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Nutrients in swine manure for use as soil fertilizer[1]

Nutrientes em dejetos de suínos para sua utilização como adubo de solo

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HIGHLIGHTS:

Liquid swine manure is a source of nitrogen, phosphorus, and potassium (NPK) and can be utilized through fertigation.
Liquid swine manure is an efficient substitute for NPK chemical fertilizers.
By using pig manure instead of NPK chemical fertilizers, it was possible to save R$11,743.44 in chemical fertilizers.

ABSTRACT: Brazil is one of the world's largest producers and exporters of animal protein, and swine farming plays a significant role in this sector. With the increase in the prices of mineral fertilizers, swine manure can be an alternative for fertilization and reduce production costs if carefully monitored to minimize damage and environmental impacts. The objective of this study was to characterize swine liquid slurry from a commercial finishing farm and determine the concentrations of total nitrogen, $N\text{-}NH_4^+$, total phosphorus, and potassium for its use as a source of nutrients for the soil. The manure volume was calculated. The body retention of nitrogen, phosphorus, and potassium and physical and chemical attributes of the feed and manure were evaluated. In the analyzed swine manure, the concentrations of the total nitrogen, ammoniacal nitrogen, total phosphorus, and potassium were 6.14, 2.87, 3.66, and 2.64 g L^{-1}, respectively. Liquid swine manure proved to be an efficient substitute for nitrogen, phosphorus, and potassium chemical fertilizers, representing cost savings of R$11,743.44 in chemical fertilizers.

Key words: swine farming, sustainability, production cost, organic fertilization, swine liquid slurry

RESUMO: O Brasil é um dos maiores produtores e exportadores mundiais de proteína animal, e a suinocultura desempenha um papel significativo neste setor. Com o aumento dos preços dos fertilizantes minerais, o dejeto de suínos pode ser uma alternativa para adubação e redução dos custos de produção se monitorado cuidadosamente para minimizar danos e impactos ambientais. O objetivo do estudo foi caracterizar os dejetos líquidos suínos de uma granja comercial de terminação e determinar as concentrações de nitrogênio total, $N\text{-}NH_4^+$, fósforo total e potássio, para sua utilização como fonte de nutrientes ao solo. O volume de esterco foi calculado. Foram avaliadas a retenção corporal de nitrogênio, fósforo e potássio e os atributos físicos e químicos da ração e do esterco. Nos dejetos de suínos analisados, as concentrações de nitrogênio total, nitrogênio amoniacal, fósforo total e potássio foram 6,14, 2,87, 3,66 e 2,64 g L de nitrogênio total, nitrogênio amoniacal, fósforo total e potássio, respectivamente. O esterco líquido de suínos mostrou-se um eficiente substituto dos fertilizantes químicos nitrogenados, fosfatados e potássicos, representando economia de R$ 11.743,44 em fertilizantes químicos.

Palavras-chave: suinocultura, sustentabilidade, custo de produção, adubação orgânica e dejetos líquidos de suínos

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Introduction

The increase in world population is directly related to the increasing demand for food, both plants and animals. Brazil is well known for producing animal proteins, and pork production has been gaining prominence in the country.

Swine farms generate significant amounts of manure, which can be a source of soil nutrients. Swine liquid manure (SLD) contains significant amounts of nutrients that can be used as organic fertilizers, promoting the economic viability of production through savings in mineral fertilizers (Guimarães & Guanziroli, 2022).

A swine weighing between 50 and 100 kg produces 5.5-7.5 L of manure daily, which can release nutrients, mainly N, P, and K (Locatelli et al., 2019). Generally, the availability of N is associated with the degree of organic N mineralization and the destination of the ammoniacal fraction. If N is stored in anaerobic reservoirs, its availability can represent more than 70% of the N. If supplied through the SLD in an organic form, P is easily decomposed and organically accumulates in the soil. After application, P accumulates in the labile fractions of the soil (Ceretta et al., 2010).

Swine farming is an important livestock activity, and approaches to minimize possible environmental impacts must be investigated, as swine farms can pollute the soil and water, cause eutrophication, and impact global warming of the environment with CO_2 emissions (Su et al., 2019), if not managed satisfactorily.

The objective of this study was to characterize SLD from a commercial finishing farm and determine the average concentrations of total N, N-NH_4^+, total P, and K for its use as a source of nutrients for the soil.

Material and Methods

Data were collected in three months at a commercial swine finishing farm in the municipality of Alto Bela Vista, SC, Brazil (27° 18' 34" S and 51° 59' 30" W, altitude: 548 m). The experimental period was from 03/11/2013 to 07/02/2014, with a predominance of southeast (SE) and northeast (NE) winds. The climate was humid subtropical mesothermal Cfa with hot summers (a mean annual air temperature of 18-19 °C and a mean annual precipitation of 1700-1900 mm) according to the Köppen classification (Pandolfo et al., 2002).

A total of 144 commercial hybrid swine from strains selected for lean meat production (Landrace and Large White), comprising females and castrated males, were randomly housed in 12 pens during the finishing phase. The investigated farm adopted an accommodation standard of four lots per year.

The volume of manure produced by the swine was estimated based on the results published by Tavares et al. (2014). The results obtained by the authors during the modeling application demonstrate that the model allows for estimation with an R^2 value of 0.993. The volume of the produced manure was determined using Eq. (1):

$$y = 4.9676 \times e^{-e^{-0.3589\times(t-0.0579)}} \tag{1}$$

where y is the production of manure (kg per swine per day), and t is the period (in weeks).

Throughout the study period, the animals received granulated feed produced from soy and corn. Samples of the feces were directly collected from the storage channels without previous packaging. Feed composite samples were collected twice a week, totaling 32 collections, for physical-chemical analysis in the food analysis laboratory of Embrapa Suínos e Aves Concórdia - SC, where they were processed and analyzed using standard methods (AOAC, 2016). The swine manure was characterized based on the variables listed in Table 1.

The volume of water in the liquid manure produced by the swine was estimated using Eq. (2):

$$\text{H deject} = \text{M eflu} - (\text{M eflu} \times \text{MS dejeto}) \tag{2}$$

where H deject is the water contained in the manure (kg), M eflu is the mass of the effluent produced (kg), and MS dejeto is the dry matter of the manure (%).

The amount of nitrogen entering the system through the feed was calculated using Eq. (3):

$$\text{N alim} = \text{ration} \times \text{N ration} \tag{3}$$

where N alim is the nitrogen ingested by the feed (kg per swine), ration is the ingested feed (kg per swine), and N ration is the nitrogen of the feed (g kg per feed).

Body nitrogen retention in the swine was calculated according to Corpen (2003), as expressed by Eq. (4):

$$\text{Nret} = \frac{e^{(-0.9385-0.0145\times\text{TVM})} \times \left(0.915 \times \text{PV}^{1.009}\right)^{(0.7364+0.0044\times\text{TVM})}}{6.25} \tag{4}$$

where N retained is the nitrogen retained in the animal carcasses (kg per swine), PV is the average live weight of animals (kg per swine), and TVM is the lean meat content in the carcass (59%).

The N in the swine manure was as a result of the removal of unused amino acids for animal protein synthesis, desquamation of the epithelium of the digestive tract, feed residues, and other minor components. It was estimated using Eq. (5):

$$\text{N deject} = \text{deject} \times \text{N} \tag{5}$$

where N deject is the nitrogen contained in the manure (kg), deject is the amount of manure produced (kg), and N is the nitrogen content of the manure (%).

The carbon ingested through food was calculated using Eq. (6):

Table 1. Physical-chemical variables analyzed and analytical method

Physicochemical variables	Analytical method
Total carbon (mg kg^{-1})	Oxidation of organic matter
Kjeldahl nitrogen (N-Total)	Kjeldahl - Titrimetric
Ammonia nitrogen (N-NH_4^+)	Reaction-based spectrophotometry of Griess
Total phosphorus (P) (mg kg^{-1})	Absorption spectrometry in the ultraviolet/visible (UV-Vis)
Potassium (K) (mg kg^{-1})	Flame photometry

$$\text{C alim} = \text{A} \times \text{C} \tag{6}$$

where C alim is the carbon ingested through the food (kg), A is the ingested food (kg), and C is the carbon in the food (calculated from dry matter/2).

The carbon content (kg) of the animals at the beginning of the lot was calculated using Eq. (7):

$$\text{C animal} = \text{PV animal} \times \text{C} \tag{7}$$

where C animal is the amount of carbon retained in the body (kg), PV animal is the live weight of the animal (kg), and C is the carbon content of the swine tissues (calculated as dry matter/2 = 200 g C per kg body weight).

The amount of carbon in the waste at the end of the batch (kg) was estimated using Eq. (8):

$$\text{C deject} = \text{deject} \times \text{C} \tag{8}$$

where C deject is the accumulated carbon in the manure (kg), Deject is the mass of manure (kg), and C is the carbon in the manure (%).

The P and K input into the system through the feed were estimated using Eqs. (9) and (10), respectively:

$$\text{P ration} = \text{ration} \times \text{P} \tag{9}$$

$$\text{K ration} = \text{ration} \times \text{K} \tag{10}$$

where P ration and K ration are the amounts of P and K that enter through the ration and feed, respectively (g kg^{-1}), ration is the amount of ration or feed consumed (kg), P and K are the phosphorus and potassium contents, respectively (mg kg^{-1}).

The P and K contents of the manure were estimated using Eqs. (11) and (12):

$$\text{P deject} = \text{deject} \times \text{P} \tag{11}$$

$$\text{K deject} = \text{deject} \times \text{K} \tag{12}$$

where P deject and K deject are the amounts of P and K accumulated in the manure, respectively (g kg^{-1}), Deject is the amount of manure produced (kg), and P and K are phosphorus and potassium contents, respectively (mg kg^{-1}).

The body retentions of P and K were estimated according to Corpen (2003) using Eqs. (13) and (14), respectively:

$$\text{P} = 5.3 \times \text{PV} \tag{13}$$

$$\text{K} = -0.0034 \times \text{PV}^2 + 2.53 \times \text{PV} \tag{14}$$

where P and K are the P and K contents retained in the carcass, respectively (g kg^{-1}), and PV is the live weight of the animal (kg).

The mass balance of each element was determined from the amount that entered the rearing system, which was retained in the swine carcass, excreted in the manure, and lost in the form of gas. Regarding the fixed elements (K and P), elements without losses via volatilization, calculations were performed to validate the mass balance. The data were adjusted using regression as a function of housing time.

Results and Discussion

The volume of feed consumed by the swine in the building (kg of swine per feed per day) during the production cycle management as a function of time (weeks) of housing was 1 kg per swine per day, and in the 15th week was 2.8 kg per swine per day. These are similar to values reported in the literature for swine reared under similar conditions (Kiefer et al., 2011).

According to Freitas (2005), studies on growth curves are more abundant for swine species that present growth, similar to the findings of this study.

Eq. (1) (presented by Tavares et al., 2014) estimates the volume of waste generated in buildings for manure production as a function of housing time (in weeks).

The results showed that, on average, the swine produced 4.59, 4.83, and 4.94 L of manure per day for 7, 10, and 14 weeks, respectively, with the mean manure production of 4.78 L per swine per day. The values obtained for the average production of manure are lower than those reported in the literature. This indicates an average production of liquid manure of 5.5-7.5 L^{-1} for a swine with a weight of 50-100 kg (Locatelli et al., 2019).

Manure production increases throughout the production cycle, showing the same trend of water consumption by the animals and an increase in live weight (Babot et al., 2011). The results for bromatological analyses of the feed consumed by the animals during the rearing period are presented in Table 2.

Carbon is one of the main constituents of feed, as it is present in proteins, carbohydrates, and lipids. Its content remained constant throughout the analyzed period. The dry matter content of a feed indicates the dry part of the feed.

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Table 2. Bromatological composition of ration as function of housing time

Variable	Accommodation (week)	Average	Mean standard error
Carbon (g kg^{-1})	11	403	4.88
	12	418	
	13	407	
	14	400	
Nitrogen (g kg^{-1})	11	32	1.81
	12	40.4	
	13	34.4	
	14	34.5	
Phosphorus (g kg^{-1})	11	5.0	0.21
	12	5.9	
	13	5.49	
	14	5.89	
Potassium (g kg^{-1})	11	6.59	0.20
	12	7.29	
	13	7.45	
	14	7.47	
Dry matter (%)	11	88.23	0.00079
	12	88.27	
	13	88.53	
	14	88.52	

remained constant throughout the analyzed period. The dry matter content of a feed indicates the dry part of the feed.

The average values of N in waste are fundamental for the appropriate management of soil as a source of nutrients. Table 3 lists the average concentrations of total N (NT) and ammoniacal N ($N\text{-}NH_4^+$) in the manure, depending on the installed equipment and swine housing time.

The mean values of the NT and $N\text{-}NH_4^+$ concentrations decreased from the 11th to the 12th week but increased from the 13th to the 14th week. This is justified by the relationship with the crude protein content supplied in swine feed because swine loses its ability to assimilate this nutrient and increase the excretion rate through feces and urine.

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Table 4 lists the average concentrations of the total P (PT) and K in the manure as a function of swine housing time.

The values obtained for the mean concentrations of PT were generally higher than those reported in the literature. The mean values obtained for K were similar or higher than the results presented in the literature (Ferreira et al., 2005).

The average K concentration showed an increasing trend during the evaluation period, which might be related to the increase in temperature in the final weeks. Thermal stress increases K excretion and consequently, may decrease the K retention of the body, thus affecting the K concentrations in waste (Bernabé et al., 2020).

Carbon is a volatile element when it exists in CH_4 and CO_2, and the excess carbon that enters the production unit is lost to the atmosphere in a gaseous form.

Table 5 lists the data for the average concentrations of NT, $N\text{-}NH_4$, PT and K in the manure (mg L^{-1}), considering 11 to 14 weeks of animal housing. Based on the average manure production per animal (4.78 L per swine per day) for 7, 10, and 14 weeks of animal housing, the average production of the elements constituting the manure produced per animal per day was calculated.

The total or partial substitution of mineral fertilizer sources with organic fertilizers can decrease production costs and, consequently, increase profitability. The use of swine manure as a fertilizer for soil is a good alternative for rural producers; however, it must be analyzed and monitored to maintain the balance between the chemical composition of the manure and the required amount of nutrients for plants, by soil chemical analysis.

According to Bolzani et al. (2022), the balance of nutrients in the soil solution and those present on the surfaces of soil colloids determines the amount of nutrients available for plant uptake.

Table 6 lists the average concentrations of N, $N\text{-}NH_4^+$, P, and K as functions of the manure produced per animal and for the lot analyzed.

The concentrations of N, $N\text{-}NH_4^+$, P, and K represent significant savings for rural producers, and manure from swine farms can be used as a source of NPK fertilizers. Sanches et al. (2022) reported that well-managed areas with swine manure fertilization show high agricultural productivity.

Table 7 lists the commercial values in reais per kg of NPK, savings in kilograms of NPK and reais for one batch of 144 animals, and savings in reais for one year, considering four batches of swine.

In one year, considering four lots of 144 animals, 11,743.44 reais of commercial NPK fertilizers can be saved per year (Table 7).

Table 3. Average concentrations of total N (NT) and ammoniacal N ($N\text{-}NH_4^+$) of manure in original matter as function of swine housing time

Variable	Accommodation (week)	Average (mg L^{-1})	Mean standard error
NT	11	7082	479.94
	12	5365	
	13	5358	
	14	6781	
$N\text{-}NH_4^+$	11	3596	285.75
	12	2479	
	13	2518	
	14	2849	

Table 4. Average concentrations of total P (PT) and K in the manure, depending on swine housing time

Accommodation (week)	Concentration PT average (mg L^{-1})	Concentration K average (mg L^{-1})	Mean standard error
11	2460	2308	76
12	4000	2409	795.5
13	4160	2680	740
14	4040	3180	430

Table 5. Average concentrations and average production of NT, $N\text{-}NH_4$, PT, and K

Element	Average concentration (g L^{-1})	Average production (g per swine per day)
NT	6.14	29.38
$N\text{-}NH_4$	2.87	13.72
PT	3.66	17.51
K	2.64	12.64

Table 6. Average concentrations of N, $N\text{-}NH_4^+$, P, and K as function of manure produced per animal and for analyzed batch of 144 animals in 51 days per batch and for four batches per year

Element	Average kg concentration per swine for 4 batches per year (swine kg^{-1} per year)	Average concentration of kg per swine for 144 animals and 51 days (kg swine per batch)	Average concentration of swine kg for 144 animals and 4 batches in the year (kg per year)
N	5.99	215.76	863.04
$N\text{-}NH_4^+$	2.79	100.75	409
P	3.57	128.59	514.36
K	2.57	92.83	371.32

Table 7. Commercial value and savings in kg of NPK in reais for one batch and per year

Element	Commercial value (Real kg^{-1})	Average savings in kg of NPK element (kg per batch)	Average savings in Reais for 144 animals and 1 lot (Real per lot)	Average savings in Reais for 144 animals and 4 lots (Real per year)
N	9.50	100.75	957.12	3,828.50
P	3.50	128.48	449.68	1,798.72
K	16.50	92.67	1,529.05	6,116.22
Amount			R$ 2,935.85	R$ 11,743.44

Each animal produces 4.78 L of waste per day; per lot, 144 animals produce 35,104.32 liters of waste in 51 days. For four lots per year, the total waste reaches 140,417.28 liters.

According to CONAMA Resolution 430 dated 13/05/2011 (Brasil, 2011), wastewater generated during the production process must receive treatment before its release into a body of water or be disposed of in an ecofriendly manner on land. Current legislation allows for the application of up to 50,000 L ha^{-1} on land. Thus, at least 2.8 hectares is required to dispose of 140,417.28 L of waste without polluting the soil.

In an area of approximately 3 ha, savings of R$ 11,743.44 in chemical fertilizer use can be achieved. This represents a significant economic benefit that represents the use of fertirrigation of swine manures as an organic fertilizer, provided that they are used properly with soil chemical control, respecting the balance in nutrients between the soil and plants. Moreover, it must be ensured that they do not compromise soil and environmental quality, and the waste is pretreated to mineralize the organic matter and minimize the load of pathogenic microorganisms.

Sousa et al. (2020) conducted an economic feasibility analysis of investments in swine waste treatment systems and investigated their use as a biofertilizer in the soil, presenting the best economic return.

The application of swine manure to the soil must be performed with respect to the soil capacity and plant requirements to avoid causing contamination of the soil and water table, nutrient imbalance, and soil salinization (Paniagua & Santos, 2021). Studies have been conducted to treat wastewater from production by controlled disposal into the soil to prevent salinization and alkalinity in irrigated agriculture (Pegoraro et al., 2021).

Using wastewater in soil has several benefits and is an effective alternative for sustainable production (Oliveira et al., 2021) and biological processes, thereby facilitating high productivity rates (Sanches et al., 2022).

Conclusions

1. In the swine manure analyzed in this study, the concentrations of total nitrogen, ammoniacal N, total phosphorus, and K were 6.14, 2.87, 3.66, and 2.64 g L^{-1}, respectively.

2. The use of liquid swine manure is an efficient substitute for NPK chemical fertilizers, representing savings of R$11,743.44 in chemical fertilizers.

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