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WHAT IS THE CONTRIBUTION OF PIGLET WASTE IN THE FIRST WEEK AFTER WEANING TO GREENHOUSE GAS EMISSIONS?

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ABSTRACT

This study aims to characterize the waste of weaned piglets and estimate the emissions of N_2O in kg of CO_2 eq/kg of weight gain in the first week of housing. Primary data were obtained in the first week after weaning of piglets to identify how much waste from this animal category may affect the environment. The life cycle assessment was applied to verify the amount of manure and the emission of nitrous oxide (N_2O) considering the weight gain (WG) of piglets in the first post-weaning week. Eight waste collections were carried out in two lots representing an average of 8,099 animals with initial and final weight of 5.01 and 5.84 kg, respectively. The production of residues was 0.128 kg of dry matter (DM) for each kilogram of WG produced. This waste production has an emission capacity of approximately 4×10^{-4} kg N_2O/kg WG in the first post-weaning week. Considering that N_2O has a global warming potential almost 300 times higher in retaining heat than CO_2, each 1 kg of piglet produced can emit about 0.129 kg of CO_2 equivalent from the N_2O produced. According to the number of piglets evaluated in this study, the total emission can reach 1.85 tons of CO_2 equivalent in the first post-weaning week alone.

QUAL A CONTRIBUIÇÃO DOS DEJETOS DE LEITÕES NA PRIMEIRA SEMANA PÓS-DESMAME SOBRE AS EMISSÕES DE GASES DE EFEITO ESTUFA?

RESUMO

Este trabalho teve como objetivo caracterizar os dejetos brutos de leitões desmamados e estimar as emissões de N_2O em kg de CO_2 eq./kg de ganho de peso na primeira semana de alojamento. Os dados primários foram obtidos na primeira semana pós-desmame dos leitões para identificar o quanto os resíduos dessa categoria animal podem impactar o meio ambiente. A avaliação do ciclo de vida foi aplicada para verificar a quantidade de dejetos e a emissão de óxido nitroso (N_2O) considerando o ganho de peso (GP) dos leitões na primeira semana pós-desmame. Foram realizadas oito coletas de dejetos considerando dois lotes, que representaram uma média de 8099 animais com peso inicial e final de 5.01 e 5.84 kg, respectivamente. A produção de resíduos foi de 0.128 kg de matéria seca (MS) para cada quilograma de GP produzido. Esta produção de dejetos brutos tem uma capacidade de emissão de aproximadamente 4×10^{-4} kg de N_2O/kg de GP na primeira semana pós-desmame. Considerando que o N_2O tem um potencial de aquecimento global quase 300 vezes mais eficaz na retenção de calor do que o CO_2, cada 1 kg de leitão produzido pode emitir cerca de 0.129 kg de CO_2 equivalente a partir do N_2O produzido, caso esses dejetos não sejam submetidos a algum processo de tratamento, pois essa produção é em relação ao dejeto bruto. De acordo com o número de leitões avaliados neste estudo, a emissão total pode chegar a 1.85 toneladas de CO_2 equivalente apenas na primeira semana pós-desmame.

SECTION EDITOR IN CHARGE

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INTRODUCTION

Pork is the second most consumed animal protein in the world, representing 40.1% of world per capita consumption. This figure means a large-scale production of pork. Brazil is in fourth position in the world ranking, with a production of 4.436 million tons of pork in 2020 (ABPA, 2021).

In order for the swine to reach the ideal slaughter weight, which is around 90 kg or more of live weight (PIÑEIRO et al., 2019), and to meet the demands of the consumer market, careful handling of the animals is necessary. Therefore, pig farming is divided into phases to ensure better quality in the final product. In this context, nutrition has been formulated and processed according to the needs of each stage of breeding, thus meeting the requirements of animals as for their physiological demands (XIONG et al., 2019). Each stage of swine has different characteristics, both in terms of handling and the residual attributes that constitute animal waste.

Among the phases of pig rearing, nursery has a significant importance in animal performance, since its beginning is marked by one of the most critical periods of pig farming, which is the weaning of piglets (JAYARAMAN & NYACHOTI, 2017). At this phase, the animals recently separated from the mother need a period of adaptation to the new diet and the rearing environment. In general, the swine diet is based on corn and soybean meal as the main ingredients. However, at the nursery phase, milk substitutes are used, especially during adaptation days, to minimize the impacts caused by weaning (PIETRAMALE et al., 2021).

During the adaptation, diarrhea resulting from changes in the conditions of the gastrointestinal tract and housing make animals vulnerable, causing a common drop in weight gain of piglets (ROCHA et al. 2016). Due to histological changes in the gastrointestinal tissue of piglets at the weaning phase, the diet provided in the nursery phase has an altered chemical composition and structure according to the development of the animals' gastrointestinal tract (WANG et al 2022). In addition, it is clear that not only physiological factors affect the performance of animals in the adaptation period, but also issues of social behavior of animals. According to Valentim et al. (2021), the mixing of litters of piglets after weaning causes a hierarchical dispute that interferes with food intake, also decreasing the performance of the animals.

Feeding directly affects the production of metabolic heat by the animal and the properties of the waste produced, emitting some forms of greenhouse gas (GHG) at the post-weaning phase (CHERUBINI et al., 2015; ANDRETTA et al., 2018). GHG emissions are present at all stages of animal production, from the extraction of natural resources to the end of the chain, when the product reaches the consumer's plate (RUVIARO et al., 2020). Among the gases that most cause concern about the volumes emitted are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O); this order follows the proportion of emitted gases (OLIVEIRA et al., 2020). However, the global warming potential follows the order N_2O, CH_4, and finally CO_2 (SHAKOOR et al., 2021).

During the nursery phase, emissions must already be taken into account, even if the piglets produce a smaller amount of manure compared to animals at the other phases. With the beginning of the ration-based feeding, the emission of gases with potential impact on the environment is already taken into account. To estimate the amount of greenhouse gases emitted by swine manure, it is common to use some mathematical models that can provide emission values according to the composition of the manure. Rigolot et al. (2010) used mathematical models to evaluate the volume, composition, and emissions of greenhouse gases from swine manure according to the characteristics of the diet and considering the housing effect of the animals.

Based on the above, this study aims to evaluate how much the adaptation process of the first week after piglet weaning may contribute to emissions of N_2O, as one of the greenhouse gases of greatest impact, calculated in CO_2-equivalent.

MATERIAL AND METHODS

Waste collection took place in a post-weaning piglet breeding unit located near the city of Dourados, MS, Brazil. The analyses were carried out at the Agricultural Residue Management

Laboratory, belonging to the Faculty of Agricultural Sciences of the Federal University of Grande Dourados, located in the municipality of Dourados, MS, Brazil (22°11'38'' S, 54°55 '49'' W, and 462 m of altitude).

The facilities on the farm where the animals were housed are made of masonry with side curtains, concrete foundations, automation of water and feed distribution systems, negative pressure ventilation, and a LED lighting system. The dimensions of each shed are 12.4 x 85 m, with a capacity for 2.700 animals each. The floor of the sheds is suspended and made of plastic, making it impossible for the animals to come into contact with the waste. The internal storage pits for residues (manure, urine, water, and feed residues) are located under the floor and have a depth of 40 cm, with a slope of 0.5% for drainage to the sides of sheds.

Waste collection was carried out in two lots of piglets at the post-weaning phase; for each lot, four collections were carried out weekly, thus totaling eight waste collections and representing an average of 8.099 piglets/lot, with an average initial weight and final weight of 5.01 and 5.84 Kg, respectively. The collections were divided into two points within each shed of the production unit for each production lot. Such these points faced the middle and the bottom of the shed in order to better represent the waste produced by the lots. These collections corresponded to male and female waste, as it was not possible to separate the production of waste by sex since piglets are mixed inside the shed. After that, the four manure collections were mixed, thus forming a composite sample of each lot.

Soon after collection, the characterization of the waste was carried out through the analysis of total solids (TS), volatile solids (VS), nitrogen (N), neutral detergent fiber (NDF), and acid detergent fiber (ADF). First, the waste was dried in a forced air ventilation oven for 72 hours at 60ºC; after drying, it was ground and sent to the laboratory for the analyses described above.

The levels of TS and VS were measured according to the methodology described by Apha (2005). The NDF and ADF contents were determined according to the methodology described by Silva & Queiros (2006). The N concentrations were determined using a VARIO MACRO Elementar analyzer.

The animals received diets to meet the requirements of the phase according to the recommendations of Rostagno et al. (2017). Table 1 shows the chemical composition of both the feed consumed by piglets at the post-weaning phase and the waste produced.

The generated waste mass was estimated from the mathematical model based on the work of Rigolot et al. (2010a), as described in Equation 1.

$$X_{feces} = X_{feed} \times (1 - CD_x) \qquad (1)$$

Where,
X_{feces} = Mass of manure produced (kg);
X_{feed} = Amount of feed consumed (kg);
CD_x = Coefficient of digestibility of ingredients' dry matter (Rostagno et al., 2017)

From the bromatological analysis of diets and the waste generated by piglets, in addition to the

Table 1. Bromatological profile of ingested feed and feces produced at the post-weaning phase

	Food profile				
	TS (%)	VS (%)	NDF (%)	ADF (%)	N (%)
Lot 1	8.28	77.46	25.62	21.68	3.71
Lot 2	6.69	80.07	27.00	22.66	3.64
Mean	7.48	78.77	26.31	22.17	3.68
	Fecal Profile				
	TS (%)	VS (%)	NDF (%)	ADF (%)	N (%)
Lot 1	9.01	82.37	28.58	26.02	3.36
Lot 2	6.44	77.55	25.25	20.44	3.81
Mean	7.72	79.96	26.92	23.23	3.59

TS – Total solids; VS – Volatile solids; NDF – Neutral detergent fiber; FDA – Acid detergent fiber; N - Nitrogen

mass of waste produced, it was possible to estimate the nitrous oxide (N_2O) emissions for each kilogram of piglet weight gain in the first week after weaning, as described in Equation 2. For this estimate, the mathematical model proposed by Rigolot et al. (2010b) was adapted to the results found through laboratory analyses.

$$N_2O_{emitted}(Kg) = 44/28 \times 0.06 \times \text{Initial N} \times \text{Final N} \quad (2)$$

Where,
N_2O = Nitrous Oxide;
44 = N_2 waste emission factor
28 = Temperature factor (estimated average for installations destined for the phase studied)
0.06 = N_2O waste emission factor
$N_{initial}$ = Estimated nitrogen from the diet of animals.
N_{final} = Nitrogen determined in laboratory analysis of animal waste.

According to Oliveira et al. (2020), the concentration of N_2O in the atmosphere is much lower than that of CO_2 and methane (CH_4). However, the heating potential of N_2O is about 300 times more potent than that of carbon dioxide (CO_2) (ALMEIDA et al., 2015). In this way, the estimated values of N_2O were multiplied by 300 to estimate the CO_2 eq. per kilogram of piglet weight gain at the end of the first week after weaning.

RESULTS AND DISCUSSION

Weight gain is a key variable to assess the performance of pigs, especially at the post-weaning phase, as the animal's developmental capacity at this first phase will determine its productive potential (ZHAI et al., 2020). During post-weaning, it is extremely important that pigs receive a balanced diet capable of meeting all their requirements. Thus, weight loss may be avoided during this period, and a correct diet provides a better modulation of the intestinal microbiota of these animals, with a good development of intestinal functions and of the immune system (CHEN et al., 2018).

The performance of pigs is also related to birth weight, as some piglets have a low birth weight, causing a disadvantage in weight gain in relation to heavier pigs (LO VERSO et al., 2020). In addition, weaning weight and age are also major influences on animal performance during subsequent phases (VALENTIM et al., 2021). The average weaning weight of piglets was 5.01 kg, with a variation between 4.91 and 5.12 kg, between the first and second lots (Table 2). The average weight gain during the first post-weaning week was 0.83 kg, with variations between the first and second lots of 0.67 and 0.99 kg, respectively. Pig weights were similar as those reported by Valentim et al. (2021) in a meta-analytic study in which the lowest value was 4.51 kg/animal at 18 days of lactation. It was not possible to identify the age of animals in these studies due to the miscegenation of animals in each lot.

GHGs are present in all industrial and non-industrial processes as factors of high environmental impact (TULLBERG et al., 2018). However, food production has been wrongly accused of increasing GHG emissions and their impacts on the environment; after all, many production factors are no longer inventoried (ELDESOUKY et al., 2018). Claiming that the potential environmental impacts of swine production do not exist is negligent if evaluating the industrial production system, since it depends on large-scale grain production for animal feed. However, ways to reduce impacts have been studied both in terms of production efficiency and manure treatment technologies

Table 2. Piglet performance during the first post-weaning week

	Productive profile				
	WE	WO	TWG	FIR	FC
Lot 1	5.12	5.79	0.67	1.43	2.13
Lot 2	4.91	5.90	0.99	1.66	1.67
Mean	5.01	5.84	0.83	1.54	1.90

WE – Average entry weight (kg); WO – Average output weight (kg); TWG – Average total weight gain (kg); FIR – Average feed intake (kg); FC-Feed conversion

applied to swine systems (PIETRAMALE et al., 2021; CHERUBINI et al., 2015).

Actions related to means of mitigating environmental impacts in the swine production activity may be applied to the management of animals, improving their housing and breeding conditions at each physiological phase. Thus, making productive efficiency a decision-making point on the mitigation of GHG emissions must be precisely calculated; after all, the more one produces with a same resource, the better it is for the environment. Martinelli et al. (2020) calculated the eco-efficiency of poultry activity and identified that greater animal weight gains dilute greenhouse gas emissions regarding CO_2, CH_4, and N_2O.

The manure dry mass was 0.128 kg/kg of WG during the studied phase, or in natural matter of waste, it resulted in 0.245 kg of manure/kg of WG. The recommendation is that the waste mass be directed to biodigesters, so that GHG emissions can be captured and used as renewable energy sources. The productive potential of N_2O was estimated at 0.0004 kg/kg of WG, transformed into kg of CO_2 eq. to assess the phase's global warming potential. In this study, even the N_2O representing a smaller portion of the gas emissions still presents a considerable amount of CO_2 eq./kg mass on the piglet weight gain (Table 3). Although the volume emitted is low in a numerical context, when considering total weight gain, the volume of CO_2 eq. is estimated at 820.71 kg/lot during the week of adaptation of the animals only from the N_2O emitted by the manure.

In a study by Gudiño et al. (2020) on Iberian swine production systems of the "Pata Negra" type in Southwest Spain with animals of breeds adapted to the system, the same more extensive and organic breeding models have similar environmental impacts as those of conventional models. In this study, the manure emitted was about 0.283 kg of N_2O/animal at the beginning of the growth phase.

In another study carried out by Reckmann et al. (2013), the post-weaning phase represented about 13% of CO_2 eq. of the production chain of finished swine, with an average of 94 kg of live weight. The N_2O/animal unit at the end of the chain was 1.07 kg, of which 30% refer to rearing stages, of which the nursery stage represents 13%, totaling 0.042 kg of N_2O/piglet at the post-weaning phase.

A volume similar as that reported in the study by Reckmann et al. (2013) on the emission of N_2O/piglet was found by Gutierrez et al. (2018), but at the phase that corresponds to that proposed here, i.e., the first days after weaning. However, the animals studied by Gutierrez et al. (2018) weaned at heavier weights, around 12.29 kg/piglet, different from the piglets housed in this study, which had 5.01 kg/animal. This weight difference may be related to age at weaning; this is an indicator to which we did not have access, by which older animals at weaning tend to weigh more and suffer less from the impacts of the first post-weaning week. This factor makes the comparison of emissions unfair, but it also expresses how weight and age at weaning may directly affect production efficiency and emissions of gases impacting the environment.

Just as productive efficiency generates an impact on GHG emissions, the type of animal waste and its respective management (storage and destination) are critical factors in these emissions. Shakoor et al. (2021) highlight the importance of obtaining detailed information on the emissions of different types of waste to assess the possibilities of applying the final waste in agricultural crops in order to mitigate GHG emissions.

Table 3. Impact profile of post-weaning swine manure

				Impactful Profile				
	TWG	AFI/kg of WG	Cddm	DM_{feces}/kg of WG	WV/kg of WG	N/WG	N_2O/WG	CO_2 eq./WG
Lot 1	0.6700	2.1343	0.9018	0.1405	0.2677	0.0048	0.0004	0.1346
Lot 2	0.9900	1.6768	0.9298	0.1165	0.2237	0.0044	0.0004	0.1246
Mean	0.8300	1.9055	0.9158	0.1285	0.2457	0.0046	0.0004	0.1296

TWG - Average total weight gain (kg); AFI/kg of WG - Average feed intake/kg of average weight gain; Cddm - Coefficient of digestibility of dry matter; DM_{feces}/kg of WG - Dry matter volume of manure per kilogram of weight gain; WV/kg of WG - Waste volume (manure + water)/kg of average weight gain; N/WG - Nitrogen (%)/kg average weight gain; N_2O/WG - kg of nitrous oxide/kg average weight gain; CO_2 eq/WG - kg of carbon dioxide equivalent/kg average weight gain

In this sense, recently Xia et al. (2020) performed a meta-analysis to identify how the application of different animal manure sources (barnyard, swine, cattle, and poultry manure) to agricultural soils affects soil N_2O and emission factors considering only tests in fieldwork carried out on a global scale. Tests carried out with manure from barnyard, swine, cattle, and poultry manure, both raw (composted) and pre-treated (digested), were analyzed. The authors stated that, regardless of the type of manure, the application increases the emission of N_2O from the soil, and such emissions are also affected by climatic conditions, agricultural practices, and initial properties of the soil. Raw manure emission was significantly higher than digested manure, indicating that pre-treatment is essential in mitigating emissions.

Shakoor et al. (2021) performed a meta-analysis similar as that of Xia et al. (2020), but also including CO_2 and CH_4 emissions, and corroborate the evidence that the effects of animal manure on GHG emissions depend on soil attributes (pH, texture, and porosity), type of crop, environmental conditions, and climatic zone. Although Shakoor et al. (2021) have observed a lack of studies in areas with a tropical climate, Xia et al. (2020) obtained indications of higher emissions of N_2O in warm temperate climates compared to tropical climates.

Aita et al (2014; 2019) developed some strategies, in experimental research, seeking to mitigate N_2O resulting from the application of liquid manure from dairy cattle and swine in a no-tillage system in Argisols and Latosols in the southern region of Brazil. The residues were applied on the surface of crop residues and also by means of subsurface injection into the soil. These experiments showed that the emissions of N_2O from liquid swine manure applied to the surface of Latosol were on average 73.9% than in the Argisols, obtaining average emission factors of 1.23% for Argisol and 0.43% for Latosol. The average emission factors of N_2O from the manure injected into the soil were higher than when applied on the surface for both types of soil. Although there was a decrease in ammonia volatilization (NH_3) and a greater retention of N in the soil, its concentration in the injection grooves together with carbon and moisture favored the production of N_2O.

Environmental conditions during waste application may be a critical moment for the loss of N by volatilization of NH_3 (BELL et al., 2016). Thus, soil temperature, followed by humidity, and the ammonia content in the soil are N_2O emission control mechanisms, as Cardoso et al. (2020) and Aita et al (2014) reported. Cardoso et al (2020) measured emission factors for various types of animal waste and found no significant differences between them, obtaining an average of 0.39% of N_2O emitted by manure applied to pastures in a tropical climate in Brazil.

The global average results found by Shakoor et al. (2020) indicate that, compared to synthetic nitrogen fertilizers (1.25%), the net emission factor of N_2O from animal waste was lower (1.11%) and similar as that recommended by the IPCC (1%). Considering these results, for the authors above, the use of animal waste may be an alternative to the application of synthetic fertilizers since it may help in soil correction, carbon sequestration, and improvement of crop fertility, with benefits for waste disposal, thus justifying a moderate additional contribution to GHG emissions.

Considering the works above, it appears that the values of emission factors of N_2O obtained in Brazil differ considerably from works carried out in warm temperate climates (CARDOSO et al., 2020; AITA et al., 2014; 2019). Shakoor et al. (2021) found that research in this area is still incipient and that statistical data are lacking for better inferences about the mechanisms of N_2O emission from biofertilized soils.

CONCLUSION

- From the discussions exposed in this study on GHG emissions from swine farming, animal manure is an aggravating factor in terms of environmental impacts, especially in relation to the emission of N_2O. The mitigation of potential N_2O emitters from manure is an action that could lead to benefits in terms of reducing the environmental impacts of swine farming.

- The mass of CO_2 eq./kg over piglets' weight gain is 0.135 and 0.125 for lots 1 and 2, respectively. This figure is considerably high for gas emissions at this stage.

- The forwarding of waste to recycling methods, such as anaerobic biodigestion, will certainly

mitigate their emission potential, leading to environmental benefits and also the recovery of waste due to the production of clean energy and biofertilizers.

AUTHORSHIP CONTRIBUTION STATEMENT

OLIVEIRA, J.D.: Formal Analysis, Investigation, Resources, Visualization, Writing – original draft; **ORRICO, A.C.A.:** Project administration, Resources, Supervision, Visualization, Writing – review & editing; **PIETRAMALE, R.T.R.:** Conceptualization, Investigation, Software, Visualization, Writing – original draft; **ROSA, C.O.:** Conceptualization, Data curation, Investigation, Validation, Writing – original draft; **RUVIARO, C.F.:** Funding acquisition, Project administration, Supervision, Writing – original draft, Writing – review & editing; **LEITE, B.K.V.:** Formal Analysis, Investigation; **MACHADO, J.F.:** Formal Analysis.

DECLARATION OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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