Revista ARACÊ
ISSN: 2358-2472

# BIODIGESTER IN BEEF CATTLE FEEDLOT

https://doi.org/10.56238/arev6n4-469

**Submitted on:** 30/11/2024 **Publication date:** 30/12/2024

**Leandro de Oliveira Silva[1], Petrônio Pinheiro Porto[2], Emília de Paiva Porto[3], Marcos Augusto Alves da Silva[4], Tiago Marques Mantovani[5], Pedro Henrique da Silva[6], Denis Sato[7]**

[1] Master's student in Sustainable Agricultural Production
State University of Northern Paraná - Luiz Meneghel campus
Bandeirantes, Paraná, Brazil
Email: escrevaparaoleandro@gmail.com
ORCID: https://orcid.org/0009-0001-0111-6377
LATTES: https://lattes.cnpq.br/5824525027349064
[2] Dr. in Animal Science
State University of Northern Paraná - Luiz Meneghel campus
Bandeirantes, Paraná, Brazil
E-mail: petronio@uenp.edu.br
ORCID: https://orcid.org/0000-0002-2808-2533
LATTES: http://lattes.cnpq.br/1751366795715746
[3] Dr. in Animal Science
State University of Northern Paraná - Luiz Meneghel campus
Bandeirantes–Paraná, Brazil
E-mail: emilia@uenp.edu.br
ORCID: https://orcid.org/0000-0002-2808-2533
LATTES: http://lattes.cnpq.br/7968074715970358
[4] Dr. in Animal Science
State University of Northern Paraná - Luiz Meneghel Campus
Bandeirantes, Paraná, Brazil
Email: marcossilva@uenp.edu.br
ORCID: https://orcid.org/0000-0002-5570-8677
LATTES: http://lattes.cnpq.br/4973981237909142
[5] Master's student in Sustainable Agricultural Production
North Paraná State University - Luiz Meneghel Campus
Bandeirantes, Paraná, Brazil
E-mail: tmmantovani@hotmail.com
LATTES: http://lattes.cnpq.br/4861215006269745
[6] Master's student in Sustainable Agricultural Production
North Paraná State University - Luiz Meneghel Campus
Bandeirantes, Paraná, Brazil
CAPES bag holder
E-mail: pedrouenpbio@gmail.com
LATTES: https://lattes.cnpq.br/0186159403434154
[7] Postdoctoral student in Sustainable Agricultural Production
State University of Northern Paraná - Luiz Meneghel Campus
Bandeirantes, Paraná, Brazil
CAPES bag holder
E-mail: denissato@alumni.usp.br
ORCID: https://orcid.org/0000-0003-0804-9928
LATTES: http://lattes.cnpq.br/8939110502384474

Revista ARACÊ
ISSN: 2358-2472

**and Amanda Ipólito Coneglian[8]**

**ABSTRACT**
This study addresses the implementation of biodigesters in beef cattle confinement systems, an economic activity of great relevance, however, which faces significant challenges in waste management. The research highlights the transformation of waste into valuable resources, such as biogas and biofertilizers, and the promotion of sustainable agricultural practices. Through a systematic literature review and documentary analysis, a theoretical research was carried out, which covered academic literature from several decades. The results indicate that biodigesters offer an effective solution for waste management in beef cattle, contributing to the reduction of waste and harmful emissions and promoting the circularity of resources on the farm. However, the implementation of these systems is not without challenges, including the need for qualified personnel for operation and maintenance, corrosion of equipment by hydrogen sulfide gas, and the complex logistics of livestock management and leachate treatment. Despite these challenges, the integration of biodigesters into beef cattle is a promising approach that offers substantial benefits for crop production and environmental preservation. The adoption of this technology can contribute significantly to the sustainability of beef cattle, turning challenges into opportunities and promoting a more balanced and efficient production model. Continuing these efforts can pave the way for more sustainable farming practices in the future.

**Keywords:** Sustainability. Waste Management. Biogas. Biofertilizers. Good Agricultural Practices.

[8] Undergraduate student in Agronomy
North Paraná State University - Luiz Meneghel Campus
Bandeirantes, Paraná, Brazil
Araucária Foundation Scholarship
E-mail: amandaiconeglian@gmail.com
ORCID: https://orcid.org/0009-0007-5178-4836
LATTES: https://lattes.cnpq.br/4096443468305181

Revista ARACÊ
ISSN: 2358-2472

## INTRODUCTION

Beef cattle production is a crucial component of the global agribusiness, providing essential protein for the human diet. According to Cepea (2023), beef production in Brazil reached a record 8.91 million tons in 2023, an increase of 11.2% compared to 2022. This places Brazil as one of the main beef producers in the world, with an industry that is both quantitative and qualitative, with technological and sustainable facilities that guarantee more quality, waste reduction and maintenance of animal welfare.

However, despite this significant growth, the industry faces considerable environmental challenges, especially when it comes to waste management. With the growing discussions about carbon credits and climate change, the need for good agricultural practices and sustainable innovations in agribusiness, the agro-industrial market has been urgently seeking new sustainable solutions. In this context, the construction and operation of a biodigester in a cattle confinement system emerges as a promising strategy for the proper management of waste and for the generation of new revenues for the property, with biogas and biofertilizers, closing a cycle of energy autonomy (Carvalho and Zen, 2017).

The agricultural confinement system produces a significant amount of waste, bringing with it a health problem that can transmit diseases to humans and animals. Biodigesters, when correctly designed and implemented, can transform waste into valuable resources, closing the nutrient loop and minimizing waste (Fernandes, 2021). During the finishing phase, the confinement system becomes a favorable scenario to deal with the waste produced by beef cattle. The implementation of technologies such as the biodigester in this context brings considerable benefits to producers and the national livestock sector. These advantages include the transformation of cattle manure into biogas and biofertilizers, which helps to reduce the amount of solid waste while minimizing negative environmental impacts. In addition, this practice provides an opportunity for diversification of revenues on the property.

From the anaerobic digestion of cattle manure, biogas is produced, a versatile energy source that can be used for heating, electricity generation or as an alternative to conventional fuels. This contributes to meeting the energy needs of the property, reducing energy costs (Lins, Furtado and Mito, 2022). The use of biogas as a substitute for fossil fuels not only contributes to the reduction of CO2 emissions, but also plays a crucial role in decreasing methane, a potent greenhouse gas. This benefit is particularly relevant in the context of the management of waste from various sources, especially animal waste. (Manso and Mendes, 2007 and Silva 2024).

The solid waste resulting from the digestion process, called digestate, is a nutrient-rich organic fertilizer that can be applied in agriculture, strengthening soil sustainability and reducing dependence on chemical inputs (Nicoloso, 2019). The implementation of biodigesters and other sustainable practices not only improves the image of the property in society, but also adds value to agricultural products and strengthens the producer's competitiveness in the market.

However, the widespread adoption of this technology faces challenges, such as high upfront costs, the need for specialized technical knowledge to operate the system, variation in biogas production, and the logistical complexities associated with collecting and transporting manure on medium and small properties (Lins, Furtado, and Mito, 2022).

The objective of this paper is to examine the application and impacts of the implementation of biodigesters in beef cattle confinement systems in Brazil, highlighting the transformation of waste into valuable resources, such as biogas and biofertilizers, and discussing the challenges and opportunities associated with this sustainable practice.

## METHODOLOGY

This study employed a methodology that encompasses a systematic literature review, based on the principles of the PRISMA methodology (Galvão, 2015), and a documentary analysis. The theoretical research covered academic literature from several decades, with research sources in English and Portuguese obtained through the Google Scholar database. The keywords used were "waste treatment in beef cattle confinement". Due to the lack of sufficient results, the search was expanded to "beef cattle confinement" in the period from 1980 to the present date, resulting in 177 publications.

In addition, databases from renowned research institutions, such as Itaipu, Embrapa and Emater, as well as websites of biodigester companies throughout the country, were consulted. Initially, 50 publications were selected based on reading the abstract or introduction. After a more careful analysis, 24 of these publications were chosen for a more detailed reading. The selected publications cover a period from 1980 to the current year 2024. This methodology enabled a comprehensive and current analysis of the most recent practices and technologies in the field of waste treatment in livestock, the use of biodigesters and the interrelationship of both in beef cattle feedlots.

In addition to the literature review and documentary analysis, empirical analyses were carried out on two farms located in the state of Paraná, Brazil. The first farm is located in Cascavel and the second in Leópolis, both in the state of Paraná. These field analyses allowed the direct observation of waste treatment practices and the use of biodigesters in beef cattle feedlots, providing complementary and practical data that enriched the theoretical research. The information collected on the farms was compared with the data obtained in the literature review, allowing a more comprehensive and detailed evaluation of the technologies and practices used in the treatment of waste in livestock.

The empirical analyses involved visits to the farms, where the waste management practices and the operation of the biodigesters were observed. Data were collected on the amount of waste generated, the efficiency of biodigesters in the production of biogas and biofertilizers, and the challenges faced in the implementation and operation of these systems. The field observations were complemented by interviews with the owners and operators of the farms, providing a practical and detailed view of the technologies and practices used.

## DEVELOPMENT

### CURRENT PERSPECTIVES OF BRAZILIAN CATTLE FARMING

The cattle farming scenario in Brazil presents significant challenges that demand innovative and sustainable solutions to ensure the economic and environmental viability of the sector. As highlighted by Lopes, et al (2022), the search for more sustainable agricultural practices has become a priority, in response to the growing demands for responsible food production. In this context, the adoption of technologies such as biodigesters in beef cattle confinement systems emerges as a promising strategy to minimize negative environmental impacts, while promoting the generation of renewable energy and biofertilizers.

With a critical look at the current situation of cattle farming in Brazil, opportunities are identified to integrate sustainable practices that not only meet the needs of the industry, but also contribute to the mitigation of adverse effects on the environment. According to Menezes, et al. (2023), the implementation of effective waste management systems, such as biodigesters, can not only reduce the carbon footprint of livestock activity, but also boost the energy autonomy of properties and favor soil fertility through the use of biofertilizers resulting from the anaerobic digestion process.

Revista ARACÊ
ISSN: 2358-2472

HANDLING OF TWO BEEF CATTLE DEPOTS

Beef cattle generate waste that needs to be properly managed to avoid negative environmental impacts. Waste from beef cattle farming involves feces, urine and food scraps. These wastes have recycling potential, but need treatment to avoid environmental damage due to the high levels of BOD and COD (Biochemical Oxygen Demand and Chemical Oxygen Demand) present, as pointed out by Ramasamy and Abbasi (2000) and Ramasamy et al. (2004).

Responsibly managing beef cattle manure is essential to mitigate their environmental impact. In many cutting properties, manure management is carried out in solid form, by scraping the floor of the facilities, resulting in manure with approximately 15 to 20% total solids (TS) (Fulhage, 1997). Unlike countries with large herds in feedlots, in Brazil, the predominance is extensive breeding and smaller herds, which can facilitate the issue of proper waste management (Xavier, 2005).

According to Xavier (2005), the factors that influence the amount and composition of manure include the production system, climate, animal weight, physiological state and production level. The variation in animal feed also plays an important role in the composition of manure. Nutritional strategies aimed at feed efficiency are essential to minimize economic and environmental losses related to the nutrients present in waste (Xavier, 2009).

The concern with the proper management of beef cattle manure extends to avoid environmental contamination. As in dairy farming, manure contains biological agents that can cause damage to human and animal health, in addition to representing economic losses (Chadwick et al., 2008). Therefore, measures such as the proper treatment of waste and the prevention of direct application to the soil are essential to avoid contamination of the environment and ensure the health of surface and groundwater (Oliveira, 2011).

The management of cattle manure continues to be a relevant concern, as evidenced since the early 2000s. With the increase in livestock production and the concentration of animals on farms and feedlots, proper waste management has become crucial to mitigate environmental impacts (Costa and Zenatti, 2023). In this context, biodigesters emerge as a promising solution. These systems convert waste into biogas, a renewable energy source, and biofertilizers, reducing waste and providing valuable resources for agriculture (Matos, 2016).

FUNCTIONING AND BENEFITS OF BIODIGESTERS

The biodigester is a system that plays a key role in the anaerobic degradation of biomass, resulting in the production of biogas and biofertilizers, essential resources to promote environmental and energy sustainability. As mentioned by Barrera (1993), the biodigester consists of a closed chamber where methanogenic bacteria degrade organic matter, releasing methane gas as the main component of the biogas. This simple and efficient technology contributes to the valorization of organic waste and the generation of renewable resources.

The benefits arising from the installation of a biodigester on a small rural property are numerous and positively impact several activities (Silva, Porto and Silva, 2024). The use of biogas reduces or eliminates the need to remove firewood from nearby forests, preserving the environment and preventing problems such as soil erosion, pest proliferation and ecosystem imbalance. In addition, the production of biofertilizers stimulates agriculture, improving soil fertility and increasing the quality of crops, as highlighted by Costa, Silva and Gomes (1985).

Replacing cooking gas with biogas results in financial and environmental savings, eliminating costs with transportation and storage of fossil fuels, in addition to providing a more hygienic and sustainable option for food preparation. The application of the biodigester is not restricted only to animal waste, but may also include human excrement, which contributes significantly to improving hygiene and sanitation in rural areas, as highlighted by Gaspar (2003).

In addition to the benefits linked to cost reduction and environmental preservation, the use of biogas in various daily activities, such as lighting, water heating, and equipment activation, demonstrates the versatility and energy potential of this renewable resource. The production of biofertilizers is also crucial for the development of agriculture, providing an organic fertilizer rich in nutrients and contributing to the sustainability of crops, as highlighted in Tolmasquim (2007).

In the state of Paraná, the implementation of biodigesters on farms dedicated to beef cattle has proven to be an effective strategy for sustainable waste management and renewable energy generation. The facilities, such as those at Fazenda Santa Alice in Leópolis - PR and Fazenda São Domingos in Cascavel - PR, are pioneers in the conversion of cattle waste into biogas and biofertilizers, exemplifying a circular economy model that values by-products and minimizes environmental impacts. The energy production of these systems reaches an average of 1.5 kW per animal per day, as reported by the farms, evidencing a significant contribution to the energy self-sufficiency of the farms.

In the farms analyzed, the integration of sustainable practices with beef cattle is evidenced by accurate environmental monitoring and efficient biogas production. The collection of climate data, carried out monthly, is essential for understanding the environmental conditions that directly influence agricultural production and energy generation. The data, which includes average temperature, relative humidity, precipitation and solar radiation, are obtained via the internet from the nearest weather station, thus ensuring the accuracy of the information.

Biogas production is monitored through a computerized system that records the average energy generation in kWh/day, correlating it with the climate variables collected. This system allows a detailed analysis of the energy performance of the biogas produced from cattle manure. The estimated biogas production per animal is a determining factor in the farm's operating costs. It is estimated that each animal produces an average of 1.5 kW per day, contributing to a total production of 650 kW/day in a feedlot of 450 animals. This production is converted into energy by a motor adapted to biogas, operating 10 to 12 hours a day with a capacity of 60 kW/hour.

In addition, the transformation of waste into solid and liquid biofertilizers enhances soil fertility and agricultural productivity, reinforcing environmental sustainability. However, challenges such as corrosion of equipment by hydrogen sulfide gas, the need for qualified personnel for operation and maintenance, and the complex logistics of livestock management and leachate treatment require attention and careful management. The experience of these farms demonstrates that, despite operational obstacles, the integration of biodigesters into beef cattle is a promising approach that offers substantial benefits for crop production and environmental preservation, paving the way for more sustainable farming practices in the future.

## INTEGRATED WASTE MANAGEMENT IN LIVESTOCK: THE VITAL ROLE OF BIOGAS PRODUCTION IN MITIGATING GREENHOUSE GAS EMISSIONS

The efficient management of livestock waste, especially in relation to biogas production and the mitigation of greenhouse gas emissions, is vital for the environmental sustainability of the sector. The energy use of biogas from the organic decomposition of

Revista ARACÊ
ISSN: 2358-2472

animal waste can be a solution both for generating energy in isolated farms and for reducing environmental impact. Companies in the poultry and pig farming sectors have already adopted this practice, transforming their waste into biogas and, later, into energy (Lora and Venturini, 2012).

Considering the national scenario, where the agricultural sector is responsible for a significant portion of greenhouse gas emissions in Brazil, the use of biodigesters to treat waste such as animal waste can be an effective strategy. It is estimated that this practice can reduce emissions by up to 40%, contributing to the mitigation of environmental impact and representing an opportunity to reward the sector due to the benefits for the environment (Lins, Furtado and Mito, 2022).

Another factor is that when integrating biogas production with cattle farming, it is important to consider the biogas production capacity from the different types of animal waste. Among the herds evaluated, cattle and horses stand out for the amount of manure produced daily, presenting a significant potential for biogas production. In general, biomass from pigs shows a higher yield in biogas production, followed by cattle manure. The animals' diet and the environment in which they are stable also influence the concentration of methane present in the gas produced (Colatto and Langer, 2011).

Integrated waste management in livestock involves not only the production of biogas, but also the consideration of environmental variables that influence the efficiency of the process. The seasons, for example, play a crucial role, as lower temperatures in winter can reduce microbial activity and, consequently, biogas production. On the other hand, summer can accelerate organic decomposition, increasing methane production (Lins, Furtado and Mito, 2022). Therefore, it is essential to develop strategies that optimize biogas production throughout the year, considering seasonal fluctuations and their impacts on the microbiology of biodigesters.

In addition, animal feed is a determining factor in the composition of manure and, therefore, in the production of biogas. High-protein diets tend to result in waste with higher potential for methane production, while high-fiber diets can suppress the activity of methanogenic bacteria (Alves, 2016). Understanding these interactions is essential to maximize the efficiency of biodigesters and minimize environmental impacts, contributing to a more sustainable livestock farming.

## RESULTS AND DISCUSSION

The critical analysis of the current situation of cattle farming in Brazil reveals opportunities to integrate sustainable practices that meet the needs of the industry and contribute to the mitigation of adverse effects on the environment. The adoption of biodigesters in beef cattle confinement systems emerges as a promising strategy to minimize negative environmental impacts, while promoting the generation of renewable energy and biofertilizers. Effective waste management through biodigesters can reduce the carbon footprint of livestock activity, boost the energy autonomy of properties and favor soil fertility.

As observed in the farms visited, the implementation of biodigesters, however, presents challenges, such as the initial installation costs, the need for technical training for operation and maintenance, and the proper management of waste and by-products. It is essential that public policies and financial incentives are implemented to support rural producers in adopting this technology.

The efficient management of livestock waste, especially in relation to biogas production and the mitigation of greenhouse gas emissions, is vital for the environmental sustainability of the sector. The energy use of biogas from the organic decomposition of animal waste can be a solution both for generating energy in isolated farms and for reducing environmental impact. Companies in the poultry and pig farming sectors have already adopted this practice, transforming their waste into biogas and, later, into energy (Lora and Venturini, 2012).

Considering the national scenario, where the agricultural sector is responsible for a significant portion of greenhouse gas emissions in Brazil, the use of biodigesters to treat waste such as animal waste can be an effective strategy. It is estimated that this practice can reduce emissions by up to 40%, contributing to the mitigation of environmental impact and representing an opportunity to reward the sector due to the benefits for the environment (Lins, Furtado and Mito, 2022).

Another factor is that when integrating biogas production with cattle farming, it is important to consider the biogas production capacity from the different types of animal waste. Among the herds evaluated, cattle stand out for the amount of manure produced daily, presenting a significant potential for the production of biogas. In general, biomass from pigs shows a higher yield in biogas production, followed by cattle manure. The

Revista ARACÊ
ISSN: 2358-2472

animals' diet and the environment in which they are stable also influence the concentration of methane present in the gas produced (Colatto and Langer, 2011).

Integrated waste management in livestock involves not only the production of biogas, but also the consideration of environmental variables that influence the efficiency of the process. The seasons, for example, play a crucial role, as lower temperatures in winter can reduce microbial activity and, consequently, biogas production. On the other hand, summer can accelerate organic decomposition, increasing methane production (Lins, Furtado and Mito, 2022). Therefore, it is essential to develop strategies that optimize biogas production throughout the year, considering seasonal fluctuations and their impacts on the microbiology of biodigesters.

In addition, animal feed is a determining factor in the composition of manure and, therefore, in the production of biogas. High-protein diets tend to result in waste with higher potential for methane production, while high-fiber diets can suppress the activity of methanogenic bacteria (Alves, 2016). Understanding these interactions is essential to maximize the efficiency of biodigesters and minimize environmental impacts, contributing to a more sustainable livestock farming.

Biogas production not only contributes to the reduction of greenhouse gas emissions, but also offers a renewable energy source that can be used in various activities on the farm (Menezes et al. 2023). The energy generated can be used for heating, lighting, and powering equipment, reducing dependence on non-renewable energy sources and farm operating costs.

The implementation of biodigesters also promotes the circular economy, where waste is transformed into valuable resources, closing the cycle of production and consumption in a sustainable way. The production of biofertilizers from animal waste improves soil fertility and agricultural productivity, reducing the need for chemical fertilizers and promoting more sustainable agricultural practices (Matos 2016).

In summary, integrated waste management in livestock, with a focus on biogas production, is an effective strategy to mitigate greenhouse gas emissions and promote the environmental and economic sustainability of the agricultural sector. Continuing these efforts and conducting more research could pave the way for more sustainable farming practices in the future.

## CONCLUSION

This study examined the application and impacts of the implementation of biodigesters in beef cattle confinement systems in Brazil. The transformation of waste into valuable resources, such as biogas and biofertilizers, contributing to the sustainability of beef cattle was highlighted. However, challenges such as the need for qualified personnel for operation and maintenance, corrosion of equipment by hydrogen sulfide gas, and the complex logistics of cattle management and leachate treatment were identified.

Despite these challenges, the integration of biodigesters into beef cattle is a promising approach that offers substantial benefits for crop production and environmental preservation. The adoption of this technology can contribute significantly to the sustainability of beef cattle in Brazil, transforming challenges into opportunities and promoting a more balanced and efficient production model. Therefore, the implementation of biodigesters in beef cattle confinement systems meets the objective of this study.

The results obtained in this research can help society and academia by providing concrete data on the benefits and challenges of implementing biodigesters in beef cattle. This data can be used to develop more sustainable public policies and agricultural practices, promoting the environmental and economic sustainability of the agricultural sector.

## RECOMMENDATIONS FOR FUTURE WORK

To expand knowledge about the implementation of biodigesters in beef cattle, it is recommended that future studies explore the application of this technology in different regions of Brazil, considering the climatic and operational variables specific to each location. In addition, it is important to investigate new technologies and practices that can complement the use of biodigesters, as well as to assess the long-term economic and social impact of implementing this technology in beef cattle. Continuing these efforts can pave the way for more sustainable farming practices in the future.

## ACKNOWLEDGMENTS

The authors would like to thank the Coordination for the Improvement of Higher Education Personnel – Brazil (CAPES), the Araucária Foundation and the State University of Northern Paraná (UENP) Campus Luiz Meneghel - Bandeirantes - Paraná - Brazil, for the financial and institutional support that made this work possible.

**REFERENCES**

1. Alves, A. R., et al. (2016). Fibra para ruminantes: Aspecto nutricional, metodológico e funcional. Pubvet, 10, 513-579.

2. Barrera, P. (1993). Biodigestores: energia, fertilidade e saneamento para a zona rural. São Paulo: Ícone.

3. Carvalho, T. B. de, & Zen, S. (2017). A cadeia de Pecuária de Corte no Brasil: evolução e tendências. Revista iPecege, 3(1), 85-99.

4. Centro de Estudos Avançados em Economia Aplicada - CEPEA. (2023). Produção de carne bovina no Brasil bate recorde em 2023. Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo. Disponível em: https://www.cepea.esalq.usp.br

5. Colatto, L., & Langer, M. (2011). Biodigestor–resíduo sólido pecuário para produção de energia. Unoesc & Ciência–ACET, 2(2), 119-128.

6. Costa, J., & Zanatti, J. (2024, May 30). Pesquisa mapeia 2,3 milhões de bovinos, 41% do gado confinado no País em 2023. Giro do Boi. Disponível em: https://girodoboi.canalrural.com.br/pecuaria/tecnologia-e-inovacao/pesquisa-mapeia-23-milhoes-de-bovinos-41-do-gado-confinado-no-pais-em-2023/

7. Costa, A. R. da, Silva, N. F. da, & Gomes, F. P. B. (1985). Biodigestor. Goiânia: Editora da Universidade Católica de Goiás.

8. Chadwick, D., et al. (2008). Management of livestock and their manure to reduce the risk of microbial transfers to water–the case for an interdisciplinary approach. Trends in Food Science & Technology, 19(5), 240-247.

9. Fernandes, M. (2021). Tratamento de dejetos bovinos gera renda e sustentabilidade ambiental no norte de Minas. EMATER MG. Disponível em: https://www.emater.mg.gov.br

10. Fulhage, C. D. (1997). Manure management considerations for expanding dairy herds. Journal of Dairy Science, 80(8), 1872-1879.

11. Galvão, et al. (2015). Principais itens para relatar revisões sistemáticas e meta-análises: A recomendação PRISMA. Epidemiologia e Serviços de Saúde, 24, 335-342.

12. Gaspar, R. M. B. L. (2003). Utilização de biodigestores em pequenas e médias propriedades rurais com ênfase na agregação de valor: um estudo de caso na região de Toledo-PR. Universidade Federal de Santa Catarina.

13. Geo Biogas e Tech. (2021). Relatório de Sustentabilidade 2021. Disponível em: https://geobiogas.tech/static/relatorios/Relatorio_de_Sustentabilidade_GEO_2021.pdf

Revista ARACÊ
ISSN: 2358-2472

14. Lins, L. P., Furtado, A. C., & Mito, J. Y. L. de. (2022). O aproveitamento energético do biogás como ferramenta para os objetivos do desenvolvimento sustentável. Interações (Campo Grande), 23(4), 1275-1286.

15. Lopes, et al. (2022, August 8-11). Monitoramento da produtividade na bovinocultura de corte brasileira. In 60º Congresso da Sociedade Brasileira de Economia, Administração e Sociologia Rural (SOBER), Natal, RN.

16. Lora, E. E. S., & Venturini, O. J. (2012). Biocombustíveis (Vol. 1). Rio de Janeiro: Interciência.

17. Manso, J. R. K., & Mendes, F. O. (2007). Confinamento de bovinos: Estudo do gerenciamento dos resíduos. Universidade Católica de Goiás – Departamento de Engenharia – Engenharia Ambiental.

18. Matos, C. F. (2016). Produção de biogás e biofertilizante a partir de dejetos de bovinos, sob sistema orgânico e convencional de produção. (Dissertação de Mestrado, Instituto de Tecnologia, Universidade Federal Rural do Rio de Janeiro).

19. Menezes, F. G., et al. (2023). O papel dos biodigestores na agropecuária para mitigação das mudanças climáticas: uma análise dos benefícios ambientais. Disponível em: https://www.alice.cnptia.embrapa.br

20. Nicoloso, R. da S., et al. (2019). Uso do digestato como fertilizante.

21. Ramasamy, E. V., et al. (2004). Feasibility studies on the treatment of dairy wastewaters with up-flow anaerobic sludge blanket reactors. Bioresource Technology, 93(2), 209-212.

22. Ramasamy, E. V., & Abbasi, S. A. (2000). Energy recovery from dairy waste-waters: Impacts of biofilm support systems on anaerobic CST reactors. Applied Energy, 65(1-4), 91-98.

23. Oliveira, L. A. G. (2011). Dejetos suínos: qualidade, utilização e o impacto ambiental. Goiânia: Pós-Graduação em Ciência Animal, Universidade Federal de Goiás.

24. Silva, L. de O. (2024). Uso de Biodigestores em Estação de Tratamento de Esgoto. UNICIÊNCIAS, 28(1), 25–31. https://doi.org/10.17921/1415-5141.2024v28n1p25-31

25. Silva, L. de O., Porto, P. P., & Silva, M. A. A. da. (2024). Fortalecimento da agricultura familiar através da implementação de biodigestores caseiros: uma abordagem sustentável e tecnológica para o manejo de resíduos orgânicos. Caderno Pedagógico, 21(13), e12485. https://doi.org/10.54033/cadpedv21n13-353

26. Tolmasquim, M. (2007). Plano Nacional de energia 2030. Conselho Nacional de Política Energética-CNPE.

27. Xavier, C. A. N. (2005). Biodigestão anaeróbia de dejetos em sistema de produção de leite: obtenção de parâmetros e dimensionamento. (Dissertação de Mestrado, Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista).

28. Xavier, C. A. N. (2009). Caldo de cana-de-açúcar na biodigestão anaeróbia com dejetos de vacas em lactação sob diferentes dietas. (Tese de Doutorado, Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista).