# NATIONAL PRELIMINARY OVERVIEW OF THE EFFLUENT GENERATED IN MILK PRODUCTION

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**Abstract**

The dairy production chain plays an important economic and social role in Brazil. However, the intensification of this activity is also associated with increased waste and effluent generation, making the development of environmental management strategies essential. In this context, the present study aimed to analyze the state of Brazilian milk production and determine how the issue of effluents is addressed in the sector's principal information sources. This descriptive and exploratory study adopted a qualitative and quantitative approach based on a literature review, document analysis, and the analysis of secondary data from the Municipal Livestock Survey (Pesquisa da Pecuária Municipal, PPM/IBGE), accessed through the IBGE Automatic Data Retrieval System (Sistema IBGE de Recuperação Automática, SIDRA), and the Milk Yearbooks published by Embrapa Dairy Cattle, covering the period from 2018 to 2023. The results revealed changes in the dynamics of the dairy chain, including growth in the cattle herd and production value, a reduction in the number of cows milked, and stable milk production, indicating gains in production efficiency. The findings also showed that, although the Milk Yearbooks expanded their discussion of sustainability over the period analyzed, official indicators related to effluent generation, treatment, and disposal remain scarce. It is concluded that incorporating this information into official statistical databases could contribute to the environmental planning of the activity and to the development of public policies and more sustainable management strategies.

***Keywords:*** Dairy chain, Effluents, Sustainability.

## INTRODUCTION

The dairy production chain is one of Brazil's principal agricultural activities and plays a fundamental role in generating employment and income and ensuring food security. Brazil is the world's

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fourth-largest milk producer, producing 35.1 billion liters per year according to Embrapa's 2018 Milk Yearbook. Production is distributed throughout all regions of the country and accounts for a substantial share of the national agricultural economy (Bacchi et al., 2022). However, the expansion of the activity and the intensification of production systems have also heightened the challenges associated with water consumption, waste generation, and effluent production, making it essential to develop environmental management strategies that reconcile productivity with sustainability.

The efficient and economically viable disposal of effluents generated by different production sectors is one of the principal environmental challenges facing livestock farming. Among the most widely used alternatives is pretreatment followed by controlled land application, a practice that promotes the degradation of organic matter and, when properly implemented, can help improve the soil's physical, chemical, and biological properties (Neto, 2014).

Milk production requires substantial water consumption throughout every stage of the production process, including providing drinking water for animals and cleaning facilities, milking equipment, storage tanks, and processing areas. According to Udaypal et al. (2025), the dairy industry accounts for approximately 34% of the water used by the food sector worldwide, with between 1 and 10 liters of water required to process each liter of milk. As a result of this high water consumption, large volumes of effluent are generated daily, making their management a fundamental aspect of the activity's sustainability.

Effluents from the dairy chain vary considerably in composition and may contain manure, feed residues, pasture residues, detergents, sanitizers, oils, fats, suspended solids, and high concentrations of organic matter (Neto, 2014). In the dairy industry, their generation is directly associated with the cleaning of tanks, pipes, pumps, processing equipment, floors, and storage areas, as well as with raw-material losses during processing. Because of these characteristics, between 1 and 10 liters of effluent may be

generated for every liter of milk processed, depending on the technological level and characteristics of the industrial facility (Saraiva et al., 2009; Udaypal et al., 2025).

When improperly discharged, these effluents can cause various environmental impacts, including increased biochemical oxygen demand (BOD), reduced dissolved oxygen in water bodies, eutrophication, contamination of soil and surface and groundwater, and greenhouse gas emissions (Udaypal et al., 2025). Proper effluent treatment is therefore essential not only for complying with current environmental legislation, represented primarily by the National Water Resources Policy and National Environmental Council (Conselho Nacional do Meio Ambiente, CONAMA) Resolutions No. 357/2005 and No. 430/2011, given that no regulations specifically govern effluents from milk production, but also for reducing the impacts associated with the activity and promoting more efficient use of natural resources (Brazil, 1997; CONAMA, 2005; CONAMA, 2011).

In recent years, effluents from the dairy chain have come to be viewed as resource streams rich in carbon, nitrogen, and phosphorus. These nutrients can be harnessed to produce biogas, bioenergy, and biofertilizers through processes such as anaerobic digestion (Kunz et al., 2020; Silva et al., 2022). In this context, the use of these effluents as feedstock for anaerobic digestion has attracted interest because it simultaneously enables the removal of the effluent's organic load and the generation of bioenergy coupled with biofertilizer production, thereby contributing to waste valorization and the adoption of circular-economy strategies (Ashekuzzaman et al., 2021; Milanez et al., 2018). These alternatives make it possible to reduce environmental impacts while adding value to the waste generated by the activity.

Despite advances in research on the treatment and reuse of effluents from milk production, consolidated information on the generation, treatment, and disposal of these wastes remains limited in official Brazilian databases. The lack of environmental indicators hinders the preparation of regional- and national-scale assessments, limits public-policy planning, and reduces the availability of information that could support environmental management strategies for the dairy production chain.

Given this scenario, this study aimed to analyze the development of the dairy production chain in Brazil based on official data from the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística, IBGE) and the Milk Yearbooks published by Embrapa Dairy Cattle, discussing the implications of these indicators for effluent generation and management in dairy farming and identifying gaps in the sector's main information sources.

## METHODOLOGY

This descriptive and exploratory study adopted a qualitative and quantitative approach and was based on a literature review, document analysis, and the analysis of secondary data from official statistical databases and technical and scientific publications concerning the dairy production chain in Brazil.

To characterize the production and economic landscape of Brazilian dairy farming, data from the Municipal Livestock Survey (Pesquisa da Pecuária Municipal, PPM), made available by the Brazilian Institute of Geography and Statistics (IBGE) through the IBGE Automatic Data Retrieval System (SIDRA), were used alongside the Milk Yearbooks published by Embrapa Dairy Cattle. The period analyzed extended from 2018 to 2023, as it represents a recent time series containing consolidated information that is comparable across the sources consulted, thus allowing an assessment of the development of the dairy chain's principal indicators and of discussions related to sustainability.

Initially, a literature search was conducted in scientific articles, specialized publications, technical reports, and institutional documents concerning the dairy production chain, with an emphasis on its production, economic, and environmental aspects. Statistical data on the cattle herd, number of cows milked, annual volume of milk produced, and value of milk production were then collected, as these indicators can characterize the development of the activity in the country.

The data obtained were organized into tables and graphical representations, allowing the temporal development of the indicators to be analyzed and trends related to production and the economic

importance of the dairy chain to be identified. In addition, a document analysis of Embrapa's Milk Yearbooks was conducted to determine how issues related to sustainability and effluent management were addressed throughout the study period. For this stage, sections concerning environmental management, water use, waste management, anaerobic digesters, biofertilizers, and other practices aimed at the sustainability of milk production were examined.

Finally, information from the statistical databases and document analysis was integrated, making it possible to develop an overview of the Brazilian dairy chain and identify gaps in the availability of information on the generation, treatment, and disposal of effluents from the activity.

## RESULTS AND DISCUSSION

The analysis of data from the IBGE Automatic Data Retrieval System (SIDRA) and Embrapa's Milk Yearbooks made it possible to characterize changes in Brazil's cattle herd, milk production, number of cows milked, and gross production value between 2018 and 2023. A joint assessment of these indicators enables an understanding of the transformations that occurred in the dairy production chain during this period and supports a discussion of their implications for effluent generation and management. In addition, the use of this system enables the retrieval of official data on Brazilian agricultural production, allowing time series to be analyzed and production indicators to be compared over time.

Table 1 presents the changes in the main indicators of the Brazilian dairy chain between 2018 and 2023. Overall, the cattle herd and gross production value increased, whereas the number of cows milked decreased over the period analyzed. In contrast, national milk production remained relatively stable, indicating changes in the activity's production dynamics. These results suggest a process of production intensification characterized by productivity gains and greater efficiency in dairy systems.

**Table 1**

*Main data on the milk-producing industry in Brazil.*

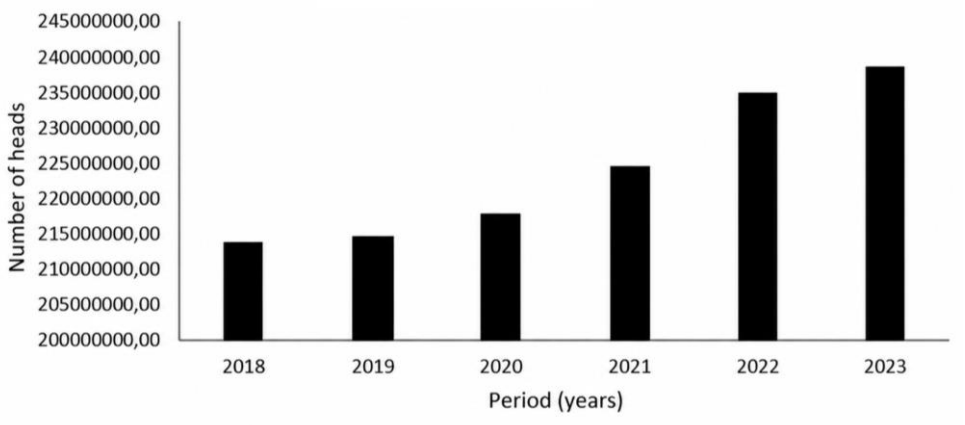
| YEAR | HERD (Head) | PRODUCT (liters) | | PRODUCT VALUE (R$) | HERD |
|---|---|---|---|---|---|
| | CATTLE (IBGE) | IBGE | EMBRAPA | MILK (IBGE) | COWS MILKED (IBGE) |
| 2018 | 213809445,00 | 33.907.899.000,00 | 24.460.000.000,00 | 39.344.516.000,00 | 16.353.091,00 |
| 2019 | 214689984,00 | 34.871.669.000,00 | 25.010.000.000,00 | 43.141.581.000,00 | 16.291.727,00 |
| 2020 | 217836282,00 | 35.316.667.000,00 | 25.060.000.000,00 | 56.348.186.000,00 | 15.953.935,00 |
| 2021 | 224601992,00 | 35.183.066.000,00 | 25.000.000.000,00 | 67.987.725.000,00 | 15.892.943,00 |
| 2022 | 234851536,00 | 34.554.161.000,00 | 35.305.000.000,00 | 79.919.856.000,00 | 15.675.519,00 |
| 2023 | 238626442,00 | 35.375.235.000,00 | 35.375.236.000,00 | 80.265.338.000,00 | 15.659.302,00 |

Source: IBGE Automatic Data Retrieval System (SIDRA) and Embrapa Dairy Cattle Milk Yearbooks.

The analysis of the national cattle herd shows an upward trend over the study period (Figure 1). However, this indicator should be interpreted cautiously when used in studies of the dairy chain because it includes animals raised for both beef and milk production. Its principal contribution is therefore to contextualize the development of Brazilian livestock farming, whereas specific indicators such as the number of cows milked and milk production more accurately characterize the dynamics of dairy farming.

**Figure 1**

*Number of head of cattle in Brazil.*



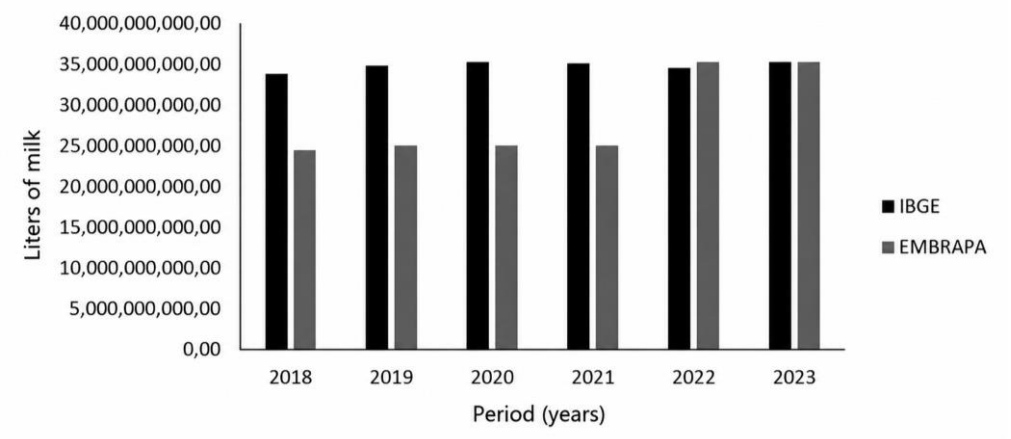

Source: IBGE Automatic Data Retrieval System (SIDRA) and Embrapa Dairy Cattle Milk Yearbooks.

Unlike the pattern observed for the cattle herd, national milk production remained relatively stable throughout the period analyzed, exhibiting only minor annual fluctuations (Figure 2). This pattern

suggests that Brazilian dairy farming is undergoing a process of production reorganization in which substantial increases in output depend less on expanding the number of animals and more on productivity gains achieved through genetic improvement, nutrition, management, and the technological advancement of farms.

**Figure 2**

*Volume of milk produced according to data collected by IBGE and EMBRAPA.*

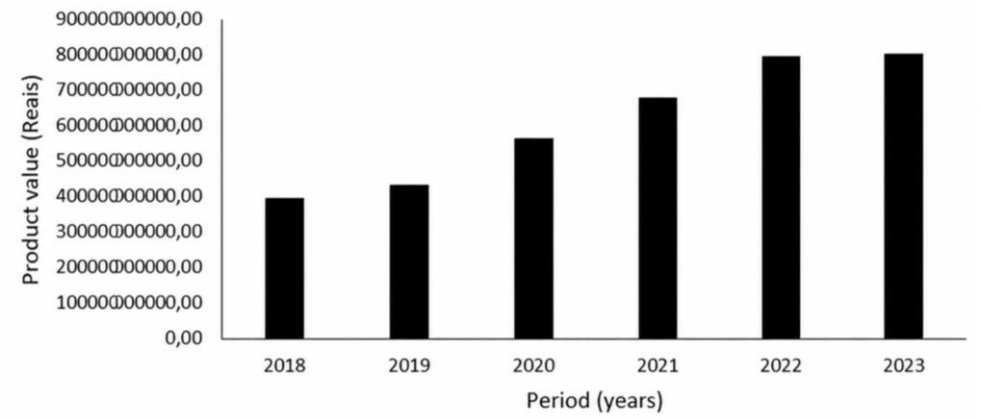



Source: IBGE Automatic Data Retrieval System (SIDRA) and Embrapa Dairy Cattle Milk Yearbooks.

Gross production value increased substantially over the study period (Figure 3), exceeding the change observed in the physical volume of milk produced. This pattern may be associated with increases in the price paid to producers, fluctuations in the national dairy market, production costs, and the inflationary effects recorded during the period, indicating that economic factors significantly influenced the activity's profitability.

**Figure 3**

*Product value in Brazil.*

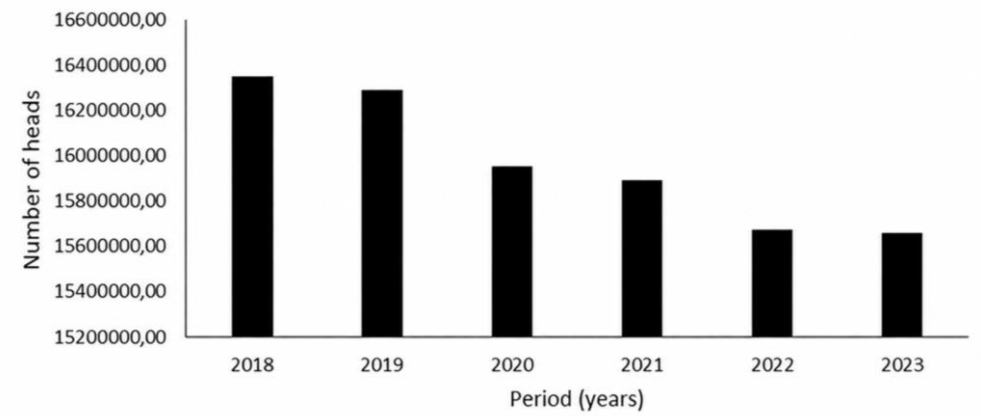



Source: IBGE Automatic Data Retrieval System (SIDRA) and Embrapa Dairy Cattle Milk Yearbooks.

One of the most significant findings of this study was the gradual reduction in the number of cows milked despite stable national milk production (Figure 4). A joint analysis of these indicators demonstrates an increase in average productivity per animal, a result consistent with the growing adoption of management technologies, genetic improvement, and precision feeding in Brazilian dairy farming.

**Figure 4**

*Number of cows milked in Brazil.*




Source: IBGE Automatic Data Retrieval System (SIDRA) and Embrapa Dairy Cattle Milk Yearbooks.

The integrated analysis of the indicators reveals changes in the dynamics of the Brazilian dairy chain between 2018 and 2023. Although the national cattle herd increased (Figure 1), the number of cows milked declined (Figure 4), while milk production remained relatively stable (Figure 2) and gross production value increased significantly (Figure 3). Taken together, these results suggest gains in production efficiency, indicating that production was maintained with fewer animals being milked, possibly because of the adoption of genetic, nutritional, and technological improvements in production systems.

From an environmental perspective, the intensification of dairy farming also creates challenges concerning the management of waste and effluents generated on farms. Although the data analyzed do not allow the volume of effluent produced to be quantified directly, Costa et al. (2021) state that between 0.2 and 10 L of effluent are generated per liter of milk processed and must be treated before disposal. This demonstrates that dairy systems consume substantial volumes of water and generate considerable quantities of effluent from cleaning facilities, washing equipment, and managing animal manure (Ruiz-González et al., 2024). As production becomes more intensive, planning strategies for the collection, treatment, reuse, and proper disposal of these effluents become equally important.

In this context, a significant gap is evident in the information made available by official agencies. Records in the IBGE Automatic Data Retrieval System (SIDRA) focus on production indicators such as herd size, number of cows milked, production, and production value, thereby enabling the development of the Brazilian dairy chain to be characterized consistently. However, no information is provided on the generation, treatment, reuse, or disposal of effluents produced on dairy farms. Incorporating these indicators into census surveys could contribute to the development of more accurate environmental assessments and support public policies aimed at the rational use of water, waste management, and the promotion of more sustainable practices throughout the production chain.

Ruiz-González et al. (2024) evaluated the effect of providing exercise areas for dairy cows on effluent properties and emissions of $NH_3$, carbon dioxide ($CO_2$), and greenhouse gases (GHGs) during

winter and summer. The authors observed that the characteristics of the effluent varied over the evaluation period and found that some parameters, such as biochemical oxygen demand (BOD) and suspended solids (SS), exceeded the limits established by environmental standards, particularly during winter. In addition to representing an environmental liability when improperly managed, effluents from dairy farming can also constitute a value-added resource. Following appropriate treatment, these wastes can be used to fertigate pastures and agricultural crops, produce biofertilizers, or generate biogas through anaerobic digestion, thereby contributing to the circular economy and reducing the environmental impacts of the activity.

Publications prepared by Embrapa Dairy Cattle, particularly the Milk Yearbooks, use data made available by IBGE through SIDRA as their statistical basis. Accordingly, the milk-production figures presented in these documents essentially correspond to the same data found in official databases. The principal distinction between the two sources lies in how this information is handled. Whereas SIDRA presents raw data organized in statistical tables, Embrapa's yearbooks incorporate interpretive analyses, technical discussions, and reflections on trends in the dairy production chain.

However, an analysis of the variables available in the system shows that there are no specific records concerning effluent generation from dairy farming, nor any data that would allow the volume of liquid waste produced, treated, or discharged into water bodies and soil throughout the production process to be quantified. Thus, although the system provides a detailed overview of the production dimension of dairy farming in the country, it does not include environmental indicators that would allow the impacts associated with the management of waste and effluents generated on rural farms or during the initial stages of the dairy production chain to be assessed directly.

A similar situation can be observed in publications prepared by Embrapa Dairy Cattle, particularly the Milk Yearbooks, which use data from IBGE's own system as their statistical basis. In these publications, quantitative data on milk production remain essentially the same because Embrapa relies on

official statistics to present sector indicators. The principal difference lies in how this information is interpreted and presented, as the yearbooks incorporate technical analyses, discussions of production trends, and reflections on the challenges facing Brazil's dairy chain.

Regarding effluents generated by milk production specifically, this information does not appear systematically in the yearbooks in the form of statistical indicators. Instead, the subject is addressed predominantly through research reports, case studies, and technical articles discussing environmental management practices, waste-treatment technologies, and initiatives aimed at making the activity more sustainable. Consequently, this study brought together and analyzed these different contributions appearing in the yearbooks to understand how the issue of effluents has been addressed over the years in the context of Brazilian milk production.

A chronological analysis of Embrapa's Milk Yearbooks reveals a gradual development in how environmental issues related to the dairy chain were addressed between 2018 and 2023. In the first years analyzed, the publications focused predominantly on production, economic, and technological indicators, whereas environmental aspects were addressed more sporadically. Beginning in 2020, discussions of sustainability expanded, with greater emphasis on topics such as the rational use of water, waste management, anaerobic digesters, biofertilizers, the circular economy, and mitigation of greenhouse gas emissions. This development demonstrates that sustainability has assumed an increasingly prominent place in discussions on the development of the Brazilian dairy chain.

Despite this progress, no quantitative indicators related to the generation, treatment, or disposal of effluents from milk production were identified in Embrapa's Milk Yearbooks. This finding reinforces the gap also observed in IBGE databases, which provide detailed information on livestock, production, and economic indicators but do not include environmental data capable of quantifying effluent generation on farms. The absence of this information limits the preparation of regional- and national-scale environmental assessments, as well as the planning of strategies aimed at efficient water use, effluent

treatment, and the use of these wastes in practices such as fertigation, biofertilizer production, and biogas generation.

In the Anuário Leite 2018 [2018 Milk Yearbook] (EMBRAPA, 2018), for example, no direct references were identified concerning the treatment or use of effluents generated by dairy farming. The publication focuses primarily on presenting production data, market trends, and structural aspects of the dairy chain without examining the environmental management of waste from the activity in greater depth.

A similar situation can be observed in the Anuário do Leite 2019 [2019 Milk Yearbook] (EMBRAPA, 2019). Although this edition contains an article on sustainable products, it does not specifically address the treatment or use of manure and effluents from milk production. This suggests that, at the time, discussion of sustainability in the sector was still at an early stage and was conducted in broader terms, with less focus on environmental issues directly related to the production process.

Beginning in 2020, however, a gradual change in how the topic was addressed can be observed. The Anuário Leite 2020 [2020 Milk Yearbook] (EMBRAPA, 2020) presents two significant topics related to sustainability in milk production. The first concerns the rational use of water and effluent management, emphasizing the importance of adopting technologies that increase production efficiency while reducing the waste of water resources. This discussion is particularly relevant because milk production requires significant volumes of water for activities such as cleaning equipment and facilities and managing animals.

The second topic addressed in this edition concerns the use of anaerobic digestion as an alternative for utilizing the organic waste generated by dairy farming. Anaerobic digestion transforms organic waste into biogas and biofertilizers, simultaneously promoting renewable energy generation and reducing environmental impacts. The material resulting from this process contains significant concentrations of nutrients such as nitrogen, phosphorus, and potassium and can be used as an agricultural fertilizer. Studies cited in this edition indicate that this type of material can partially replace inorganic fertilizers, reducing

the need for mineral fertilization by as much as 22% in crops such as corn, depending on management conditions.

In the Anuário Leite 2021 [2021 Milk Yearbook] (EMBRAPA, 2021), the sustainability debate takes on a broader dimension and begins to encompass strategies related to the environmental management of companies in the sector. In this context, initiatives by different organizations seeking to incorporate sustainable practices into their operations are presented. These initiatives include the incorporation of costs associated with carbon emissions into companies' financial statements, a practice that demonstrates growing concern with internalizing environmental impacts into the economic management of the activity.

In addition, some companies have begun adopting circular-economy principles by promoting the recycling of packaging materials such as plastics and paper and seeking to reduce waste generation throughout the production chain. These initiatives indicate that the sector is gradually moving toward more sustainable production models in which environmental management is regarded as an integral component of competitiveness and market-positioning strategies.

This trend becomes even more apparent in the Anuário Leite 2022 [2022 Milk Yearbook] (EMBRAPA, 2022), which more directly addresses the relationship between milk production and climate change. This edition focuses on strategies for reducing or neutralizing carbon emissions associated with the activity. The practices suggested include improvements in the management of production systems, the adoption of low-impact technologies, and the development of products aligned with emission-reduction targets.

The Anuário Leite 2023 [2023 Milk Yearbook] (EMBRAPA, 2023), in turn, highlights the role of sustainable dairy farms and emphasizes the importance of properly managing production systems to mitigate greenhouse gas emissions. According to the discussions presented, approximately 5% of global greenhouse gas emissions are associated with milk production. In this context, practices such as proper

pasture management, improvements in animal feed efficiency, and appropriate waste management are identified as important strategies for reducing the emission intensity associated with the activity.

The Anuário Leite 2024 [2024 Milk Yearbook] (EMBRAPA, 2024) introduces a discussion of environmental labeling and the carbon footprint of milk. Environmental labeling is presented as an instrument capable of informing consumers about the environmental impacts associated with the production of specific products throughout their life cycles. In the case of milk, the carbon footprint corresponds to the quantity of greenhouse gases emitted during the production process, expressed in kilograms of carbon dioxide equivalent ($CO_2eq$) per unit of product. This indicator considers different emission sources, including carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$), which are converted into equivalent $CO_2$ values for comparison purposes.

Reducing the carbon footprint of milk involves a series of stages ranging from selecting calculation tools to continuously monitoring emissions and implementing mitigation strategies. These stages include collecting data on the production system, identifying the principal emission sources, critically analyzing the results obtained, and planning measures to reduce emissions throughout the production chain.

Finally, the Anuário Leite 2025 [2025 Milk Yearbook] (EMBRAPA, 2025) presents a more comprehensive approach to the relationship between milk production and environmental sustainability, including more direct discussions of effluent treatment. This edition mentions several technological alternatives for properly managing waste generated by the activity, such as anaerobic digesters and composting systems. These technologies reduce the release of gases such as methane and nitrous oxide while allowing the waste to be used to produce biogas and organic fertilizers.

The yearbook also highlights the potential use of agricultural, livestock, and industrial biological inputs as tools for the sustainable management of waste generated by milk production. Although these initiatives are still presented in general terms and without an in-depth account of their implementation

nationwide, they indicate a growing movement within the sector toward adopting more sustainable practices aligned with contemporary demands for environmentally responsible agricultural production.

The analysis conducted throughout this study made it possible to understand how the issue of effluents generated by milk production has been addressed in Brazil, both statistically and in the technical discussions contained in specialized publications. By evaluating the information available in the official databases of the Brazilian Institute of Geography and Statistics (IBGE), particularly through the IBGE Automatic Data Retrieval System, and analyzing the technical publications prepared by Embrapa Dairy Cattle, significant gaps were identified in the consolidation of information concerning the generation, treatment, and disposal of effluents from dairy farming.

One of the main points revealed by this study concerns the absence of specific regulations governing the treatment and management of effluents generated in the milk production process. Although various environmental laws address effluent discharges and the protection of water resources in general, including the National Water Resources Policy (Law No. 9,433/1997) and CONAMA Resolutions No. 357/2005 and No. 430/2011, the analysis did not identify a national regulatory framework specifically addressing the characteristics of effluents generated by milk production. This absence of more specific regulation may hinder the implementation of standardized environmental management practices on rural farms because producers frequently need to interpret broader rules and adapt them to the realities of their production systems.

Another relevant aspect identified concerns how the issue of effluents has been addressed in technical and scientific circles. The analysis of the publications consulted indicates that research and initiatives concerning waste management and effluent use in milk production do exist. However, these studies are relatively scattered and are often associated with specific projects or isolated experiences developed by research institutions. This characteristic prevents the knowledge generated in this field from becoming fully integrated, potentially hindering access to and application of this information by rural producers and other stakeholders in the production chain.

In this context, there is still no clear framework that brings together and systematizes the various existing proposals for managing effluents from milk production. Although technical studies and institutional reports discuss a range of environmental management technologies and practices, such as anaerobic digesters, composting systems, and nutrient-reuse strategies, these solutions are not always organized systematically in guidance documents that can serve as a direct reference for producers.

This gap becomes particularly significant when the scale of Brazil's dairy production chain is considered. The yearbooks analyzed show that milk production involves many rural properties distributed throughout different regions of the country, with production systems that vary considerably in scale, technological level, and investment capacity. In this context, the absence of clearer guidelines may create difficulties in adopting appropriate effluent-management practices, particularly on smaller farms or those with less access to specialized technical assistance.

Another point that warrants attention concerns the responsibility assigned to rural producers for managing the effluents generated by the activity. The analysis shows that a substantial share of the decisions concerning the selection of treatment systems, waste-reduction strategies, and forms of effluent reuse ultimately rests directly with producers themselves. In practice, this means that producers must often seek information, evaluate the technological alternatives available, and decide which measures can be implemented on their farms. Although this autonomy may promote the adoption of solutions tailored to the specific characteristics of each production system, it can also pose a challenge, particularly when accessible information or adequate technical guidance is lacking. In this regard, the absence of clearer guidelines and support instruments may lead to the adoption of inefficient practices or even the continuation of management systems that do not fully meet environmental requirements.

Furthermore, the availability of data on effluent generation and disposal remains limited. As observed in the analysis of IBGE's statistical databases, the available information focuses primarily on the production and economic indicators of dairy farming and does not include specific variables concerning

its environmental dimensions. The absence of consolidated data makes it difficult to prepare more accurate assessments of the volume of effluents generated by the sector and the practices effectively adopted for their treatment and disposal.

It is therefore clearly necessary to expand the mechanisms used to monitor and record information concerning the environmental management of milk production. Incorporating indicators of effluent generation and management into official statistical databases could contribute significantly to the development of more targeted public policies, while also providing support for future research and the formulation of more efficient environmental management strategies.

Another aspect emerging from the study's results concerns the potential integration of production practices and environmental sustainability strategies throughout the dairy chain. Technologies such as anaerobic digesters, nutrient-reuse systems, and proper manure management have the potential not only to reduce environmental impacts but also to generate additional economic benefits for producers, including biogas production and the use of biofertilizers on their own farms. However, for these alternatives to become more widespread, stronger coordination among research institutions, rural extension agencies, and public policies directed toward the sector is essential.

In this regard, initiatives aimed at disseminating knowledge, training producers, and developing incentive programs for the adoption of sustainable technologies could play an important role in promoting more appropriate management practices. Developing technical instruments that bring together and systematize the different solutions available may also help make the decision-making process more accessible to producers.

Finally, the results obtained in this study indicate that, although progress has been made in discussions of sustainability within the dairy production chain, significant gaps remain in the management of effluents generated by the production process. The absence of specific regulations, the fragmented nature of existing research, and the limited availability of consolidated data constitute challenges that must be addressed if the sector is to move toward more sustainable production models.

The importance of expanding the debate on the environmental management of milk production in Brazil is therefore reaffirmed, with a view to promoting greater integration among research, public policy, and production practices. Strengthening this coordination could contribute to the development of more effective effluent-management strategies, thereby supporting both the environmental sustainability of the activity and the continuity and competitiveness of milk production in the country.

Finally, the quantitative data obtained from the statistical databases were analyzed in conjunction with the qualitative information from the literature review. This integrated analysis made it possible to establish relationships between changes in milk production in Brazil and the environmental challenges associated with the activity, particularly regarding the generation and management of effluents in the production process. The methodological approach adopted thus enabled a more comprehensive understanding of the production, economic, and environmental aspects characterizing the country's dairy chain.

The absence of specific indicators in official statistical databases limits the ability to quantitatively assess these environmental impacts, reinforcing the need to expand systems for monitoring and producing information concerning the environmental management of dairy farming in Brazil.

## CONCLUSION

This study made it possible to analyze the recent development of the Brazilian dairy chain and identify how the issue of effluents has been addressed in the sector's principal information sources and technical publications. IBGE data revealed changes in production dynamics between 2018 and 2023, characterized by an increase in the cattle herd, a reduction in the number of cows milked, stable milk production, and growth in gross production value. At the same time, the analysis of Embrapa's Milk Yearbooks revealed the increasing incorporation of sustainability-related topics over the years, although

quantitative indicators concerning the generation, treatment, and disposal of effluents from dairy farming remain unavailable.

The results demonstrate the need for greater integration between production and environmental information in the dairy chain by incorporating indicators related to effluent management into official statistical databases and strengthening technical instruments that support producers and public administrators. Consolidating this information could contribute to the environmental planning of the activity, support the formulation of public policies, and encourage the adoption of technologies for treating and reusing effluents, thereby promoting the development of more efficient and sustainable production systems.

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