e.g. roasted biomass (to produce a higher energy-dense and hydrophobic product). This product is in first commercial demonstrations in Canada. Despite that the plantations of switchgrass for combustion purposes starting to be relatively well establishment in Ontario, Quebec, and Manitoba (Canada), the combustion of agricultural biomass is not really popular. This fact is mainly due to technical concerns about biomass and combustion systems e.g. moisture, fuel composition, emissions (particulate matter and pollutant gases) and fouling in appliances. Thus improvements are needed implanted in each combustion system in order to increase efficiency, reducing emission levels and to reduce costs. The development of efficient combustion technologies for moderate to high ash fuels is also highly required.

Ethanol production and its usage: are encouraged by federal and provincial governments in the last few years in Canada by giving incentives in research, tax incentives and political will. As a result, ethanol production increased from less than 200 Ml in 1990 (Olar et al., 2004) to 1,777 Ml in mid-2011. There are 16 commercial ethanol plants in Canada either operating or under construction in 2010. Their production output ranges from approximately 12.5 Ml/yr to 225 Ml/yr (Doiltech Corporation, 2010). Most of ethanol fuel available in Canada is produced from corn (in eastern Canada) and wheat (in western Canada). However, according to Champagne (2007), the cost and availability of suitable crops are considered major hurdles for larger commercial development of bioethanol in Canada. Additionally, the environmental benefits of converting corn and grain to ethanol (e.g. lower greenhouse gases) can be compromised by the large amounts of energy, fossil fuels and fertilizer needed to grow these crops. Thus, in order to overcome the inconvenience, a new biotechnology process for making cellulosic ethanol from the plant fibers (i.e. stalks, corn cobs and straw) is being developed. This method promises the development of the methanol industry on a large viable commercial scale.

Gasification: allows converting a relatively heterogeneous feedstock into a consistent synthetic gas (syngas) which can be used as a fuel for power generation or as a feedstock for production of fuels and chemicals. Landfill gas produced by decaying of municipal solid waste is the main source of biogas in Canada [there were over 30 sites in 2006 (Kajat, 2006)]. Biomass, manure and/or biosolids are also used as feedstock to produce biogas by an anaerobic digestion process. According to Natural Resources Canada (NRC) (2010), agricultural biogas industry is growing; currently 20 farm digesters are operating across the country. In 2012, the province of Ontario passed to have 13 to 28 operating farm based digesters. The current trend in Canada is to use waste residues as co-substrates with manure, with less emphasis on co-digesting manure with energy crops.

The Biodiesel market: in Canada is at a nascent stage; while there was no commercial-scale biodiesel production facilities in 2004 (Kajat 2006), there were 12 biodiesel plants operating or planned for being under construction (Doiltech Corporation, 2010). Including plants under construction, biodiesel production capacity in Canada is 471 Ml/yr. In eastern Canada, the feedstock for biodiesel plants is usually animal fats; alternative feedstock includes used vegetable oil and tallow. In western Canada (Manitoba to Alberta), the usual feedstock for biodiesel is oil derived from canola (Doiltech Corporation, 2010).

Pyrolysis: involves the heating of biomass in the absence of oxygen, producing pyrolysis oil (BioOil) and a biochar by-product. Regarding BioOil production, Canada is seen as a leader in technology and development. However pyrolysis systems are in a minority with regard to commercially available gasification systems; only two companies produce currently pyrolysis oil at a commercial scale in Canada. In addition, three pyrolysis systems are in advanced stages of development (Kajat, 2006). The first one is a patented fast-pyrolysis process that converts forest and agricultural residues into liquid BioOil, and focusing on modular plants of 100, 200 and 500 tonnes per day (tpd). The second one includes the use of core technology (Rapid Thermal Processing or RTP™) to transform carbon-based feedstocks, either woody biomass or petroleum hydrocarbons, to more valuable chemical and fuel products. Lastly, conversion of harvest waste to liquid BioOil in mobile units of 50 tpd BioOil output capacity. On the other hand, NRC is providing technical support to Canadian companies involved in research about biochar production.

In summary: the vast quantities of available land, the different biomass sources, the wide range of technologies for energy production, the constant innovation in energy processes and the huge research and development capacity, makes Canada a promising country to lead potentially the development and the establishment of a strong renewable energy system based on agricultural biomass and energy crops as feedstock. But nowadays many barriers are obstructing the Canadian green potential that even the well-established forest industry cannot overcome. These barriers are characterized by: an undeveloped biomass supply chain; a relatively small or spread biomass sources; the significant reserve and investment in fossil fuels – oil, gas and coal; a lack of capital; the poorly distribution of information between different involved actors (biomass producers, biotechnology producers, energy distributors, energy projects financiers and energy end users); an undeveloped carbon market and evolved policies, and the misinformation on environmental impacts.

Biomass combustion: the major biomass energy conversion process in Canada

Emissions and technical problems: are related to the direct combustion. The direct combustion of biomass as thermal process for energy conversion presents an interesting and effective avenue under certain circumstances. Although with growing interest, this avenue confronts several technical problems. Regarding chemical composition, agricultural lignocellulosic biomass has higher Cl ratios than wood [e.g. Cl content is 60 mg/kg in wood, 220 mg/kg in bark and 4,900 mg/kg in straw (Obernberger; Thek, 2004)]. During biomass combustion processes, Cl forms unwanted particles (i.e. HCl, Cl_2 and alkali chlorides) and influences the formation of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F) (Van Loo; Koppejan, 2008). PCDD/F have shown to be extremely toxic, mutagenic, and linked to the suppression of the human immune system (Lavric, et al., 2004). In addition, the alkaline nature of the biomass ash and the Cl content in the biomass fuel decrease the melting temperature of ashes and causes fouling and corrosion in combustion appliances (Demirbas, 2005). Straw is one of the most problematic biomass regarding this issue. On the other hand, important quantities of ash are rejected from the combustion of biomass and, additionally, the fuel-bound N produces NO and NO_2 emissions (Johansson et al., 2004).

Moreover, both emission rate and composition are also influenced by the physical properties of the fuel (e.g. moisture content, density, porosity, size and active surface area), the type of combustion equipment (including operational and technical aspects) and the emission reduction measures. In a combustion process, all these variables interact and produce an extensive variety of emission levels and substances [gases and particular matter (PM)] (Godbout et al., 2010).

Because several factors influence the quality of agricultural biomass harvested, different studies aims to develop better agricultural and conditioning practices of biomass in order to get suitable biomass properties for combustion processes (Hadders; Olsson, 1997; Schroeder, et al., 2009; Morissette et al., 2010). For instance, it is important to harvest with low ash and humidity levels. Ash is reduced by harvesting dedicated woody crops (such as willow and hybrid poplar) once all leaves have been lost. Also when harvesting agricultural biomass with high Cl levels such as straws, corn, switchgrass, etc…, it is preferable to cut the crop in the autumn and harvest in the spring after rain and snow have washed away Cl and K residues.

Legislative issues: impact directly on biomass combustion development. Environmental legislation is a provincial jurisdiction in Canada where each province is free to establish specific air quality standards, guidelines and emission levels as long as they agree with the Canada-wide Environmental Standards (Canada-Wide Standards, 2000), which meet common environmental standards across the country. Moreover, biomass legislative issues can even complicate further where individual municipalities can enact bylaws regulating emissions from this sector. Presently in Canada, there are no clear regulations for the combustion of agricultural biomass. However the amounts of PM, as well as PCDD/F emitted from different processes (e.g. combustion) are limited by the CWS. These standards could indirectly impact the combustion process of biomass since biomass is closely linked to the production of these pollutants. However, the CWS are non-binding on any level of government and have no legal consequences if they are not met, thus they can be described as voluntary guidelines according to Boyd (2006).

The Canadian Standards Association (CSA) has adopted a recommended particulate limit and test protocol (B415.1) (Canadian Standards Association, 2010) for wood and corn burning devices (heat outputs up to 2 MW). Even if the standard is not yet enforceable as a Canadian national or provincial standard, manufacturers are obliged to develop new solid-fuel-burning appliances in compliance with this standard. On the other hand, this standard has no effect on current air quality legislation in most provinces and territories as stringent as the CSA-B415 standard. This can potentially have a negative impact on emission were certified CSA-B415 combustion unit owners might be inclined to neglect maintenance on their combustion units knowing they will continue to respect current air quality legislation.

Only the provinces of Quebec and British Columbia (BC) have a specific standard for the combustion of biomass. British Columbia's standard emission regulation applies to boilers with a facility capacity of 50 MW or less and engaged solely in agricultural operations that are located wholly in the agricultural land reserve of the greater Vancouver regional district (Metro

Vancouver, 2009). In the province of Quebec, the use of biomass fuels is legislated according to the regulation respecting the quality of the atmosphere (c. Q-2, r.20) (MDDEP, 2011) which is part of the Environmental Quality Act. This standard concerns all activities and equipment that may change air quality. However, municipalities are free to adopt more restrictive regulations. Thus, regulation regarding biomass combustion from municipalities can differ significantly from provincial legislation, which can considerably limit the implementation of this renewable energy source. Present provincial legislation concerns regulation of wood combustion furnace or boiler of a capacity less than 3 MW. However, no further details are presented for combustion systems based on biomass other than wood, such as agriculture biomass (dedicated energy crops or agricultural residues). The legislation presents only details for incinerators (regardless of capacity) regulating PM emission limits. Furthermore, appliances with a combustion capacity lower than 1 t/h must be equipped with a secondary combustion chamber and an external fossil fuel source. No details are presented for combustion appliances. In addition, a current project planning to modify legislation is in the process suggesting adding opacity, PM, NOx, CO, PCDD/F emission limits. However, the current air quality regulations in Quebec make the combustion of agricultural biomass impossible in a standard combustion unit. The limitations are mainly based on a misunderstanding of emissions issues and lack of scientific information regarding the combustion reactions and emission levels of various agricultural biomasses. A work frame must be set to define specific parameters and characteristics of biomass and appliances in order to be compliant with actual emission regulation of combustion processes.

Conclusions

Canada accounts with a huge potential to produce agricultural biomass as feedstock for energy production using different processes. However, different barriers (political, technical, economic and environmental) obstruct the establishment and the growth of an agricultural-based energy system. Effective programs should be led by the Canadian government regarding policy initiatives, models for the financing of start-up costs, and the establishment of a carbon credit market, as a solution to promote this industry. The impact on air quality is the major concern around the direct combustion process. To be compliant with actual regulation, a framework must be set to define a range of specific parameters and characteristics of biomass used for combustion. Such a frame will provide practical tools to develop innovative burning devices and a more uniform “fuel” resulting in a better flue gas control.

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EMISSIONS AND IN-BARN MITIGATION TECHNIQUES IN SWINE PRODUCTION

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Abstract: several technologies have been developed to reduce gas and odour emissions from swine housing. However, efficiency from such technologies is difficult to compare because results are usually presented in different units. Therefore, in order to provide reliable information to pig producers about in-barn techniques to reduce gaseous and odour emissions, the present study aimed to target the most promising techniques for the Quebec (Canada) context and to evaluate their emission reductions. Techniques evaluated included a special formulated diet and an in-barn manure management by liquid-solid fraction separation using a V-shape scraper under slats. In addition, a treatment combining both techniques was evaluated. A control treatment (traditional diet and under slat liquid manure) was also included in order to compare emissions mitigation efficiency. NH_3, N_2O, CH_4, CO_2 and odour emissions were measured for seven weeks in an experimental setup of twelve independent chambers each housing four castrated pigs. The diet and the in-barn separation system showed a significant reduction ($P<0.1$) in NH_3 emissions (63% and 36%, respectively). However, any significant reduction was observed for N_2O, CH_4 and CO_2 emissions. The formulated diet increased CH_4 emissions significantly ($P>0.1$). Odour emissions were reduced up to 20% combining both techniques, but not significantly compared to emissions from control treatment. In conclusion, these techniques were effective for NH_3 mitigation; however, they should be improved regarding odour mitigation in order to draw the attention of producers to adopt them.

Keywords: diet, manure treatment, V-shape scraper, liquid-solid fraction separation and odour emission.

EMISSÕES E TÉCNICAS DE MITIGAÇÃO EM EDIFÍCIOS DE PRODUÇÃO DE SUÍNOS

Resumo: várias tecnologias têm sido desenvolvidas para redução das emissões de gases e odores nos edifícios de produção de suínos. No entanto, a comparação entre as eficiências dessas tecnologias é difícil, porque, usualmente, os resultados são apresentados em unidades diferentes. Assim, de modo a fornecer informações técnicas confiáveis aos produtores de suínos para reduzir as emissões de gases e odores nos edifícios de alojamento, o presente estudo teve como objetivos indicar as técnicas mais promissoras no contexto do Québec (Canadá) e avaliar a redução nas emissões. As técnicas avaliadas incluíram a formulação de uma dieta especial e o manejo dos dejetos no edifício de alojamento através da separação da fração sólido-líquida usando nas canaletas internas, um raspador em V. Adicionalmente, um tratamento combinando as duas técnicas foi avaliado, bem como um tratamento de controlo (dieta tradicional e dejeto líquido na canaleta) para comparação das eficiências de mitigação das emissões. As emissões de NH_3, N_2O, CH_4, CO_2 e odores foram mensuradas durante sete semanas numa instalação experimental, com doze câmaras independentes, e quatro suínos castrados em cada. A dieta e o sistema de separação no edifício mostraram uma redução significativa (P<0,1) nas emissões de NH_3 (63% e 36%, respectivamente). No entanto, para as emissões de N_2O, CH_4, CO_2 não foram observadas reduções significativas. A dieta formulada aumentou significativamente as emissões de CH_4 (P>0,1). As emissões de odores foram reduzidas até 20% combinando ambas as técnicas, mas sem significância quando comparadas às do tratamento de controlo. Concluindo, estas técnicas foram eficientes para a mitigação de NH_3, no entanto, estas devem ser melhoradas no que respeita à mitigação de odores para chamar à atenção dos produtores para a sua adoção.

Palavras-chave: ração, tratamento dejetos, raspador em V, separação da fração sólido-líquida e emissão de odores

Introduction

Livestock production in confinement facilities produces high emissions of pollutants gas such as ammonia (NH_3), methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). Furthermore, swine barns, particularly, release high levels of odour emissions generating important cohabitation concerns. Therefore, several technologies have been developed in order to reduce gas and odour emissions from swine housing. The most promising techniques can be categorized into five groups:

1. Formulation of diets and food additives;
2. In-barn manure management;
3. In-barn manure treatment;
4. Air quality control;
5. Cleanliness and management.

Two in-barn approaches seem to be interesting for the Quebec (Canada) context: the under slat separation system and the diet formulation. In Quebec, manure is usually cumulated under slats into the barn during several days and subsequently flushed. Both the manure sticks to the flooring material and the stored liquid produce gases and odour. Some studies have shown that separating urine from feces under slats and frequently removing both fractions were suitable to reduce gas and odour emissions from swine production buildings (Jongebreur, 1981; Andersson, 1995; Arogo et al., 2001; Bernard et al., 2003). Under-slat separation systems can reduce NH_3 and odour emissions up to 50% (Kroodsma, 1986; Voermans; van Asseldonk, 1990; Voermans; van Poppel, 1993; Hendriks; van de Weerdhof, 1999; Kaspers; Koger; van Kempen, 2002; Koger et al., 2002; van Kempen et al., 2003; Belzile et al. 2006). Mainly, three major under slats manure separation systems have been studied over the years: the conveyor net, the V-shape scraper and the conveyor belt.

On the other hand, nutrient management in the animal diet has also been reported as an effective way for reducing gas and odour emissions (Honeyman, 1996). Special diets can be formulated aiming to reduce nitrogen content in manure and urine. Dietary requirements for each essential amino acid of grower-finisher pigs are met by including enough crude protein. In order to reduce emissions caused by excess nitrogen, particularly NH_3, one of diet formulation methods involves the alteration of the ratio of nitrogen excretion in urine versus feces (Mroz et al., 1993). Reduction of nitrogen excretion in urine as urea, the primary precursor for NH_3 volatilization, combined with shifting nitrogen excretion into the feces, primarily as bacterial protein, will reduce NH_3 volatilization and thereby NH_3 emission in swine barns. Moreover, Hobbs et al. (1996) reported a significantly lower concentration of some major odour components in slurry from pigs fed with low crude protein diets compared to a control diet.

One approach in formulating pig diets involves the reduction of dietary protein combined with supplementation of synthetic amino acids, which might reduce total nitrogen excretion from 25 to 40% (Hartung; Phillips, 1994; Kay; Lee, 1997). For instance, reduction of dietary protein by 29% produced a direct reduction of NH_3 emission by 52% in the study carried out by Kay and Lee (1997). Another approach involves inclusion of fermentable carbohydrates or non-starch polysaccharides (NSP) into diets. In this way, bacterial fermentation in the hindgut is stimulated and urinary versus fecal nitrogen ratio is reduced by 68% (Canh et al., 1997a). In a subsequent study carried out by the same authors, NH_3 emissions were reduced up to 40% by dietary inclusion of fermentable carbohydrates (Canh et al., 1997b). However, increased bacterial fermentation increased the production of volatile fatty acids (for example: acetate, propionate, and butyrate), which are also part of the total odour.

However, to compare mitigation efficiency from different studies is difficult because results are presented in different units. Therefore, in order to provide reliable information to pig producers about in-barn techniques to reduce gaseous and odour emissions, the present study aimed to test and quantify odour and gas emission reduction from these two in-barn techniques.

Materials and methods

The experimental laboratory barn consisted of twelve identical chambers (1.2 m width x 2.44 m long x 2.44 m high) laid out side-by-side and controllable individually. Each room was equipped with a fully concrete slatted floor and its own manure handling system. Four growing-finishing pigs were housed per chamber for seven weeks (three weeks of accommodation and four weeks of testing). The ventilation system consisted of an inlet and exhaust fan mounted in the ceiling of each chamber. The exhaust fan was able to vary the airflow from 14 to 75 L/s according to the set point temperature (starting at 21 °C and reduced gradually at 0.6 °C/week up to 18 °C). Airflow was measured downstream the room by a 204 mm iris orifice damper (Model 200; Continental fan manufacturers Inc., Buffalo, NY) (± 5% accuracy). A differential pressure transducer measured the pressure across the orifice plate. The chambers were provided with uniform heating and ventilation rates, and with sensors to continuously measure temperature (type T thermocouples) and humidity (Model CHG-UGS, TDK Corporation of America, IL). Each sensor was scanned every 10 s and the average was recorded every 15 min., furthermore, animal-related data (feed and water consumption, weight gain, volume of manure) as well as manure samples were taken weekly.

An air sample was continuously taken from each room (close to the exhaust fan) every 3.25h for quantifying gas concentrations. A gas chromatograph (Varian 3600, USA) equipped with a flame ionization detector (FID) detected and quantified CH_4 concentration, an electron capture detector (ECD) detected and quantified CO_2 and N_2O concentration, and a non-dispersive infrared (NDIR) analyzer (Ultramat 6E, Siemens, Germany) measured NH_3 concentration. Gas emissions were measured continuously during the four weeks of each rearing. These measures were compiled to have a single cumulative measure per room per week in the statistical analysis.

Odour analysis was done weekly. Odour concentration was evaluated by dynamic olfactometry (Afnor, 2003) and odour intensity was evaluated in situ by nasal rangers (Feddes et al., 2001; BSI, 2003). For the latter, two trained odour assessors evaluated the ambient odour intensity in each room and in the air intake with a nine-point n-butanol scale as described by the Standard Practices for Referencing Suprathreshold Odour Intensity standard (ASTM, 1999).

The in-barn manure management system involved in a V-shaped scraper and a V-shaped gutter which separated urine from faeces (Figure 1). Faeces stay on the inclined walls while urine is gathered into the middle trench and stored under the gutter. A mobile squeegee-type scraper was used to remove faeces once every day.

Figure 1. V-shaped scraper under one of the chambers.

A standard commercial diet was used as control and the treatment diet is a special diet formulated to reduce odour emissions. The composition of the control and the specially formulated diets is shown in Table 1. In both types of feed, the pigs were fed "ad libitum". Corn grain was reduced in the treatment diet due to the addition of soy hull which is a source of dietary fiber (different from starch) (NSP) that favours the passage of nitrogen towards faeces rather than to urine and, consequently, reducing the potential for generating ammonia. However, as the soy hull is less energy-efficient than corn grain, animal fat has been added in order to balance the energy content. Soybean meal is a source of protein for the reduction of crude protein content and, according to the literature; it should reduce the odour emissions. The lysine of the treatment diet is supplemented with HCl in order to reduce the pH. Indeed, a lower pH reduces NH_3 volatilization by maintaining it in the form of NH4+. Synthetic amino acids, methionine and tryptophan have been added in the optimized diet in order to compensate for the lack of amino acid caused by the decrease in protein content. However, they have been added only to meet minimum requirements because these amino acids are sulfur-containing, which has a negative effect on odours. In addition, the commercial enzyme Porzyme was added to the diet in order to improve digestibility which was expected to have a positive effect on decreasing odour emissions.

The experimental design involved three individual chambers for each of the following four treatments:

1. C: control (no technology implemented, manure handled with a pull plug system emptied every week);
2. D: dietary formulation;

3. V: under slat separation system by a V-shaped scraper;
4. D+V: a combination of the treatment D and V. The experience was repeated twice.

Table 1. Composition of the two types of diets to be administered during the experiment.

Ingredients	Quantity (%)	
	Standard commercial diet (control)	Treatment diet (formulated for odour reduction)
Corn grain	67.69	54.24
Soybean cake	15.0	8.0
Wheat	15.0	15.0
Animal fats	0.0	5.0
Soya hulls	0.0	15.0
Limestone	0.85	0.7
D. Phosphate	0.4	0.4
Calcium chloride	0.0	0.15
Lysine - HCL	0.15	0.35
DL - Methionine	0.0	0.03
L - Tryptophan	0.0	0.03
L - Threonine	0.0	0.15
NatuPhos5000 liquid (phytase)	0.015	0.015
Porzyme9310 granular	0.0	0.04
Choline 60	0.095	0.095
Premix (Vitamin and minerals)	0.5	0.5
NaCl	0.3	0.3
Total (%)	**100.0**	**100.0**
Protein content (%)	**15**	**12**

The experimental design involved three individual chambers for each of the following four treatments:

1. C: control (no technology implemented, manure handled with a pull plug system emptied every week);
2. D: dietary formulation;
3. V: under slat separation system by a V-shaped scraper;
4. D+V: a combination of the treatment D and V. The experience was repeated twice.

Results

The initial and final average pig weights were 60.4 kg and 90.25 kg, respectively. The mean daily weight gain in all treatments and control ranged from 0.99 to 1.05 kg/day/pig. Any significant difference between treatments was found which guarantees the absence of detrimental effects of the treatments on the performance of the animals. The mean daily weight gain is slightly larger than the mean value of Quebec (0.795 kg/day/pig). This difference could be explained by the small number of pigs in the same room allowing better access to feed and less competition between pigs. On the other hand, the feed conversion in pigs from treatments ranged from 2.6 to 2.8 which is similar to the average in the province of Quebec (2.66 kg food/kg gain). However, pigs in the control treatment showed a higher efficiency on feed conversion (3.1 kg food/kg gain).

The ventilation resulted constant and similar to all treatments in both repetitions. The average flow rate was 1.9±0.08 and 4.3±0.11 m^3/min for the first and second breeding, respectively. Only one group had an atypical tendency, i.e. one chamber with the V+D treatment at the second breeding (≈3.6 m^3/min). However, since the calculated emission values are based on a total of six replicates, this outcome was considered no to affect significantly the final results.

Gas and odour emissions results are resumed in Table 2. Difference from control for each treatment is also resumed and coded by a colour scale: green for reduction >10%, orange for reductions <10% and red for an increase of the emission. On the one hand, it can be observed that all technologies significantly reduced NH_3 emissions. The diet was more efficient than the V-shaped scrapper (63% and 36% reduction compared to control, respectively), however, the combination of both techniques was even more efficient (79%). On the other hand, regarding odour emissions reduction, the diet was not as efficient as for NH_3 resulting only 4% reduction. The V-scrapper and the diet combined with the V-shaped scrapper performed similar and better than the diet. However the statistical analysis showed no significant differences for any treatment and control.

Regarding N_2O, CH_4 and CO_2, all treatments had practically no impact on emission reduction. However, some treatments seemed to increase some of the emissions. V-shaped scrapper seemed to have impact increasing N_2O emissions by 13%. However result was not statistically significant compared to the control (P>0.1). The treatments using the diet resulted in a statistically significant increase of CH_4 emissions by 120% and 64% for D and D+V, respectively. These results diverge with literature data which mainly indicate a reduction or no impact on CH_4 emissions by the in-barn separation systems.

Table 2. Gas and odour emissions.

Treatments	NH_3	N_2O	CH_4	CO_2	Odour
	mg/h-kgpig				OU/h-kgpig
Control	3.33	0.069	1.28	701	141
Diet	1.22	0.071	2.82	652	136
V-Shaped scrapper	2.12	0.078	1.26	671	114
Diet + V-Shaped scrapper	0.69	0.072	2.10	548	113

Discussion

Emissions: difference on emissions among treatments was not linked to a difference in the animal performance nor ventilation system. Thus, emissions differences can be completely related to the treatments. As observed in other scientific studies, both techniques evaluated resulted in a significant impact in NH_3 emissions reduction. The reduction becomes even more important if both techniques are implemented simultaneously. However, the techniques should be improved regarding odour emissions mitigation. 4-20% odour reduction seems to be not enough to be distinguished from an usual swine production (control treatment). This would limit the interest of swine producers on the adoption of such techniques.

Management of the Manure Solid Fraction: manure separation techniques produce a solid fraction with high phosphorus (P) content. Indeed, major quantity of P originally found in the manure is transferred to the solid fraction. Godbout et al. (2006) reported that the separation of faeces and urine with under-slat techniques produces a concentration of P in the solid part of at least 90%. In the study carried out by Pelletier et al. (2007) in which manure were treated by centrifugal separation, P was also concentrated mainly (88%) in the solid fraction. In this context, because of Quebec regulations restrict phosphate fertilization on farmland in order to reduce eutrophication problems, the surplus solid fraction of the separation treatment should sustainably managed. However, solid-liquid separation offers the opportunity to facilitate P management by concentrating P in a product which could be exported to a region needing or being able to receive the P surplus.

Conclusions

After a literature review about techniques allowing odour and gas emission reduction, two techniques were selected in order to be evaluated and compared: the V-shaped scrapper and a formulated diet. The in-barn techniques selected were tested in an experimental swine barn for seven weeks where emission and animal performance were measured. Treatments also included the combination of both techniques and a control or typical treatment. All technologies assessed have significantly reduced ammonia emissions. The treatment combining both techniques showed the highest efficiency for reducing ammonia emissions (63%). Odour emissions were reduced by 19% and 20% by the V-shaped scrapper and the combination of both technic, respectively. However, reduction efficiency was not statistically different from control treatment. Manure separation facilitates P management by producing a solid fraction with high P content which could be efficiently exported outside the region having P surplus. However, it is recommended to improve performance on odour emissions in order to attract the producer's interest.

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GREENHOUSE GASES DYNAMICS IN BRAZILIAN LIVESTOCK PRODUCTION SYSTEMS

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Abstract: global warming is intensified by greenhouse gases (GHG) emissions from human activities, resulting in climate change and many environmental disorders. Livestock produces GHG such as methane (CH_4) and nitrous oxide (N_2O) and the increase in emissions is linked to increased livestock production. The degradation of pastures is considered the most important contributor to GHG emissions in the livestock sector and may lead to desertification. Mitigation actions can reduce emissions by livestock production systems and improve their carbon balance, which considers carbon sequestration besides the emission of GHG. Mitigating emissions in the livestock sector is possible through reductions in CH_4 and N_2O emissions but the carbon sequestration that occurs during the recovery of pasture has the greatest potential for mitigating GHG. Nevertheless, great emphasis is given to aspects involving the issue of enteric methane production by ruminants and methods of mitigation. In this context, it is important the estimation of the contribution of different Brazilian animal production systems to GHG dynamics; determination of the mitigation potential of improved pastures and integrated systems; indication of management practices necessary to higher competitiveness and sustainability of livestock production in Brazil; provision of the scientific community, government agencies and society in general with GHG data collected using adequate tiers and avoiding extrapolation of default indexes (mostly obtained in temperate areas) to Brazilian conditions.

Keywords: CH_4, N_2O, bovine, degraded pastures, climate changes.

DINÂMICA DE GASES DE EFEITO ESTUFA NOS SISTEMAS DE PRODUÇÃO PECUÁRIOS BRASILEIROS

Resumo: o aquecimento global, acentuado por ações antrópicas de emissão de gases de efeito estufa (GEE), tem como consequência as mudanças climáticas, que causam muitos transtornos ambientais para a humanidade. A atividade pecuária produz gases de efeito estufa na forma de metano (CH_4) e óxido nitroso (N_2O) principalmente, com tendência de aumento de emissão atrelado ao aumento da produção pecuária. A degradação de pastagens, o mais importante problema ambiental da pecuária, também pode contribuir para a emissão desses gases e pode levar à desertificação. Ações de mitigação

dessas emissões podem amenizar o problema e devem ser observadas considerando-se o balanço de carbono dos sistemas de produção pecuários, onde, além da emissão de gases de efeito estufa, o sequestro de carbono é também considerado. Na pecuária, existe possibilidade de mitigação das emissões pela redução da emissão do CH_4 e do N_2O, entretanto, o maior potencial de mitigação das emissões está no sequestro de carbono devido à recuperação das pastagens. Apesar disso, grande ênfase é dada aos aspectos envolvendo a emissão de CH_4 entérico pelos ruminantes e suas formas de mitigação. Nesse contexto, é importante a estimativa da contribuição da dinâmica de GEE dos diferentes sistemas de produção; determinação do potencial de mitigação da recuperação de pastagens degradadas e da adoção de sistemas integrados, indicação de práticas de manejo necessárias para aumentar a competitividade e sustentabilidade da produção pecuária brasileira, provisionamento da comunidade científica, órgãos governamentais e a sociedade em geral com informações sobre a dinâmica de GEE, provendo resultados em melhor grau de aproximação (tier) evitando o uso de padrões de fatores de emissão de GEE inadequados (default) para as condições brasileiras.

Palavras-chave: CH_4, N_2O, bovinos, pastagens degradadas, mudanças climáticas.

Greenhouse gases (GHG): emissions by livestock production systems

Livestock production is responsible for 8% to 11% of global GHG emissions. If the life cycle of the livestock sector is considered, its contribution represents more than 18% of global emissions. Asia is the main source of enteric methane (CH_4) but Latin and North America, Africa and West Europe are also important sources of this gas. Most of the emissions are from domestic ruminant herds (O'Mara, 2011).

According to data presented in "Estimation of Annual GHG Emissions" (MCTI, 2014), total GHG emission in Brazil is 1,203,424 Gg CO_2eq. Emissions by the livestock sector are estimated at 446,445 Gg CO_2eq (37% of the total emission, approximately) and by land-use changes and forestry at 175,685 Gg CO_2eq (15% of the total emission, approximately). Brazilian annual emissions of GHG (CO_2eq), from 1990 to 2012, are presented in Figure 1. During that period, there was a reduction in the percentual participation of emissions by land-use change in the total emission and, consequently, emissions by agriculture (including livestock production) became proportionately the greatest contributors, despite the small increase in absolute values. The energy sector and agriculture emitted almost the same amount of GHG, around 37% of the total emission, what is attributed to the use of fossil fuel in energy production. Considering GHG emissions by agriculture, 38% are in the form of N_2O and 62% of CH_4. Contributions of agriculture sub-sectors to total emissions from agriculture in 2012 were: 55.9% from enteric fermentation; 35.9% from soils under agriculture; 4.8% from animal waste; 1.9% from rice cultivation and 1.5% from the burning of cotton crop residues.

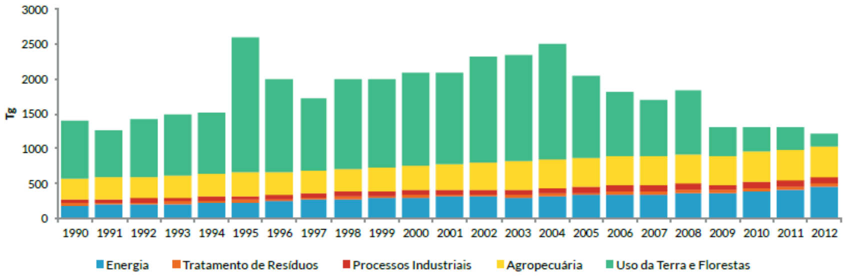

Figure 1. Greenhouse gases emissions in Brazil (CO_2eq), from 1990 to 2012.
Source: MCTI (2014)

Cattle (89% beef and 11% dairy cattle) represent 83.9% of the Brazilian livestock (Berndt et al., 2014). Emissions of enteric CH_4, resultant from a natural process intrinsic to ruminants, increase as the size of the national herd increases. The First Inventory of Anthropogenic Greenhouse Gases Emissions (MCT, 2004) reported total emissions of enteric CH_4 as 184.8 Gg CO_2eq/year. The second inventory (MCT, 2010) indicated emissions of enteric methane as 241,227 Gg CO_2eq/year. In the Report of Annual GHG Emissions in Brazil (MCTI, 2013), enteric CH_4 emissions in 2010 are indicated as being 246,569 Gg CO_2eq/year. In those publications, the national herd is estimated at 158,243,229; 207,156,696 and 209,541,109 animals, respectively. In 2010, cattle contributed with 96.8% of enteric CH_4 emissions.

According to a review by Berndt et al. (2014), the amount of CH_4 produced depends on the quantity and quality of digested feed (USEPA, 1990); type of animal, as well as of the conditions and management system in which the animals are raised. Available data indicates that cattle produce from 150 to 420 L of CH_4 per day, while sheep produce 25 to 55 L/d (Holter; Young, 1992; McAllister et al., 1996), corresponding to emission rates of 39.1 to 109.5 kg/year and 6.5 to 14.4 kg/year, respectively.

Research carried out in Brazil highlighted the benefits of improving digestibility of ruminant diets, with the consequent increases in feed intake, weight gain and dilution of CH_4 emission per product unit. The lack in management improvements results in an average emission rate of 57 kg CH_4/animal per year. Emission rates suggested for Latin America by the IPCC (2006) are 63 kg CH_4/animal per year and 56 kg CH_4/animal per year, respectively, for dairy and beef cattle, values close to those found by Brazilian research (Berndt et al., 2014).On the other hand, Berndt et al. (2014) affirm that the direct interference in the rumen, the reduction of methanogenic microorganisms and higher animal performance resulted in an average emission rate of 37.7 kg CH_4/animal per year for beef cattle, value 34.8 % lower than the average rate for animals managed without mitigation strategies (57.0 kg CH_4/animal per year). These results indicate that there is a great potential for GHG mitigation under the conditions cattle are raised in Brazil (Berndt; Tomkins, 2013 in Berndt et al., 2014).

In this scenario, the new challenge for the cattle raising sector is to develop diets and management strategies which can minimize the relative production of CH_4 (kg de CH_4/kg of beef or milk), resulting in higher efficiency in production and reduction in the negative impact of livestock production on global warming (Berndt et al., 2014).

On the contrary, N_2O emissions under Brazilian conditions are proving to be insignificant, and N_2O emissions by denitrification may be null when low N doses are applied to low fertility soils. When evaluating two pasture systems - extensive pasture managed as a continuous grazing system, without fertilization or soil correction and intensively managed and irrigated pasture fertilized with 456 kg/ha/year of a 20.05.20 + 5% S formula, dived in 12 applications (six applications of 36 kg N/ha in the rainy season and six applications of 36 kg N/ha in the dry season) - Oliveira et al. (2013) observed lower N_2O emission during spring by the extensive compared with the intensive pasture. The magnitude of emissions was very low, representing only 0.01% of the N applied in the intensively managed pasture, which is much lower than the emission factor (N-N_2O emitted when N is applied - N-N_2O emitted without N application)*100/amount of N applied) proposed by the IPCC. This phenomenon may be attributed to the unfavourable to denitrification conditions found in the Brazilian tropical soils in which the pastures were established, which had low N availability and good structure, drainage, porosity and aeration (Oliveira et al., 2014).

Morais et al. (2013) evaluated emissions in an Elephant Grass (Pennisetum purpureum) pasture during 618 days and found N-N_2O losses of 726 g/ha. In the grazing cycles, N_2O emissions amounted to 173; 410 and 705 g/ha de N-N_2O, equivalent to 0.51% of the emission factor proposed by the IPCC (1% of the N applied).

In the evaluation of pasture systems in the subtropical area of Brazil, Sordi et al. (2014) found emission factors of 0.15% for cattle feces and 0.26% for urine, values below the 2% factor proposed by the IPCC for those animal wastes when deposited on the soil surface. Lessa et al. (2014) also concluded that it is necessary to review N_2O emission values presently assumed for pastures in the Brazilian Cerrado (savanna).

The Brazilian government assumed audacious Nationally Appropriate Mitigation Actions (NAMAs) at the COP-15 (Copenhagen Climate Change Conference - 2009) involving the following goals to be reached until 2020 by the agricultural sector: emission reduction of 83 to 104 Mt CO_2eq through pasture recuperation; 18 to 22 Mt CO_2eq through silvopastoral integrated systems; 16 to 20 Mt CO_2eq with no-till farming and 16 to 20 Mt CO_2eq through the biological fixation of N (Brasil, 2010).

Therefore, the effort to evaluate GHG emissions and carbon sequestration in Brazilian agriculture systems is extremely important and data is being generated that will support actions aiming at improving efficiency and sustainability in the sector. Besides that, GHG emission data obtained will permit to certify that the proposed NAMAs were reached

Pecus research network

Concept/Introduction: the increase in GHG concentration in the atmosphere and the consequent global warming are of great concern to a great part of the world population. Actions to reduce GHG emissions and increase mitigation are expected from governments and those involved in agriculture, which is recognized as one of the major sources of these gases. Brazil, an important player in the international agricultural commodity market, has voluntarily compromised to reduce significantly GHG emissions by the livestock-raising sector by 2020.

The volume of animal production in Brazil has consistently increased in recent years. Contrary to unbiased assumptions, this has been achieved through better farm management and overall increase in productivity, rather than at the cost of the expansion of pasture areas. As such, it has contributed to the reduction of deforestation rates and increased sustainability of agricultural systems. Nonetheless, despite productivity gains in beef and dairy production, most pastures in Brazil present some degree of degradation and GHG emissions by cattle is considered to be excessive, due to poor forage quality and lower than optimum animal performance.

Accumulated scientific evidences indicate the intensification of pasture management and implementation of crop-livestock and crop-livestock-forest integrated systems as viable tools for reducing GHG emissions by cattle raising enterprises. However, most of the available data has been obtained in temperate zones of the globe while GHG actual emission levels by Brazilian livestock production systems are yet to be estimated.

In this context, the Pecus Research Network was conceived by Brazilian Agricultural Research Corporation (Embrapa) with the objective of obtaining the necessary data on GHG, using internationally accepted research protocols, in order to subsidize governmental policies and to contribute to the development of mitigation alternatives for GHG emission.

Scenario/justification/objectives: there is a lack of scientific information about the actual contribution of Brazilian livestock production to total GHG emission, despite recent achievements by national research teams.

Pecus Research Network was conceived considering the diversity of Brazilian landscapes and production systems, the complexity of components to be evaluated in each system and the necessity of evaluations to be made for extended periods. Pecus is a multi-institutional research project, involving interdisciplinary research teams devoted to long-term experiments distributed throughout the most important Brazilian biomes: Cerrado ("savanna"), Mata Atlântica (Atlantic forest), Amazônia (Amazon forest), Caatinga (semi-arid), Pantanal (lowlands) and Pampa (grassy plains).

Pecus Network main objective is to contribute to higher competiveness and sustainability of Brazilian livestock sector through the development of research aimed at determining GHG dynamics and carbon sequestration potential in representative production systems, in order to subsidize government policies and to indicate mitigation alternatives.

Project structure: Pecus component-projects aim at evaluating the balance between GHG emission and carbon sequestration in livestock production systems located in areas that represent all major Brazilian biomes. Specific projects have been delineated to store and process data, bio-physic modeling, evaluation of socio-economic impacts and geophysics. New methodologies for the estimation and nutritional strategies for enteric methane emission reduction by cattle will also be evaluated. The basic network structure is presented in Figure 2.

Coordinated research, state and privately financed, will involve several Embrapa Research Centers, universities and other national and international research institutions.

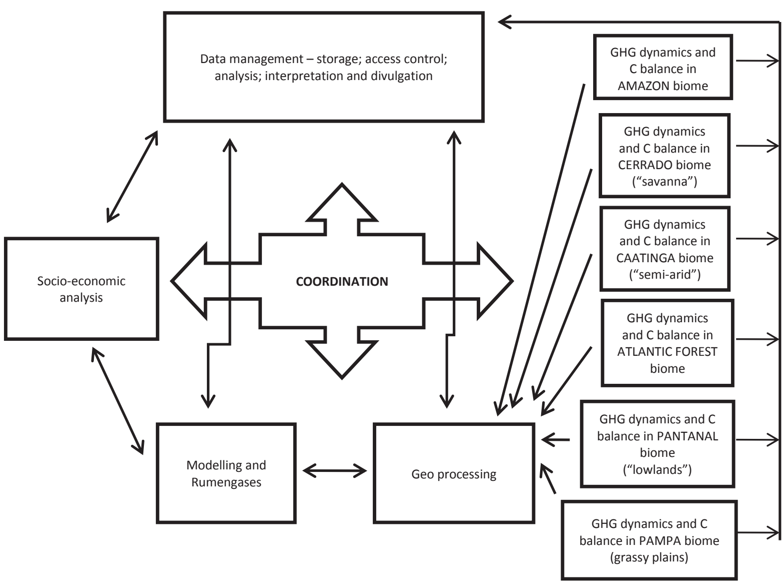

Figure 2. *Pecus* Research Network structure.

Points of research: in each of the six biomes, sub-projects (PAs) will scrutinize aspects related to GHG emission and mitigation in animal production systems using MRV methods - IPCC (Intergovernmental Panel on Climate Change), simultaneously covering the study of soil-plant-animal-atmosphere compartments (Figure 3). Trials will be repeated in time and space and will allow the determination of carbon balance in cattle (on pasture and feedlots), buffalo, sheep, goat, swine and poultry production systems. Evaluations will cover intensive and extensive cattle production, on pasture exclusively and on crop/forest/pasture integrated systems, using degraded pastures as negative and natural forests as positive control.

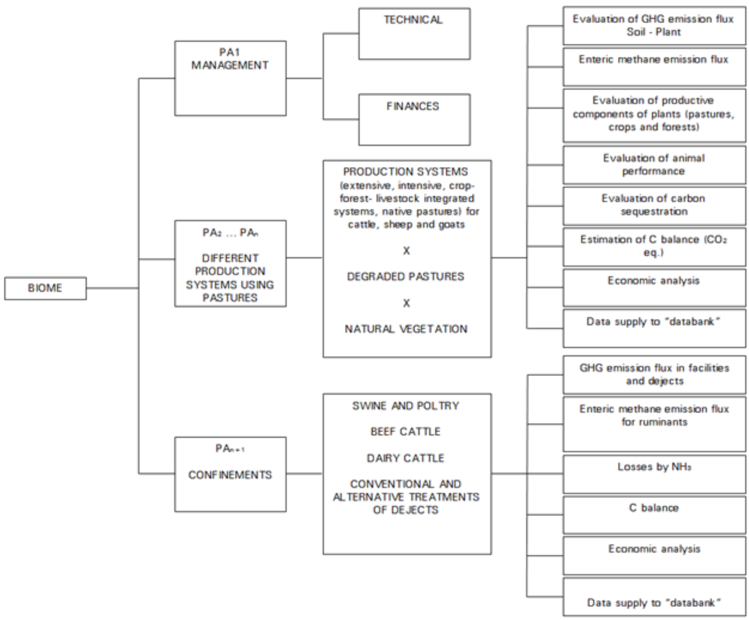

Figure 3. *Pecus* sub-projects (PAs) and research activities in Brazilian biomes.

Expected results: the main expected results from this project are: estimation of the contribution of different Brazilian animal production systems to GHG dynamics; determination of the mitigation potential of improved pastures and integrated systems; indication of management practices necessary to higher competitiveness and sustainability of livestock production in Brazil; provision of the scientific community, government agencies and society in general with GHG data, collected using adequate tiers and avoiding extrapolation of default indexes (mostly obtained in temperate areas) to Brazilian conditions.

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Embrapa
Swine & Poultry

This book provides a compilation of the papers presented at the second International Symposium on EMIssion of Gas and Dust from LIvestock (EMILI 2015). In regions of intensive livestock production as Santa Catarina State – Brazil, several regions must cope with environmental impacts due to livestock activities.

These impacts concern all compartments of the environment: water, soil, and air. According to national inventories emissions, confined animal feeding operations are major contributors of pollutant gas emissions, such as nitrous oxide, methane, ammonia, dusts (considering different particle sizes). For several years, academic, and scientific research has focused on: (1) determining the emission factors, (2) develop the best methods to calculate accurately those emissions, (3) understand the emitting processes, and (4) propose possible mitigation strategies.

This Symposium was held in 2015 to provide state-of-the-art research on gas and dust emissions from livestock and, also to bring up hot topics and relevant scientific questions. Scientists interested in livestock gas and dust emissions were able, in the second edition of this Symposium, to meet and evaluate the experimental results obtained since EMILI 2012. Invited speakers, and oral presentations were organized to communicate up-to-date information on emission factors, emitting processes, measuring methods, mitigation strategies, and environmental evaluation of pig, poultry, and cattle production.

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