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Energy Potential of Animal Waste in the State of Paraná (Brazil)

Fabrízio Nicolai Mancini[1*]
https://orcid.org/0000-0001-9365-3673

Jackson Milano[1*]
https://orcid.org/0000-0002-8560-1694

Joilson Gonçalves de Araújo[1]
https://orcid.org/0000-0001-8556-4670

Karen Techy Iastrenski[1]
https://orcid.org/0000-0002-8692-6239

Nicolli Sperança Silveira[1]
https://orcid.org/0000-0001-9468-5802

Rodrigo Creuz Pertile[1]
https://orcid.org/0000-0002-0843-6373

[1]Positivo University, Polytechnic School, Energy Engineering – Energy Lab, Curitiba, Paraná, Brazil

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*Correspondence: fabrizio.mancini@up.edu.br; Tel.: +51-41-99941-8899 (FNM);
jackson.milano@up.edu.br; Tel.: +51-41-99985-7799 (JM).

HIGHLIGHTS

- Rural energy consumption can be supplied by methane present biogas from biomass.
- Biodigestion of dairy cattle, pigs and broilers residues protect environment.
- Paraná (Brazil) has a great energetic potential in dairy cattle and cutting.
- Biomass as the first form of energy consciously used by humans.

Abstract: Animal biomass is a source of energy commonly discarded without or with low utilization, but its availability draws attention to its reuse [1]. The utilization can be carried out in different ways, varying in terms of generation time and efficiency. The use of biodigestion requires a relatively small area compared to landfills or natural composting, and it provides other materials besides biogas, that can be recycled as fertilizer and has a short residence time of residues [2]. The energy supplied as biogas can be harnessed as heat or electricity in case of conversion. Considering the energy needs of animal husbandry and the

ease of reinsertion of energy in the production cycle, the possibility of distributed generation of biogas was studied as a way to complement the rural energy consumption matrix. Poultry farms require heat for chicks [3], dairy production centers require sterilization of used equipment [4] and pig farms require good heating systems to ensure animal weight gain [5]. In this way, the production can take advantage of the heat of the gas without the conversion into electricity, minimizing losses. Creation centers themselves can also generate electricity, eliminating the need for large transmission lines.

Keywords: biodigestion; rural energy consumption; biogas.

INTRODUCTION

Biomass can be considered the first form of energy consciously used by humans. The material can be presented in various ways, such as animal and vegetable waste, excluding charcoal. The earliest records of known energy use refer to fire, the source of which is commonly associated with plant biomass, firewood. This form of generation was later left aside with the beginning of the use of coal, but its low cost and high availability, besides the finitude of the mineral coal, make biomass a promising source of energy [1].

The animal production of Paraná stands out from the national scene. The state is the third largest producer of pigs and largest producer of poultry in the country, having a high energy potential from animal waste [6]. Cattle breeding, on the other hand, is small, and the use of bovine waste is hampered by the complexity of the collection. Therefore, although it has great calorific power, it becomes the least efficient source among those considered, but still collaborating with the state energy potential.

The use of animal waste can occur in several ways such as landfill treatment, incineration, biodigestion and natural or accelerated composting. Natural composting and biodigestion are economic forms of utilization and can also generate compounds useful as biofertilizers [2].

Characteristics as percentage of methane and carbon nitrogen ratio alter the quality and potential of animal waste. For this reason, since different animals have different digestive processes, the generation of biogas depends on the species, the feeding and the conditions of animal rearing [7].

Biogas is still composed of noxious gases. In systems of confined creation, the care with the gases demands implementation of control tools, being the aeration of the place the most practical and economic form. Biodigestion, concentrating animal waste, concentrates noxious gases, requiring care and planning so that there is no inhalation of large amounts of the material [5].

The present article compares the energy potential of the source with the local rural consumption aiming to observe the possibility of complementing the rural electric matrix as a Distributed Energy Resource based on biogas. Distributed energy resources include Distributed Generation, which is the term used to characterize localized power generation sources close to consumers of power less than or equal to 5 MW from renewable sources, which reduce the need for long transmission lines and can improve the quality and reliability of electric power at these sites [8].

The general objective of this article is to study the viability of feeding the rural community of the state of Paraná from energy generated with animal waste. For comparison, different animals were considered, since different regions of Paraná specialize in the creation of different animals.

MATERIAL AND METHODS

Bibliographic research was used to raise the characteristics of animal waste, and documentary research was used to work with the information of animal rearing and herds of Parana. With the acquired material, data analysis was performed to compare discrepant information from different sources, always adopting the value most frequently used.

RESULTS

Cattle

In order to calculate the energy potential of biogas resulting from the biodigestion of accessible bovine manure, parameters were delimited according to the picture of cattle management for milking. Thus, it was considered that a large portion of cattle is confined only to milking, which occurs, on average, twice a day. According to [9] the milking time is currently 4.5 minutes. If the time of preparation and management of the pre and post-milking animal is considered, this totals a stay of approximately 15 minutes or 0.25 hours per animal [9]. Data [5] indicate that cow manure production is around 12.5 kg / day or 0.52 kg / h. Thus, the mass of manure produced daily usable is 0.13 kg / day. Also, according to [5], 0.04 mare produced3 for each kg of manure, with the cow herd milking a total of 1,550,396 heads, there is an annual production of 2,799,999.03 m3 of biogas. Considering the loss of energy in the generation of electric energy, it is possible to generate 1.43 kWh / m3 of biogas [10]. Thus, the estimated electric energy is 4,004 MWh, not representing 0.1% of rural consumption, but is significant in the localities that use the biomass produced. For the purpose of comparison, a calculation was made considering the whole bovine herd being permanently kept in covered confinement. The results were very surprising, there would be a production of more than 1.6 billionm3 of biogas and energy generated 2,352,324.01 MWh able to supply all rural consumption and to participate in 16% of energy supply in Paraná [11]. The generation capacity was also studied in case the whole herd of cattle was raised in confinement, a common practice [4]. In this way it was possible to calculate the potential allied to the confined breeding estimate [12] [13]. Accurate data on the amount of livestock reared in confinement was not found. Different considerations and its potential are shown in Table 1 below, the second scenario being used for subsequent comparisons.

Table 1. Bovine energetic potential for different types of breeding.

Cattle rearing system	Electric energy potential (MWh/year)
Confinement only during milking	4,004.00
Total confinement of milk cattle	384,383.87
Total confinement of total cattle herd	2,352,324.01

Pigs

To find the energy potential of pig waste it was first necessary to know the size of the herd in the state. Data taken from IPARDES [14] bring the livestock census by classifying the data by city, allowing the analysis by the mesoregions of the state. For comparison purposes, consumption data provided by IPARDES [11] were also considered, according to categories and municipalities of Paraná [15]. Expected waste production was calculated according to information from the Manual of Handling and Utilization of Swine Debris provided by Embrapa and De Cortez, providing data such as the manure production per day of different animals and the amount of biogas expected per kg of manure [5]. The conversion factor used to obtain the kWh power of the biogas was 1.43 kWh / m³ of biogas, since Comastri Filho indicates that 0.7 m³ of biogas corresponds to 1 kWh of electricity [10].

Birds

For birds, the calculation was made considering the weight of the animals to then obtain the daily production of manure in the state of Paraná. According to [14] [16] [17], the bird population is estimated to be approximately 345 million animals, of which 97% are chickens. Data [18] indicate that small farmed birds produce around 140 g of manure a day, while larger birds produce up to 170 g. It also states that only 20% of this manure is dry mass. Each kilogram of this mass, according to [19], will produce 0.0821 m³ of biogas. This biogas will be constituted 60% of methane, gas of calorific value of 18,676 kJ / m³ states [7].

Considering a 40% efficiency generator, we would get 730,306,175 MWh / year. The energy energetic potential of the animal can be observed in Table 2.

Table 2. Energetic potential of birds.

Animal	Electric energy potential (MWh/year)
Cattle	4,004.00
Pigs	503,827.27
Birds	730,306.18

It is possible observe limitations in the research since the data provided by IPARDES refer to the 2006 IBGE studies, and are therefore outdated. The possibility of using data from the 2017 census has been studied, but these are still subject to change.

DISCUSSION

The results should be analyzed differently for each animal. Their different forms of creation and energetic needs generate different results according to the source.

Cattle

The herd of Paraná counts more than 9 million heads, however, since extensive breeding is more common for beef cattle, only milk cattle were considered in the present study [14]. The confinement of the milked cows facilitates the collection of material, being more relevant to the biodigestion study. Animals reared in partial confinement could be considered, but no precise data were found on the amount of cattle raised in this condition.

The large generation of manure per animal means greater biogas generation per head of cattle, compensating the small amount of cattle considered in the study and making the source as viable as other animals. The breeding cycle of milking cattle can use the energy as gas for the sterilization of the equipment, promoting the heating of water for instrument hygiene [4].

Pigs

The energy potential of biogas originating from pork material in Paraná stands out in the national scenario thanks to the large state flock. The agricultural censuses of 2006 [14] and 2017 [6] show that Paraná is, and remains, the third state with the highest number of pigs, corresponding to 14% of the national herd, exceeding 4.5 million heads. In addition to the number of animals, confined production is common, collaborating with the collection of material that can be used for biodigestion [5].

The energy generated, whether in the form of gas or electricity, thanks to the pig waste can be inserted in the production cycle of the animals. In the first weeks of life, piglets require temperature control for survival and subsequent fattening, and energy can be withdrawn from the biogas generated [20]. Energy can also be converted to electricity and can be used for the maintenance of adult pigs, since they require ventilation systems to control the gases generated by the herd [20].

Birds

Contrary to cattle production, the herd of birds in Paraná is the largest in the country, with more than 345 million heads, of which 335 million are chickens [14]. Chickens produce a quantity of organic matter equivalent to 6.21% [18] [21], of their total weight, while cattle produce 4.73% [18] [22] and pigs 3% [18] [23]]. Therefore, the low yield of manure per head does not prevent the residue of chickens from showing the highest potential residue in the state of Paraná among the animals considered in this article.

The utilization of the energy generated by the birds can occur in the maintenance of the temperature of the chicks, since these require a strict heating control in order to survive. The

sensibility of the animals often causes early deaths causing damage to the breeders, which could be avoided with greater control and attention to the chickens' breeding [3].

Something to be considered in the feasibility study of the use of animal waste from chickens is the common practice of selling chickens' beds. Often this sale occurs due to good quality of the material for it to be used as fertilizer, so it is important to compare the return on sale and the generation of energy.

Energy potential and rural consumption

After obtaining the energy potential by city and region, the percentage of rural consumption that can be supplied with the generation of energy from animal waste was calculated. Table 3 shows the different regions, the animal potential and the percentage of gas supply capacity. It can be observed, for example, that the western region has a potential to supply 134% of its rural electric energy needs. In addition, the region is the one with the largest biogas production, meaning a large concentration of breeding and consumption, a characteristic favorable to distributed generation.

Table 3. Comparison of the biogas energy potential and rural consumption in the state of Paraná.

Mesoregion	Energy potential of animal biogas (MWh / year)	Relation of biogas potential and rural electric energy consumption
Northwest	154.605,37	66%
Midwest	69,874.73	62%
Central-North	185,098.19	62%
Pioneer North	104,099.43	81%
Eastern center	143,154.95	91%
West	745,941.95	134%
Southwest	199,026.04	68%
South-center	93,782.94	69%
Southeast	48,224.13	34%
Metropolitan area of Curitiba	55,218.35	36%
Total	**1,799,026.08**	**81%**

Among the limitations of the use of animal waste by biodigestion are technical, geographic and social factors. The biodigestion process requires caution and studies, since the risk of explosion and the frequent problems with bad smell are disadvantages hampering the acceptance of projects [2]. The way in which animals are harvested by harming the collection of material can also be a great deterrent to the cost-effectiveness of a project. Geographic factors, such as areas with lower temperature averages, require a greater investment in heating and temperature control not only in livestock but also in the biodigestion process [24]. Quantification of the relevance of these difficulties is complex, and no studies have been found to demonstrate such values. Relevant methodologies for mitigating the problems mentioned here are relevant study areas.

CONCLUSION

Animal waste has proved to be a cheap, efficient and available source of energy. It is important to consider the use of biodigestion as a source of thermal energy, which may assist in the creation of animals, the waste producers, thus perpetuating the material generation cycle. The different breeding characteristics, the residues, their varied methods of husbandry and the well distributed farms across the state cooperate to present the use of animal waste as a source of distributed generation of thermal and electric energy, the second one being beneficial for rural transmission and distribution lines, without forgetting to mention the contribution to the conservation of water bodies, avoiding the eutrophication

of surface water or even contamination of groundwater with the presence of organic material due to these residues [5].

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