DEVELOPMENT OF LABORATORY COMPOSTERS SYSTEM TO MIMIC BOVINE CONFINEMENT "COMPOST BARN"

Gabriela M. F. Fiães[1]*, Camila S. Coelli[2], Alessandro de Sá Guimarães[3], Bruno Campos de Carvalho[3] & Marcelo H. Otenio[3]

[1] Graduate Program in Biodiversity and Nature Conservation, Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil.
[2] Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil.
[3] Embrapa Dairy Cattle, Juiz de Fora, Brazil.
** Corresponding author's email address: gabriela.fiaes@estudante.ufjf.br*

ABSTRACT

The livestock sector faces constant challenges in the pursuit of sustainable and efficient practices. In the context of dairy production, the search for housing systems that promote animal welfare, productive efficiency, and environmental management intensified from the second half of the 20th century onwards. The Compost Barn (CB) emerges as an innovative alternative, providing a comfortable and low-stress environment for dairy cattle. The objective of this study is to construct 3-liter bench-scale aerobic bioreactors designed to simulate the Compost Barn under laboratory conditions, aiming at technological innovation and enabling new studies on the CB. Therefore, three bench-scale bioreactors filled with compost bedding and sawdust were assembled, and their temperature was monitored every 30 seconds for three months. The results revealed the need for adjustments in operational conditions, such as aeration, waste proportion, and material turning intervals, highlighting the significance of this equipment for future research endeavors.

Keywords: Aerobic bioreactors. Environmental biotechnology. Composting. Temperature monitoring. Technological innovation.

1 INTRODUCTION

The pursuit of sustainable and efficient agricultural practices has driven the adoption of innovations in dairy herd management[6]. One of these innovations is the "compost barn," an innovative option to conventional housing systems for dairy cattle[2]. The Compost Barn system has emerged as an effective alternative for manure management in dairy cattle farms. However, the complexity of this system and its interaction with environmental and microbiological factors still present challenges that need to be addressed[4]. In this context, there is an urgent need to study the Compost Barn on a laboratory scale.

Firstly, replicating the Compost Barn environment in a laboratory offers the opportunity to control specific variables, such as temperature, humidity, and material composition, in a way that would not be possible in a farm setting. This allows for a more detailed study of decomposition and composting processes, as well as the evaluation of different management strategies. Additionally, the laboratory scale provides a more controlled environment to investigate the effects of different additives or interventions in the composting process[5]. For example, it is possible to test the effectiveness of different bedding materials, microbial additives, or aeration techniques without the costs associated with large-scale testing and without risk to works and animals. Another advantage is the ability to conduct more detailed microbiological studies. Analyzing the microbiome present in the composted material can provide important insights into the microbial communities involved in decomposition processes and their effects on the quality of the resulting compost. Furthermore, laboratory-scale research can be complemented by computational modeling, allowing for the prediction of system performance in different scenarios and the optimization of management parameters.

Initially, bench-scale aerobic bioreactors of 3 liters were constructed with the aim of accelerating the decomposition of organic waste with a high organic matter content. In this work, however, the adaptation of these bioreactors to simulate the operating conditions of the Compost Barn is targeted. In this context, adjustments to the bioreactors and modifications to operational conditions, such as aeration, waste proportion, or introduction of decomposition-promoting agents, are necessary. Therefore, the main objective of this work is the construction of 3-liter bench-scale aerobic bioreactors intended to simulate the Compost Barn under laboratory conditions.

2 MATERIAL & METHODS

The confinement and dairy cattle rearing system, where samples were collected for the "Compost Barn" experiment, is located at the José Henrique Brusque Experimental Field of Embrapa Dairy Cattle, in the municipality of Coronel Pacheco, MG. During the experiment, the number of animals confined in the Compost Barn system (Figure 1) was 85 Holstein dairy cows. Moisture and temperature analyses of the bioreactors were conducted in the Rumen Microbiology Laboratory, located at the headquarters of EMBRAPA, in Juiz de Fora, MG.

The assembly of the bioreactors was carried out between November 27 and 30, 2023, with the assistance of researchers from Embrapa Soils, located in the Rio de Janeiro Botanical Garden - RJ. The bioreactors were filled with 50% wood shavings and 50% compost bedding from the farm, being daily replenished with manure and urine from Holstein cows in the Compost Barn system of the Experimental Field. Cattle manure samples are collected on the farm every 15 days, while cattle urine samples are collected as needed. Daily replenishment, started on January 31, 2024, continues to the present moment. During this process, each reactor is opened and transferred to a tray, where mixing and addition of feces and urine occur, followed by turning over all the material. The amount of feces and urine inserted during replenishment is determined by the ratio between the area and the actual volume of the Compost Barn and the number of confined animals, so the proportion is made regarding the volume of the bioreactors and the daily amount of urine (1543.6 kg/d) and manure (3515.6 kg/d) generated in the volume of compost bedding daily (612 m^3), in relation to the volume of each bioreactor (0.0033 m^3), totaling a daily addition of 19g of feces and 8.3g of urine. The bioreactors were maintained with continuous forced aeration of 2 L/h.Temperature fluctuations are continuously monitored every 30 seconds, providing a strict monitoring of the composting process. In addition, total solids of the bioreactors were monitored weekly.

3 RESULTS & DISCUSSION

The first outcome was the assembly of the equipment, consisting of three 3-liter bioreactors, an air compressor with external and internal pressure regulators, tubes for air and water passage (for air humidification), general pressure valves, and unit pressure valves for each composter, three flow meters to regulate air intake, three humidifiers (one for each reactor), and temperature and oxygen sensors embedded in the bioreactors for monitoring these parameters. This system is integrated with the Sitrad PRO software, which records information on the operation of the bioprocess, including temperatures and respirometry of the laboratory composters, as shown in Figure 1.

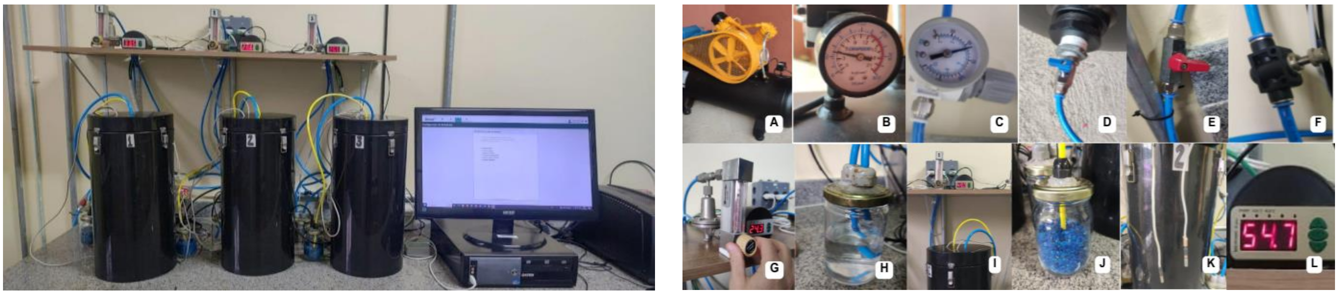

Figure 1 Compost Barn System of Embrapa Dairy Cattle, Juiz de Fora - MG.

The intake of air is carried out through a compressor (Figure 1A), and its pressure is controlled by external (Figure 1B) and internal (Figure 1C) pressure controllers, as well as by the air outlet valves of the compressor (Figure 1D), composter pressure valve (Figure 1E), which closes the passage to the 3 bioreactors, and unit pressure valves for each composter (Figure 1F). Each composter has a flow meter installed in it (Figure 1G). Thus, the air exits the compressor and passes through the flow meter, and goes to the humidifier (Figure 1H), to humidify the dry air, and thus, not damage the natural humidity of the composters. The air exits the humidifier and goes to the composters (forced aeration), then to the composters (Figure 1I) and into the container with silica (Figure 1J), to reduce the moisture content and not damage the oxygen sensor. The temperature sensors (Figure 1K) are in contact with the substrates inside the bioreactors and are coupled to the Microsol II plus (Figure 1L).

The temperature monitoring results (Figure 2) of the bioreactors provided significant insights into their operation and potential system adaptations. C1 was able to reach high temperature values, up to 53.4°C, but these values were not maintained high, averaging 35°C, with variations in temperature (highs and lows). Thus, C1 demonstrated some efficiency in the degradation of organic materials, but temperature stabilization was not maintained, with fluctuations above the set point[1]. C2 also did not maintain constant high temperatures, experiencing a brief heating to 49°C, followed by constant maintenance at 29.4°C. The initial higher peak may have occurred due to intense microbiological activity during the initial phase of composting, resulting in significant heat release. The subsequent stabilization around 30°C may indicate that composting entered a more mature phase, where microbiological activity decreased, resulting in lower heat production. This may be a response to possible over aeration conditions or an inappropriate carbon-to-nitrogen ratio. Conversely, C3 revealed challenges in activating the microorganisms responsible for degradation. Additionally, it presented a strong ammonia odor during its turning over and replenishment. The absence of high temperature and ammonia odor may be indicative of imbalance in the compost components. Ammonia is produced when there is an excess of nitrogen compared to carbon, resulting in favorable conditions for anaerobic decomposition[3]. To solve this problem, it is essential to adjust the carbon/nitrogen ratio by adding more sawdust, i.e., material rich in carbon. Furthermore, to try to recover composting, it is recommended to regularly monitor humidity and aeration, as well as perform frequent turnings[1]. After attempts to correct the conditions of the composters, we discovered that C3 was improperly installed, resulting in its temperature not being able to stay high. Consequently, we initiated the second test, repaired the wiring connections, and will conduct a new follow-up. These findings underscore the importance of controlling variables such as temperature, C/N ratio, and aeration in composting, directly influencing the effectiveness of the process. Optimizing these factors may be essential for the proper functioning of the composters. These results highlight the importance of controlling variables such as temperature, C/N ratio, and aeration in composting, directly influencing the effectiveness of the process. The optimization of these factors may be essential for the proper functioning of the composters.

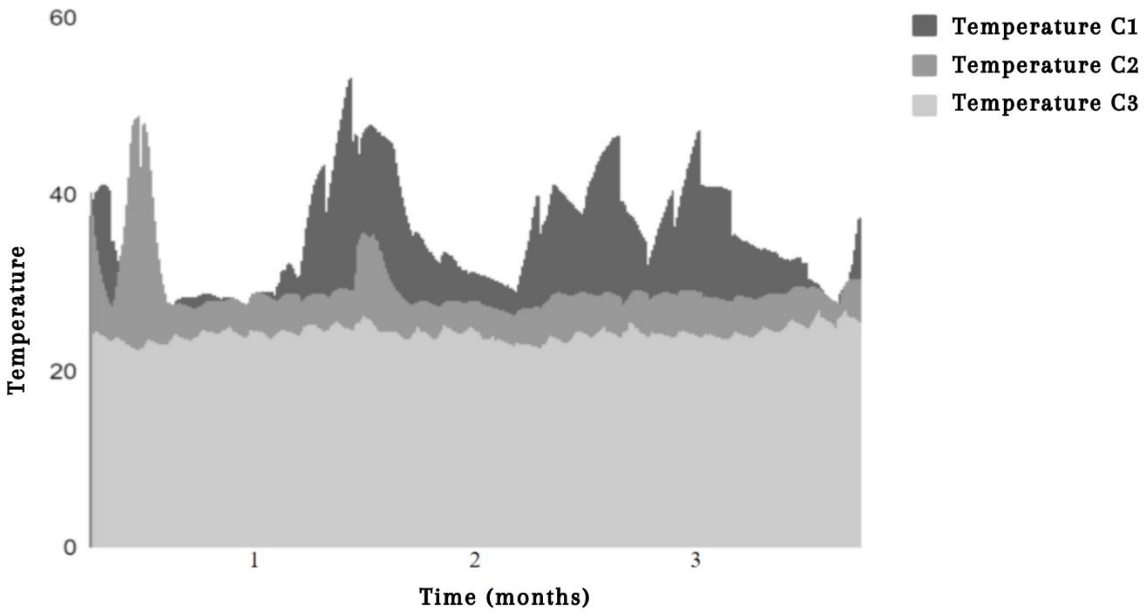

Figure 2 Temperature monitoring of the bioreactors every 30 seconds.

4 CONCLUSION

The application of aerobic bench-scale bioreactors to mimic the composting of bedding in the Compost Barn confinement system provided relevant insights for optimizing this process, even though they did not reach and maintain desired temperatures. Despite the lack of ideal heating, it was observed that the bioreactors still played a role in the decomposition of manure, as there was a change in the material's appearance comparing its state from the first day to the last day of this study, suggesting composting activity and the importance of solid waste management within an aerobic process, aiming for material recycling. The inadequate temperature rise may indicate the need for adjustments in operational conditions, such as aeration, waste proportion, interval between material turning, or the introduction of decomposition-promoting agents, as well as a better understanding of equipment operation. These results provide clues for future investigations aiming to enhance the efficiency of laboratory bioreactors, emphasizing the ongoing relevance of research and innovation in organic waste composting. Furthermore, the use of laboratory-scale composters can provide support for future research with this equipment, enabling the study on a smaller scale of the composting process with Compost Barn bedding.

REFERENCES

[1] AVIDOV, R., LUBLIN, A., VARMA, V. S., SAADI, I., YOSELEWITZ, I, CHEN, Y, LAOR, Y. Utilization of polyethylene sleeves with forced aeration for composting of broiler carcasses on mass depopulation events: Laboratory- scale simulations and sensitivity analyses. Waste Management. Volume 155. 107-117.

[2] BEAVER, A., WEARY, D. M., KEYSERLINGK, M. A.G. vo. Invited review: The welfare of dairy cattle housed in tiestalls compared to less-restrictive housing types: A systematic review, Journal of Dairy Science, Volume 104. Edição 9, 2021. Paginas 9383-9417.

[3] DE LIMA, J. G. P., MUNIZ, M. C., DA COSTA, M. E. A., & DA SILVA, A. B. Compostagem: Interface Com O Meio Ambiente E Agricultura. *Revista OWL (OWL Journal) - Revista Interdisciplinar De Ensino E Educação*, *1*(3), 464–494. 2023.10275222

[4] SILVA, M. V., PANDORFI, H., ALMEIDA, G. L. P., JARDIM, A., M., R., F., BATISTA, P. H. D., SILVA, R. A. B., LOPES, I., OLIVEIRA, M. E. G., SILVA, J. L. B., MORAES, A. S. 2020. Spatial variability and exploratory inference of abiotic factors in barn compost confinement for cattle in the semiarid. *J. Therm. Biol*, *94*, 102782–102782.

[5] THOMAS, C., IDLER, C., AMMON, C., AMON, T. 2024. Applied Research Note: Survival of Escherichia coli and temperature development during composting of chicken manure with a typically low carbon/nitrogen ratio and moisture content. Journal of Applied Poultry Research, 33(2), 100402.

[6] VIANA, G. A. V., BARROS, C. A. P., RIBEIRO, C. G., MINELLA, J. P. G., SANTOS, C. F., RIBEIRO, C. CM., SILVEIRA, V. C. P. 2023. Sustainability attributes from the water-energy-food nexus: An application to livestock systems in the Brazilian Pampa biome. Energy Nexus. 12. 100248

ACKNOWLEDGEMENTS

To FAPEMIG: Process No. APQ-00000-18 – Project: 'Health during the transition period of dairy cows housed in Compost Barn Systems', for research funding; and to CAPES for the co-doctoral scholarship code 32005016012P4, and to the postgraduate program in Biodiversity and Nature Conservation at Federal University of Juiz de Fora; and to Embrapa Dairy Cattle for the internship.