

Review

Treatments and utilization of swine waste in Brazil

Kesia Damaris de Azevedo Frigo^{1*}, Armin Feiden¹, Silvio César Sampaio¹, Geraldo Camilo Alberton², Lara Talita Schneider¹, Gabriela Bonassa¹, Elisadro Pires Frigo² and Reginaldo Ferreira Santos¹

¹State University of West Parana, University Street, University Garden, Cascavel, PR 85819-110, Brazil.

²Federal University of Parana, Pioneiro Street, Palotina, PR 85950-000, Brazil.

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Swine wastes obtained from farming activities have the greatest impact on the environment by environmental agencies. Swine wastes together with poor management represent risks to the environment. In Brazil, these activities significantly increased in the last years and from 2014, the country became the fourth largest producer in the world. Swine wastes are generated in high amounts due to the confinement system used nowadays. This, coupled with the poor management of these wastes is now a serious problem to the environment. Therefore, the treatment of this waste is essential to maximize integration between environment and production. Based on this, the aim of this study is to perform a bibliographic survey of the swine waste treatment used mostly in Brazil and the ones that stand out most.

Key words: Swine waste, reuse, environment.

INTRODUCTION

Unlike other agribusiness production chain, Brazilian pig farms have grown significantly over the years. This growth is perceived when social and economic indicators are analyzed. Pig production of the past evolved technologically and activated the models of the rural and agroindustrial producers.

Among the agricultural activities, the production of pigs is considered to have the greatest environmental impact, because it has a high polluting power. A farm with 600 animals has a polluting power just like a number of 2100 people (Diesel et al., 2002; Rizzoni et al., 2012).

Targeted as a practice around the world, swine breeding is important for the social and economy development of countries. The largest world producer in the year 2015 was China with a production of 56375 (thousand/t), followed by Europe with an approximate production of 56375 (thousand/t) and United States with a production of 11158 (thousand/t). Brazil ranked fourth with a production of 3643 (thousand/t), followed by Russian with a production of 2630 (thousand/t) (USDA, 2016).

The swine industry got a major breakthrough in Brazil when it began to introduce new technologies primarily in

*Corresponding author. E-mail: kesia.damaris@gmail.com. Tel: +55 (45) 3220-3000.

Table 1. Physical and chemical features of the swine waste.

Parameter	Medium values
pH	7.8
Alkalinity (mg/L)	3135
Ammoniacal nitrogen (mg/L)	4.26
Total solids (%)	18.9
Volatile solids (%)	76.4
COD (g/L)	210.0
K (mg/L)	293
Ca (mg/L)	64
Mg (mg/L)	13
Fe (mg/L)	1.6
Cu (mg/L)	0.8
Zn (mg/L)	0.5

Source: Huang et al. (2015, 2016).

the areas of genetics, nutrition and health (Espindola, 2012). The total production of pork meat in Brazil that was exported had an approximate value of 1279 (thousand/t), which triggered revenue of 555 million dollars. The south states are predominately responsible for the country's exports accounting for 80.3% of the total. The main countries importing Brazilian pork are located in Extra-EU Europe, Oceania, the Middle East and the European Union (ABPA, 2016).

The Brazilian production of pork meat occurs in small and medium scales using the model of confinement, along with escalating consumption of pork meat. There had been an increase in its production, and such activity is directly dependent on natural resources, requiring a high water demand and generating a high wastes amount which should be properly treated. This is why it is necessary that here must be proper awareness of the impact of such activity upon water resources and the environment (Gomes et al., 2014; Schneider and Carra, 2016).

The effluent coming from this activity has a high content of suspended solids and organic matter, and high concentration of nutrients, mainly phosphorus and nitrogen (Chelme-Ayala et al., 2011).

Studies on the levels of contamination of water resources have been increasing due to the launching of swine manure without proper treatment (Schoenhals et al., 2007). The present study aims to study the main forms of treatment and subsequent use of swine waste in Brazil.

BIBLIOGRAPHIC REVIEW

Residuary waste water from swine farming

Swine farming activity directly influences the socio-

economic and cultural aspects of a nation that uses it for subsistence farming. However, it is considered a low environmental quality activity; it is hazardous to water, soil and air, causes unpleasant odors, insect proliferation on site and environmental discomfort to people living near it (Belli Filho et al., 2001). A study by Carvalho et al. (2015) demonstrates that about 62% of the farms studied had their environmental management system considered unsatisfactory and potentially generating environmental risks.

Due to the fact that the pig production system in Brazil is confinement type, it results in higher water consumption on the premises and therefore increases in the production of water waste. The amount of residuary wastewater which is generated may vary between 5 and 10 L swine⁻¹.day⁻¹ (Schoenhals et al., 2007; Batista et al., 2013).

This amount of swine manure will vary according to the animal development; on average, the values are 4.9 to 8.5% in relation with the live weight per day in the range of 15 to 100 kg. That is, on average, adult pig produces between 7 and 8 L of liquid waste per day or 0.21 to 0.24 m³ per month (Diesel et al., 2002). Orrico Junior et al. (2010) evidenced that the composition features of swine waste are related to the quality and quantity of the reasons for which it is used. With this in mind, it triggers a larger variation in concentration of each component as present in the waste. In Table 1, it can be observed the physical and chemical features of untreated swine waste.

The large production of waste in a small confinement causes an environmental concern. With the study of new technologies for proper treatment and the proper release of such waste, the Brazilian farmer finds it difficult to reach these technologies which are interfered by factors such as the capacity of the soil and the plant to receive such water waste, the finance available for investment in equipment used for proper treatment of such effluents (Kunz et al., 2009).

Treatment systems applied on swine waste

The improper handling of swine waste causes damage to the environment, such as the emission of harmful gases and pollution of water sources from the surface water as well as to the groundwater (Cardoso et al., 2015).

The emergence of new alternatives for the treatment of swine waste is evidenced to be more efficient compared to the environmental impact which it generates by treatment upon the possibility of reutilization of waste and recycling of nutrients (Kunz et al., 2016).

Phase in, phase out separation

There are techniques used to separate waste into solid and liquid phase in and out, enabling waste management.

In the physical processes, effective decomposition of waste only reduces the complexity of these fractions making it suitable for treatment or storage (Higarashi et al., 2007).

According to Kunz et al. (2016), it is essential to use phase in and out separation for the treatment of swine waste, and high concentrations of suspended sedimentary deposit as well as solids.

Waste separating sieves

Sieving process is very important to avoid overloading with solid and subsequent treatment processes, separating the liquid portion of particles in larger grain sizes (Ramme and Kunz, 2009). The sieves are classified into static, vibratory and rotary, with different types of settings and capabilities. The solid sieving removal capacity is between 3 to 10% for the static and 40% for the vibratory, bearing in mind the lower removal rate from the one obtained by decantation (Oliveira, 1993).

Less diluted waste and lower storage time may reduce BOD, COD, total solids, fixed, volatile and total phosphorus of up to 80% and total nitrogen of about 60% (Higarashi, 2005). Orrico Junior et al. (2009) demonstrated that the use of sieves for the separation of solid fraction of swine wastewater potentiated the efficiency of biodigesters, produced higher amounts of biogas with a higher methane content in the gas and the biofertilizer presented higher levels of mineral elements.

Decantation

Sedimentation is a process in which the flakes in suspension are removed from water by using gravitational forces in order to separate particles of higher density from water, placing them on the surface (Netto and Richter, 2001).

It is considered an effective split system, of a low cost and easy to operate. However, its disadvantage is the high sludge production. This process can be applied for the swine wastes treatment since it promotes high efficient treatment and biofertilizer quality. Decantation removes approximately 50% of solid materials from wastes, with a volume of 15% of the total liquid waste produced (Dartora et al., 1998).

Chemical processes

Flocculation agents: The efficiency and speed of separation stages can be enhanced for the removal of solids with the use of flocculating agents, chemical compounds that act as aggregate particles in suspension. They mold bigger dimensioned flakes and then facilitate the decantation separation processes or by sieves. The

flocculating agents most used are inorganic salts of aluminum or calcium and iron. Therefore, the disadvantage of these compounds is the high concentration required, which requires a high amount of flocculants (> 1500 mg/L), resulting in a large volume of sludge with high concentrations of metals. An alternative to these are organic polymers such as polyacrylamide (PAM) and natural organic flocculants such as tannin. The addition of flocculating agents allows better formation of the flakes and better sedimentation of the sludge (Higarashi et al., 2007; Orrico Junior et al., 2009).

Biological processes

After the separation phase, the solids and liquid fractions are addressed to different treatments depending on the physicochemical feature of the waste in order to increase the treatment efficiency. The liquid fraction passes through aerobic and anaerobic biological treatment processes for the production of biogas and/or liquid fertilizer and the solid fraction is treated by composting of biogas (Higarashi et al., 2007).

Anaerobic treatment: Anaerobic digestion is a recycling method which renders the gas fuel and bio-fertilizer production, from the organic waste material of both animals and plants. When it is intended to preserve natural resources and recycling of organic materials reuse of swine manure is of great benefit for environmental sustainability (Andrade et al., 2012). Treatment of waste through anaerobic digestion emerges as an important alternative without high cost and it is efficient in reducing organic matter (Amaral et al., 2014).

Basically, the process of anaerobic digestion occurs in two phases. In the first, occurs the transformation of complex organic matter by extracellular enzymes; acidogenic and acetogenic bacteria are responsible for the degradation into simple compounds like volatile organic acids (CO₂ and H₂). In the second phase, these simple compounds are transformed by archaea methanogenics into CH₄ and CO₂. This part of the process occurs more slowly and the microorganisms are more sensitive to environmental conditions (Souza, 1984).

In addition to be strictly anaerobes, it requires a pH under neutral parameters and a temperature higher than 15°C. In case of unfavorable conditions and if its development is interrupted, there is stagnation of DBO removal and accumulation of acids triggering bad odors. The anaerobic matter decomposition process through anaerobic microorganism till date is the most widely used because of the swine waste present in ideal conditions for the development and permanence of such microorganisms (Von Sperling, 1996).

The anaerobic process is realized with the metabolization

Table 2. Averages (g/L) of the organic load determinations and nutrients for feeding purposes and the effluent from the digester from March 2004 to April 2005.

Parameter	Affluent	Effluent	Reduction (%)
COD	65.09 ± 14.56	8.27 ± 1.58	87.3
BOD ₅	34.30 ± 8.11	3.00 ± 1.34	91.25
N-NH ₃	2.52 ± 0.75	2.36 ± 0.63	6.34
N-NTK	4.53 ± 1.07	3.14 ± 0.50	30.68
P _{TOTAL}	1.60 ± 17.54	0.22 ± 0.02	86.25
Volatile solids	39.22 ± 17.54	8.29 ± 4.57	78.86

Source: Kunz et al. (2005).

of organic matter in an oxygen free environment. Degradation of this organic matter is realized into four different metabolic processes and via various groups of microorganisms (Khanal, 2008).

Manure compost dumps-dunghill: It is a place where the volume of manure produced in the creation system is disposed. It rests for a time (between 4 and 6 months), where it undergoes an anaerobic fermentation and then is tapped as fertilizer. In this process, any separation phase occurs, therefore, even with the DQO removal, the manure remains concentrated, requiring larger areas for its final disposal (Diesel et al., 2002).

Anaerobic pond: They are customized biological reactors to receive high organic loading per reactor unit volume. There is the absence of oxygen, photosynthetic activity, and digestion in association with fermentation and anaerobic respiration (Oleszkiewicz, 1986). It is a process rendered as a primary treatment of swine waste with high concentrations of organic compounds and high solids content, which is the purpose of the partial stabilization of organic raw material (EMBRAPA, 1995).

Facultative pond: Facultative pond is a type of biological treatment of organic matter stabilization and is featured by having two layers: aerobic layer (top) and anaerobic layer (lower). Generally, it is applied as second treatment after the anaerobic treatment. It reduces the number of pathogen organisms and increases the treatment efficiency (Von Sperling, 1996).

After the effluent enters the pond, the fragmented DBO settles down, forming a bottom sludge (deposit of sedimented organic material) which undergoes a treatment in the anaerobic zone of the pond; while the dissolved organic matter (soluble COD) and suspension (low particulate BOD) have aerobic treatment on the surface of the pond. Oxygen responsible for such degradation is in charge of the liquid surface gas exchange with the atmosphere by photosynthesis done by some algae (Earnest, 1971).

Still according to the author quoted above, major

profundity of the lagoons positively assists in the environmental anaerobic facultative maintenance; it reduces lose by evaporation and provides lower salinity to the effluent, which is a positive characteristic for its use in the fertigation activity.

Bio-digester

For more than two centuries, knowledge about biodigester already exists, where it responds well to the use and treatment of waste, power generation and biofertilizer production (Ferreira and Silva, 2009). With the necessity to find an adequate treatment to the wastes coming from animals, the treatments realized with biodigesters are attractive, because in addition to reducing their pollution factor, they generate biogas and biofertilizer that can be used later to generate profit for producers (Frigo et al., 2015).

Bio-digester is an alternative to the use of swine waste; it decreases soil and water contamination, and still produces biogas as a source of energy and bio-fertilizer for crops and pastures. With the proper treatment in bio-digester, the manure can be used in farming areas according to their needs. This reduces the use of chemical fertilizers, improves soil structure and increases crop production capacity (Da Silva et al., 2012).

The advantages of using biodigesters are: the low operational and deployment costs; simplicity of operation, maintenance and control, are efficient in removing various categories of pollutants, have low requirements, can be applied on a small scale with little dependence on the existence of large interceptors, have high useful life and the possibility of recovery of useful by-products such as biofertilizer and biogas (Samulak et al., 2010). Regarding the operation mode, bio-digester may be continuous or discontinuous and the treatment efficiency may vary according to the concentration residue and the residence time thereof in the digester (Campos, 1999). In Table 2, the average removal was observed after the treatment of swine waste with anaerobic bio-digestion. Vivan et al. (2010) evidenced in her studies that digester compound and stabilization ponds are effective for the treatment of swine waste, and reduction of organic matter.

Hydraulic retention time (HDT)

Hydraulic retention time is defined as time required for the residue to be digested through the digester. It is determined in a continuous process by the relationship between the digester volume and daily volume of introduced charge. The HDT is directly related to the speed of the degradation process, with the dilution and the total solids content of the substrate. It targets the end of the process in relation to the treatment and reduction in COD (Magalhães, 1986).

In the continuous flow structures, each organic charge which arrives generally needs an HDT of 30 to 50 days depending on the room temperature in which the digester is deployed. This time can be reduced by stirring and temperature increase (Florentino, 2003). Silva (1996) studied the hydraulic retention time of waste in anaerobic pond, with volumetric organic loads of 0.03; 0.05; 0.07 kg of BOD₅/m³/day; in 30 days, the best performance was the one with initial load of 0.05 BOD₅/m³/day. Costa et al. (1995) studied degradation of swine waste with organic volumetric load of 0.03 to 0.12 BOD₅/m³/day, in anaerobic ponds, and HDT for 66 days. There was a reduction on the average of 85% of COD, in 117 days (90%).

Biogas production

The production of biogas through anaerobic digestion process is common in rural areas because of its low operating costs and clean fuel capacity (Cheng et al., 2015). The biogas produced in anaerobic conditions is composed of methane (60 to 70%), CO₂ (30 to 40%), H₂S, NH₃, hydrocarbons and some other compounds. The consumption of 1 g of DQO eliminates the medium to 0.36 L of methane. The performance in the production of biogas by means of microorganisms is a function of several variables, such as C/N, environmental conditions (pressure and temperature) and operation (temperature, pH and HDT, volume availability, organic load) (Hohfeld and Sasse, 1986).

Swine waste under anaerobic process and favorable temperature and pH conditions produce methane in variable proportions. The fermentation product has a deodorization of 80 to 90% pollutant load reduction of 60 to 70%, and the concentration of fertilizer elements is similar to the undigested swine manure waste (Gosmann, 1997).

Biogas produced by swine manure waste is a renewable source of energy because it can be converted into electrical energy that can be used to meet the needs of farmers and properties and also contributes to the reduction of environmental damage (Avaci et al., 2005). In studies conducted by Campos et al. (2005) on the evaluation of biogas production potential and the anaerobic treatment efficiency sludge cover (UASB) as fed by swine waste, the average production of biogas and methane ranges from 0.03 and 0.36 L/day, with an average performance of 0.14 L/day. According to Trevisan (2013), for biogas produced by swine manure supplemented with ractopamine, there was a biogas production between 0.024 and 0.029 m³/kg, with TDH of 35 days.

Avaci et al. (2013) evidenced that when a farmer generated income from carbon credit sales in just one single situation, he had a loss of approximately 82 thousand real when 10 hday⁻¹ was generated and there is the amortization loop of 10 years. The farmer insisted on

the generation of electricity. This is because till date carbon credit industry is more favorable to farmers; in addition to being an area that is booming in the world, it contributes to the environment, and is a source of income for both large and small farmers.

Hydrogen production

Studies regarding hydrogen production are limited to the use of synthetic substrates rich in carbohydrates (glucose, sucrose and starch), which are easily degradable consortium of H₂, therefore, producing microorganisms. However, such practice is not economically viable. In this context, some agricultural/industrial by-products rich in organic matter, supplemented with synthetic substrates, may pass to enable the production process for cost reduction (Ismail et al., 2010) (Liu et al., 2011).

To Wagner et al. (2009) and Wu et al. (2013), swine waste has high concentrations of nitrogen and phosphorus, and when used as the only substrate in fermentation, some bio-hydrogen is produced; however, they are likely to be used as glucose in other substrates in anaerobic reactors conducted in batch.

Wu et al. (2009) and Zhu et al. (2009) obtained satisfactory results with the addition of glucose residue, reinforcing the hypothesis that it is a good co-substrate for fermentation with carbon rich materials.

Tenca et al. (2011) evaluated the application of swine manure as co-substrate in the production of hydrogen by thermophile fermentation residues of fruits and vegetables, in order to maximize production, where the swine manure waste would serve as a buffering agent. The percentage for greater gas production rate was 65% of swine waste and 35% of fruit and vegetable waste, thus avoiding the need of adding alkali substance in the reaction vessel.

H₂ production fermentation using acid crops is a highly complex process influenced by several factors such as reactor configuration, hydraulic retention time, the substrate specificity as the organic load, pH, temperature, redox potential and nutrients. According to Wu et al. (2010), among such parameters, pH is one of the most significant, because it directly affects the hydrogen and metabolic pathways, as it inhibits methanogen activity, maximizing the production of bio-hydrogen.

According to Alves et al. (2013), biogas has a great potential in the production of hydrogen. However, this production depends on several factors such as the composition of biogas, the purity required for the production of H₂ and the availability of investment in this technology.

Bio-fertilizers

The effluent generated on the biodigester is called biofertilizer, but this effluent cannot be directly discarded

in water resources, since even though it has undergone a treatment process, it still presents high polluting potential. This fertilizer can be used in agriculture, but for its proper use it is necessary to follow the same indications of the chemical fertilizers (Kunz et al., 2005).

Bio-fertilizers present a high quality because they have certain characteristics such as the reduction of carbon material. The digested organic matter releases carbon in methane and carbon dioxide. It increases the nitrogen content and other nutrients, as a result of carbon release. It decreases in the carbon/nitrogen ratio (C/N) of the organic matter, which improves agricultural use. The use of bio-fertilizer by microorganisms in the soil is easier, since the degree of decomposition is advanced. Already there is a part of the solubilization of nutrients, making it more available to plants. Besides bio-fertilizers can be used to control pests and diseases inured to agricultural crops (Oliver and Neto, 2008).

Panzenhagem et al. (2008) used bio-fertilizers in the installation of fruit farming; they enhanced the best performance of citrus trees and enabled the planting of annual intermediate species, such as maize, cassava and beans, particularly in the early years of citrus plants development. Oliveira et al. (2011) demonstrated that the use of biofertilizer in coffee and corn plantation represents only 40% of the total fertilizer needed for plant nutrition and development. Because of this, it is necessary to perform mixed fertilization with chemical fertilizers to keep production up.

According to Sedyama et al. (2014), the increase in the applied doses of biofertilizer improves nutrition and the productivity of colored pepper, when the culture system is organic. The author also showed that biofertilizer from swine manure has potential for fertilization in the unconventional form of soil, brings positive reflexes in the foliar contents of nutrients and the commercial productivities and early appearance of extra fruits. Seidel et al. (2010) demonstrated that the use of biofertilizer in corn crop provided the same results with chemical fertilizer, demonstrating that this is a viable option for farmers.

Water reuse in agriculture

According to Asano and Levini (1996), the reuse of wastewater in agriculture through sewage in the soil or irrigation took place in Athens from time immemorial, before Christianity came. The United States' planning and reuse of wastewater occurred in the early twentieth century (Asano and Levini 1996). The use of wastewater started in sugarcane mills, by using effluents from mills/distilleries, in order to irrigate sugarcane plantations (Leite, 2003). In agriculture, the use of such alternative water is important, enabling the use of nutrients for the growth of various plants (Pereira, 2006).

The swine residuary wastewater (SW) has enough

nutrients to be taken in the ferti-irrigation of diverse cultures. It increases production and productivity. In wastewater, there is almost 100% potassium, a third quarter of phosphorus and almost two thirds of nitrogen; in mineral form the nutrients that are not available in organic form can be utilized by the plant (Gomes et al, 2001). According to Freitas et al. (2004), the maize culture silage, when irrigated with wastewater, increases the productivity of green matter, with an average values from 45 to 46 t ha⁻¹, about 50% higher than irrigated water supply. There was also an increase in plant height values, corn cob statistics, length and weight of corn cobs.

Hermes et al. (2012), evaluating the development of the soybean crop with swine wastewater, observed the application of such water induced a greater absorption of nitrogen and lower absorption of potassium, an increase on the height of the plant, green mass and leaf area as well as an increase in soybean productivity. Constant ARS application as fertilizers favors a greater accumulation of nutrients such as phosphorus, potassium, copper and zinc in the surface of soil layers as compared to mineral fertilizer (Scherer et al., 2010). Dieter (2009) said that there are losses of nitrogen and phosphorus flow and observed highest peaks of eutrophication in source of water. Medeiros et al. (2015) observed that the cotton cultivars that were fertilized with swine wastewater obtained a better performance of dry mass, absorption and accumulation of nutrients when compared to the crop that was not irrigated with this biofertilizer. Souza et al. (2013) observed that the production of sweet peppers was not contaminated by coliforms termotoleranets and *Salmonella* ssp., when using wastewater from swine after preliminary treatment.

Bosco et al. (2016) concluded that nitrogen functional groups are released into the soil when swine manure undergoes some treatment process, thus demonstrating the great potential of reusing swine wastewater in agriculture as a form of fertigation.

CONCLUSION

Swine farming is a crucial activity in Brazilian economic sector. As such, it needs to be developed as it reduces costs and increases productivity. Swine waste is produced in large amounts due to specialization and agglomeration of a vast number of farm herds, and the improper handling of such manure is the major problem that affects environment. Therefore, the treatment of such waste is essential for the proper integration between environment and production.

It is a process which offers several benefits, from environmental to economic and social. In addition to causing degradation of organic matter present in the waste, there is a generation of bio-fertilizers, which can be rendered in agricultural and biogas premises, having

the advantage of the co-generation of thermic or electric energy.

CONFLICTS OF INTERESTS

The authors have not declared any conflict of interests.

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