

UNIVERSIDADE FEDERAL DE VIÇOSA

Challenges in agricultural production: the quality of BRS capiaçu silage and the effects of the Fundão dam collapse in Mariana (MG) on dairy production

Maria Isabela Moreira Silva
Magister Scientiae

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Challenges in agricultural production: the quality of BRS capiaçu silage and the effects of the Fundão dam collapse in Mariana (MG) on dairy production

Dissertation submitted to the Animal Science Graduate Program of the Universidade Federal de Viçosa in partial fulfillment of the requirements for the degree of *Magister Scientiae*.

Adviser: Alex Lopes da Silva

Co-adviser: Polyana Pizzi Rotta

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To my parents,
I dedicate.

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“Não fui eu que lhe ordenei? Seja forte e corajoso! Não se apavore, nem se desanime, pois o senhor, o seu Deus, estará com você por onde você andar”.

(Josué 1;9)

ABSTRACT

SILVA, Maria Isabela Moreira, M.Sc., Universidade Federal de Viçosa, March, 2025. **Challenges in agricultural production: the quality of BRS capiaçu silage and the effects of the Fundão dam collapse in Mariana (MG) on dairy production.** Adviser: Alex Lopes da Silva. Co-adviser: Polyana Pizzi Rotta.

This dissertation consists of two studies, both focusing on aspects that can influence agricultural production. In the first study, the quality of *Cenchrus purpureus* (Schumach.) Morrone cv. BRS Capiáçu silage was evaluated with the addition of cornmeal or after 3 or 5 days of wilting in terms of fermentation profile, chemical composition and in situ degradation. A completely randomized design was used, with 4 treatments and 3 replicates. The treatments studied were Control (CON), ensiling with the addition of 8% cornmeal (SGC), ensiling wilted grass for 3 days (WI3), and 5 days (WI5). The variables analyzed included pH values, volatile fatty acids, chemical composition and, in situ degradability in the rumen. Data were subjected to ANOVA with means compared using Tukey's test ($P < 0.05$). Treatments SGC and WI3 were different from each other, but with similar results, presenting showed the lowest pH values (4.55, and 4.52%, respectively), the highest lactic acid production (2.32, and 1.57%, respectively) and the lowest butyric acid concentration (0.27, and 0.33%, respectively) ($P < 0.001$ for both variables). In terms of chemical composition, SGC and WI3 had higher dry matter (257.2, and 318.3 g/kg, respectively) and higher crude protein (63.8, and 58.5 g/kg, respectively) and lower concentrations of neutral detergent fiber (700.2, and 765.8 g/kg, respectively), acid detergent fiber (453.3, and 504 g/kg, respectively) and lignin (82.1, and 88.4 g/kg, respectively) ($P < 0.001$ for all variables except for CP ($P = 0.001$)). As far as degradation in the rumen is concerned, the SGC treatment achieved the best results. The of cornmeal and WI3 improved the chemical and fermentative quality of the elephant grass silage cv. BRS Capiáçu. However, degradation was only improved with the inclusion of cornmeal. The second study investigated dairy farms affected by the Fundão dam breach in Mariana (MG) in 2015 and compared the situation of dairy farms affected by a dam breach disaster (AFD) with that of unaffected farms (UFD) in terms of management, management practices and socio-economic conditions. Sixty dairy farms managed by the Família do Leite Program of the Federal University of Viçosa (UFV) were analyzed based on agronomic, productive, and environmental indicators. The statistical analysis was performed using the UNIVARIATE procedure of SAS for continuous variables and logistic regression with GLIMMIX of SAS for binary variables ($P < 0.10$). The results showed that AFD

were more likely to receive technical support, purchase forage, analyze the soil, and leave the activity ($P < 0.10$). On the other hand, AFD were less likely to use exogenous oxytocin, less likely to have parasitic sadness, use pit water, and have fewer problems with roads ($P < 0.10$). These results highlight the significant differences in management practices and socio-economic conditions between AFD and UFD farms. These findings emphasize the need for targeted support to mitigate the long-term effects of environmental disasters on agriculture.

Keywords: environmental disaster; forage conservation; milk production; mining

RESUMO

SILVA, Maria Isabela Moreira, M.Sc., Universidade Federal de Viçosa, março de 2025. **Desafios na produção agrícola: a qualidade da silagem de BRS capiaçu e os efeitos do rompimento da barragem de Fundão em Mariana (MG) na produção leiteira.** Orientador: Alex Lopes da Silva. Coorientadora: Polyana Pizzi Rotta.

Esta dissertação é composta por dois estudos, ambos focados em aspectos que podem impactar a produção agropecuária. O primeiro estudo avaliou a qualidade da silagem de capim elefante cv. BRS Capiáçu com adição de fubá ou submetidas ao emurchecimento por 3 ou 5 dias, quanto ao perfil fermentativo, composição química e degradação in situ. Utilizou-se um delineamento experimental inteiramente casualizado, com 4 tratamentos e 3 repetições. Os tratamentos investigados foram: controle (CON), ensilagem com adição de 8% de fubá (SGC), ensilagem do capim murcho por 3 dias (WI3) e por 5 dias (WI5). As variáveis analisadas incluíram os valores de pH, ácidos graxos voláteis, composição química e degradabilidade ruminal in situ. Os dados foram submetidos à ANOVA, com médias comparadas pelo teste de Tukey ($P < 0,05$). Os tratamentos SGC e WI3 foram diferentes entre si, porém com resultados similares, apresentando os menores valores de pH (4,55 e 4,52%, respectivamente), maior produção de ácido láctico (2,32 e 1,57%) e menor concentração de ácido butírico (0,27 e 0,33%) ($P < 0,001$ para ambas as variáveis). Na composição química, os tratamentos SGC e WI3 apresentaram maior valor de matéria seca (257,2 e 318,3 g/kg) e proteína bruta (63,8 e 58,5 g/kg) e menores concentrações de fibra em detergente neutro (700,2 e 765,8 g/kg), fibra em detergente ácido (453,3 e 504 g/kg) e lignina (82,1 e 88,4 g/kg) ($P < 0,001$ para todas as variáveis, exceto PB ($P = 0,001$)). Em relação à degradação ruminal, o tratamento SGC obteve os melhores resultados. A inclusão de fubá e o emurchecimento por 3 dias melhoraram a qualidade química e fermentativa da silagem de capim-elefante cv. BRS Capiáçu. No entanto, a degradação só foi melhorada com a inclusão de fubá. O segundo estudo investigou as propriedades leiteiras afetadas pelo rompimento da barragem de Fundão, em Mariana (MG), em 2015, comparando a situação de propriedades leiteiras afetadas por desastre de barragem (AFD) com a de propriedades não afetadas (UFD) em termos de gestão, práticas de manejo e condições socioeconômicas. Foram analisadas 60 propriedades atendidas pelo Programa Família do Leite da Universidade Federal de Viçosa (UFV), utilizando os indicadores agrônômicos, produtivos e ambientais. A análise estatística foi realizada utilizando o procedimento UNIVARIATE do SAS para variáveis contínuas e regressão logística com GLIMMIX do SAS para variáveis binárias. ($P < 0,10$).

Os resultados indicaram que as AFD apresentaram maior chance de receber assistência técnica, comprar de forragem, analisar o solo e abandonar a atividade ($P < 0,10$). Por outro lado, as AFD demonstraram menores chances de utilizar ocitocina exógena, ter tristeza parasitária, utilizar água de mina e ter problemas com estradas ($P < 0,10$). Esses resultados destacam as diferenças significativas nas práticas de gestão e nas condições socioeconômicas entre as fazendas AFD e UFD. Essas descobertas reforçam a necessidade de apoio direcionado para mitigar os efeitos de longo prazo dos desastres ambientais na agricultura.

Palavras-chave: conservação de forragem; desastre ambiental; mineração; produção de leite

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GENERAL INTRODUCTION

Cattle production stands out as one of the most important agricultural activities in Brazil and of crucial importance for the national economy (BIANCHINI; SECHI; MARIN, 2025). Dairy production systems, in turn, have great social, cultural, and economic importance and play an essential role in food security, in the supply of nutrients and as a livelihood for many families (SILVEIRA et al., 2022).

In Brazil, livestock production on pastures is predominant and occupies a large part of the territory (PARENTE et al., 2019). However, one of the biggest challenges for farmers using this system is the seasonal variation in feed supply, a problem that tends to worsen with the effects of climate change (JOSEPH et al., 2025). This seasonality is characterized by a significant decrease in the quantity and quality of forage during the dry season, which leads to a reduction in animal performance (SILVA et al., 2022). To compensate for feed deficits, which are largely due to scarcity during the dry season, it is crucial to apply appropriate forage conservation and preservation practices to maintain quantities, reduce nutrient and energy losses and minimize spoilage (BALEHEGN et al., 2022). Forage preservation by ensiling is a viable solution to ensure a constant supply of forage throughout the year (DISANAYAKA et al., 2025).

The BRS Capiaçú grass, launched by Embrapa Gado de Leite at the end of 2015, stands out as one of the most productive tropical forages in the world and is widely used by livestock farmers in Brazil, especially for silage production (RIBAS et al., 2021). However, tropical grasses usually have a high moisture content (> 700 g/kg fresh mass), which can lead to undesirable fermentation in the ensiled mass and impair the quality of the finished silage (AMARAL et al., 2020; CARVALHO et al., 2024). Ensiling high-moisture forages increases the risk of butyric acid fermentation and wastewater production, which leads to high fermentation losses and negatively affects both the quality and nutritional value of the silage (GOMES et al., 2019).

To obtain good quality silage, it is important to reduce free water as this helps to control the proliferation of undesirable bacteria and reduce wastewater production (RAZAK et al., 2012; SINGH; SINGH; IMAM, 2014). The addition of by-products or dry residues can reduce water activity in the silo, limiting excessive yeast growth and favoring the preservation of nutrients in the silage (BONFÁ et al., 2020, 2022). Among the most effective materials for moisture retention in the ensiling of elephant grass, cornmeal stands out, as it has a high-water absorption capacity (PAULA, 2020).

However, the growing demand for ethanol production has led to an increase in corn prices (RANUM; PEÑA-ROSAS; GARCIA-CASAL, 2014), which means that the inclusion of this cereal in silage can lead to increased production costs.

An alternative approach is the wilting technique, which is an effective method for reducing moisture content (GUO et al., 2021) and also helps to inhibit the proliferation of undesirable microorganisms and improve silage quality (LIU et al., 2011; NISHINO et al., 2012; WANG et al., 2018). GUO et al. (2021) observed that the relative abundance of *Lactobacillus* increased while that of *Enterobacter* and *Pseudomonas* decreased in paper mulberry silage after wilting treatment.

However, several studies cannot be used as a definitive reference for understanding the effect of wilting on silage quality, as many of them provide inconclusive results. For example, NISHINO et al. (2012) and ZHENG et al. (2018) reported divergent results in terms of pH. In this context, there is a lack of studies on the ensiling of BRS Capiapu grass, especially in relation to conservation techniques such as the use of moisture sequestrants and wilting. It is important to develop efficient methods to improve the fermentation quality and nutritional value of the silage.

However, the challenges facing the Brazilian livestock industry are not limited to feeding and silage production. Mining, another important sector of the Brazilian economy, has a significant impact on the environment and communities and directly affects agricultural activities, especially in regions such as Minas Gerais, where a large part of the country's mining activities is concentrated. In 2024, Minas Gerais was the leader with a 40% share of the sector's total revenue (IBRAM, 2024).

Although mining brings considerable economic benefits, it is also associated with significant environmental impacts, such as pollution of water resources, air pollution, land degradation and damage to biodiversity (CORDY et al., 2011; WORLANYO; JIANGFENG, 2021). The collapse of the Samarco dam, which occurred on November 5, 2015 in Mariana (Minas Gerais), released more than 62 million tons of iron ore tailings into riverbeds and plains, affecting the Gualaxo do Norte, Carmo, and Doce rivers. This disaster led to the death of 19 people and contaminated 668 km of watercourses that reached the Atlantic Ocean (FERNANDES et al., 2016; VERGILIO et al., 2020; BOTELHO et al., 2021). atualmente sob controle das empresas Vale S.A e BHP Billiton Brasil

The social impacts of the dam burst include the destruction of infrastructure, changes in the way of life of traditional communities, the loss of cultural heritage and

a decline in the production capacity of small farmers. These events also affect the health of riverside communities, causing psychological damage, disease, and the spread of vectors. In addition, access to drinking water is restricted, which is detrimental to people's well-being (POLIGNANO; LEMOS, 2020).

The intensive soil erosion in mining areas makes it difficult to maintain agriculture in these regions (ASENSIO et al., 2013). In addition, the deposition of overburden can lead to contamination of soil and water with toxic substances such as arsenic (As), cadmium (Cd), and lead (Pb) (SILVA et al., 2022). After the disaster, cadmium and arsenic levels in sediments exceeded the limits set by the National Environmental Council (DUARTE et al., 2021). In contaminated agricultural soils, the uptake of these metals by plants has been associated with adverse health effects, both for the human population (LIU et al., 2019) and for the local fauna (PICAUD; PETIT, 2013; NACCARATO et al., 2020).

AGUIAR et al. (2020) investigated the bioavailability and ecological risks of trace metals in the sediments of the continental shelf of the Doce River before and after the collapse of the Fundão dam. The results showed significant differences in metal concentrations between the period before and after the disaster, with a notable increase in the values of the elements $Cu > Pb > Ni > Zn > Cr$. In this context, the proximity of mining activities can pose a threat to livestock farmers, as contamination of water resources and soil erosion jeopardize the sustainability of production and affect the health of livestock and dairy farmers. Therefore, it is crucial to analyze the consequences of mining disasters, such as dam failures, in order to understand the vulnerabilities and adaptation strategies of producers.

Therefore, the main objective of this study was to investigate different aspects affecting agricultural production, focusing on the problems faced by livestock farmers in different contexts. The first study, presented in Chapter 1, aimed to evaluate the effects of adding corn meal or wilting BRS Capiáçu grass for 3 or 5 days and to analyze the influences on the fermentation characteristics, chemical composition and in situ degradation of silage from this forage. Chapter 2 focused on analyzing the impact of the Fundão dam burst in 2015 on milk production. The current situation of milk producers affected by this disaster was compared with that of unaffected producers in order to understand the social and economic consequences of this event on agricultural activity.

REFERENCES

AGUIAR, Valquíria Maria de Carvalho; NETO, José Antônio Baptista; QUARESMA, Valéria da Silva; BASTOS, Alex Cardoso; ATHAYDE, João Pedro Moreno De. Bioavailability and ecological risks of trace metals in bottom sediments from Doce river continental shelf before and after the biggest environmental disaster in Brazil: The collapse of the Fundão dam. **Journal of Environmental Management**, [S. l.], v. 272, n. July, 2020. DOI: 10.1016/j.jenvman.2020.111086.

AMARAL, Rafael Carvalho; CARVALHO, Beatriz Ferreira; COSTA, Daviane Martinele; MORENZ, Mirton José Frota; SCHWAN, Rosane Freitas; ÁVILA, Carla Luiza da Silva. Novel lactic acid bacteria strains enhance the conservation of elephant grass silage cv. BRS Capiaçú. **Animal Feed Science and Technology**, [S. l.], v. 264, n. March, p. 114472, 2020. DOI: 10.1016/j.anifeedsci.2020.114472. Disponível em: <https://doi.org/10.1016/j.anifeedsci.2020.114472>.

ASENSIO, V.; VEGA, F. A.; ANDRADE, M. L.; COVELO, E. F. Tree vegetation and waste amendments to improve the physical condition of copper mine soils. **Chemosphere**, [S. l.], v. 90, n. 2, p. 603–610, 2013. DOI: 10.1016/j.chemosphere.2012.08.050. Disponível em: <http://dx.doi.org/10.1016/j.chemosphere.2012.08.050>.

BALEHEGN, Mulubrhan et al. Forage conservation in sub-Saharan Africa: Review of experiences, challenges, and opportunities. **Agronomy Journal**, [S. l.], v. 114, n. 1, p. 75–99, 2022. DOI: 10.1002/agj2.20954.

BIANCHINI, Vitor de J. M.; SECHI, Alex da S.; MARIN, Fábio R. Seasonal patterns of CO₂ exchange in a tropical intensively managed pasture in Southeastern Brazil. **Agricultural and Forest Meteorology**, [S. l.], v. 361, n. June 2024, 2025. DOI: 10.1016/j.agrformet.2024.110324.

BONFÁ, Caroline Salezzi; GUIMARÃES, Cíntia Gonçalves; EVANGELISTA, Antônio Ricardo; SANTOS, Alexandre Soares Dos; GUIMARÃES, Amanda Gonçalves; GANDINI, Elizandra Marta Martins. Chemical composition of sugarcane silages with crambe bran. **Ciencia e Agrotecnologia**, [S. l.], v. 44, p. 1–9, 2020. DOI: 10.1590/1413-7054202044016920.

BONFÁ, Caroline Salezzi; GUIMARÃES, Cíntia Gonçalves; EVANGELISTA, Antônio Ricardo; SANTOS, Alexandre Soares Dos; PANTOJA, Lílian de Araújo; MAGALHÃES, Marcela Azevedo. Ethanol and organic acid production related to the microbial population in sugarcane silages with admixed crambe (*Crambe abyssinica* Hochst) bran. **New Zealand Journal of Agricultural Research**, [S. l.], v. 66, n. 3, p. 224–243, 2022. DOI: <https://doi.org/10.1080/00288233.2022.2054826>.

CARVALHO, M. G. M.; BRAGATTO, J. M.; BUTTOW, S. C.; SILVA, A. F.; SILVA, L. S.; SILVA, N. G.; AUERBACH, H. U.; NUSSIO, L. G.; DANIEL, J. L. P. Applying the fermentability coefficient concept in tropical grass silages. **Animal Feed Science and Technology**, [S. l.], v. 314, n. April, p. 115995, 2024. DOI: 10.1016/j.anifeedsci.2024.115995. Disponível em: <https://doi.org/10.1016/j.anifeedsci.2024.115995>.

CORDY, Paul; VEIGA, Marcello M.; SALIH, Ibrahim; AL-SAAD, Sari; CONSOLE, Stephanie; GARCIA, Oseas; MESA, Luis Alberto; VELÁSQUEZ-LÓPEZ, Patricio C.; ROESER, Monika. Mercury contamination from artisanal gold mining in Antioquia, Colombia: The world's highest per capita mercury pollution. **Science of the Total Environment**, [S. l.], v. 410–411, p. 154–160, 2011. DOI: 10.1016/j.scitotenv.2011.09.006. Disponível em: <http://dx.doi.org/10.1016/j.scitotenv.2011.09.006>.

DA SILVA, Ana Paula Valadares et al. Potentially toxic elements in iron mine tailings: Effects of reducing soil pH on available concentrations of toxic elements. **Environmental Research**, [S. l.], v. 215, n. August, 2022. DOI: 10.1016/j.envres.2022.114321.

DISANAYAKA, L. M. J. N. K.; WARALLANDA, A. P.; SENANAYAKA, S. D.; RAJAPAKSE, S.; JINADASA, H. R. N.; WEERASINGHE, W. M. P. B.; DEVINDI, K. Mithila; MAHIPALA, M. B. P. Kumar. Isolation and Characterization of Lactic Acid Bacteria: A Strategy to Produce Inoculum for Forage Ensiling. **Journal of Agricultural Sciences - Sri Lanka**, [S. l.], v. 20, n. 1, p. 153–159, 2025. DOI: 10.4038/jas.v20i1.11035.

DUARTE, Eduardo Baudson; NEVES, Mirna Aparecida; DE OLIVEIRA, Fabricia Benda; MARTINS, Marx Engel; DE OLIVEIRA, Carlos Henrique Rodrigues; BURAK, Diego Lang; ORLANDO, Marcos Tadeu D. Azered.; RANGEL, Caio Vinícius Gabrig Turbay. Trace metals in Rio Doce sediments before and after the collapse of the Fundão iron ore tailing dam, Southeastern Brazil. **Chemosphere**, [S. l.], v. 262, p. 127879, 2021. DOI: 10.1016/j.chemosphere.2020.127879. Disponível em: <https://doi.org/10.1016/j.chemosphere.2020.127879>.

FERNANDES, Geraldo Wilson et al. Deep into the mud: ecological and socio-economic impacts of the dam breach in Mariana, Brazil. **Natureza e Conservacao**, [S. l.], v. 14, n. 2, p. 35–45, 2016. DOI: 10.1016/j.ncon.2016.10.003. Disponível em: <http://dx.doi.org/10.1016/j.ncon.2016.10.003>.

GOMES, A. L. M.; JACOVACI, F. A.; BOLSON, D. C.; NUSSIO, L. G.; JOBIM, C. C.; DANIEL, J. L. P. Effects of light wilting and heterolactic inoculant on the formation of volatile organic compounds, fermentative losses and aerobic stability of oat silage. **Animal Feed Science and Technology**, [S. l.], v. 247, n. June 2018, p. 194–198, 2019. DOI: 10.1016/j.anifeedsci.2018.11.016. Disponível em: <https://doi.org/10.1016/j.anifeedsci.2018.11.016>.

GUO, Linna; WANG, Xuekai; LIN, Yanli; YANG, Xueping; NI, Kuikui; YANG, Fuyu. Microorganisms that are critical for the fermentation quality of paper mulberry silage. **Food and Energy Security**, [S. l.], v. 10, n. 4, p. 1–14, 2021. DOI: 10.1002/fes3.304.

IBRAM. Setor mineral 2024. [S. l.], p. 41, 2025. Disponível em: https://www.ibram.org.br/wp-content/uploads/2025/02/DADOS_Setor-Mineral_2024_5FEV2025.pdf

JOSEPH, Julian; TRAMBEREND, Sylvia; KABI, Fred; FISCHER, Günther; KAHIL,

Taher. Sustainable intensification of fodder crop production can mitigate feed shortage and seasonality in East Africa. **Environmental Development**, [S. l.], v. 54, n. March 2024, p. 101158, 2025. DOI: 10.1016/j.envdev.2025.101158. Disponível em: <https://doi.org/10.1016/j.envdev.2025.101158>.

LIU, Juan et al. Thallium contamination in farmlands and common vegetables in a pyrite mining city and potential health risks. **Environmental Pollution**, [S. l.], v. 248, p. 906–915, 2019. DOI: 10.1016/j.envpol.2019.02.092. Disponível em: <https://doi.org/10.1016/j.envpol.2019.02.092>.

LIU, Qinghua; ZHANG, Jianguo; SHI, Shangli; SUN, Qizhong. The effects of wilting and storage temperatures on the fermentation quality and aerobic stability of stylo silage. **Animal Science Journal**, [S. l.], v. 82, n. 4, p. 549–553, 2011. DOI: 10.1111/j.1740-0929.2011.00873.x.

NACCARATO, Attilio; TASSONE, Antonella; CAVALIERE, Francesco; ELLIANI, Rosangela; PIRRONE, Nicola; SPROVIERI, Francesca; TAGARELLI, Antonio; GIGLIO, Anita. Agrochemical treatments as a source of heavy metals and rare earth elements in agricultural soils and bioaccumulation in ground beetles. **Science of the Total Environment**, [S. l.], v. 749, p. 141438, 2020. DOI: 10.1016/j.scitotenv.2020.141438. Disponível em: <https://doi.org/10.1016/j.scitotenv.2020.141438>.

NISHINO, N.; LI, Y.; WANG, C.; PARVIN, S. Effects of wilting and molasses addition on fermentation and bacterial community in guinea grass silage. **Letters in Applied Microbiology**, [S. l.], v. 54, n. 3, p. 175–181, 2012. DOI: 10.1111/j.1472-765X.2011.03191.x.

PARENTE, Leandro; MESQUITA, Vinícius; MIZIARA, Fausto; BAUMANN, Luis; FERREIRA, Laerte. Assessing the pasturelands and livestock dynamics in Brazil, from 1985 to 2017: A novel approach based on high spatial resolution imagery and Google Earth Engine cloud computing. **Remote Sensing of Environment**, [S. l.], v. 232, n. October 2018, p. 111301, 2019. DOI: 10.1016/j.rse.2019.111301. Disponível em: <https://doi.org/10.1016/j.rse.2019.111301>.

PAULA, Paulo. Composição bromatológica da silagem de capim- elefante BRS Capiaçú com inclusão fubá de milho. **Pubvet**, [S. l.], v. 14, n. 10, 2020. DOI: 10.31533/pubvet.v14n10a682.1-11.

PICAUD, Frédérique; PETIT, Daniel Pierre. Primary succession of Orthoptera on mine tailings: Role of vegetation. **Annales de la Societe Entomologique de France**, [S. l.], v. 43, n. 1, p. 69–79, 2013. DOI: 10.1080/00379271.2007.10697496.

POLIGNANO, Marcus Vinicius; LEMOS, Rodrigo Silva. Rompimento da barragem da Vale em Brumadinho: impactos socioambientais na Bacia do Rio Paraopeba. **Ciência e Cultura**, [S. l.], v. 72, n. 2, p. 37–43, 2020. DOI: 10.21800/2317-66602020000200011.

RANUM, Peter; PEÑA-ROSAS, Juan Pablo; GARCIA-CASAL, Maria Nieves. Global maize production, utilization, and consumption. **Annals of the New York Academy of**

Sciences, [S. l.], v. 1312, n. 1, p. 105–112, 2014. DOI: 10.1111/nyas.12396.

RAZAK, Okine Abdul; MASAACKI, Hanada; YIMAMU, Aibibula; MEIJI, Okamoto. Potential water retention capacity as a factor in silage effluent control: Experiments with high moisture by-product feedstuffs. **Asian-Australasian Journal of Animal Sciences**, [S. l.], v. 25, n. 4, p. 471–478, 2012. DOI: 10.5713/ajas.2011.11349.

RIBAS, Wemerson Fábio Gomes; MONÇÃO, Flávio Pinto; JÚNIOR, Vicente Ribeiro Rocha; DE ALBUQUERQUE MARANHÃO, Camila Maida; FERREIRA, Heberth Christian; DOS SANTOS, Alexandre Soares; GOMES, Virgílio Mesquita; RIGUEIRA, João Paulo Sampaio. Effect of wilting time and enzymatic-bacterial inoculant on the fermentative profile, aerobic stability, and nutritional value of BRS capiaçu grass silage. **Revista Brasileira de Zootecnia**, [S. l.], v. 50, p. 1–13, 2021. DOI: 10.37496/RBZ5020200207.

SILVA, Camile Sanches; EUCLIDES, Valéria Pacheco Batista; MONTAGNER, Denise Baptaglin; DE ARAÚJO, Itânia Maria Medeiros; DIFANTE, Gelson Dos Santos; JÚNIOR, Marco Antonio Previdelli Orrico. Effects of different supplements on performance of steers grazing Mombaça guineagrass (*Megathyrsus maximus*) during the dry period. **Tropical Grasslands-Forrajes Tropicales**, [S. l.], v. 10, n. 1, p. 44–51, 2022. DOI: 10.17138/TGFT(10)44-51.

SILVEIRA, Robson Mateus Freitas et al. Diversity in smallholder dairy production systems in the Brazilian semiarid region: Farm typologies and characteristics of raw milk and water used in milking. **Journal of Arid Environments**, [S. l.], v. 203, n. April, 2022. DOI: 10.1016/j.jaridenv.2022.104774.

SINGH, N. B.; SINGH, Ruchi; IMAM, Mohammed Manzer. Waste Water Management in Dairy Industry: Pollution Abatement and Preventive Attitudes. **International Journal of Science, Environment and Technology**, [S. l.], v. 3, n. 2, p. 672–683, 2014.

VERGILIO, Cristiane dos Santos et al. Metal concentrations and biological effects from one of the largest mining disasters in the world (Brumadinho, Minas Gerais, Brazil). **Scientific Reports**, [S. l.], v. 10, n. 1, p. 1–12, 2020. DOI: 10.1038/s41598-020-62700-w.

WANG, Yi; WANG, Cheng; ZHOU, Wei; YANG, Fu Yu; CHEN, Xiao Yang; ZHANG, Qing. Effects of wilting and *Lactobacillus plantarum* Addition on the Fermentation quality and microbial community of moringa oleifera Leaf silage. **Frontiers in Microbiology**, [S. l.], v. 9, n. AUG, 2018. DOI: 10.3389/fmicb.2018.01817.

WORLANYO, Adator Stephanie; JIANGFENG, Li. Evaluating the environmental and economic impact of mining for post-mined land restoration and land-use: A review. **Journal of Environmental Management**, [S. l.], v. 279, n. September 2020, p. 111623, 2021. DOI: 10.1016/j.jenvman.2020.111623. Disponível em: <https://doi.org/10.1016/j.jenvman.2020.111623>.

ZHENG, Mingli; NIU, Dongze; ZUO, Sasa; MAO, Peichun; MENG, Lin; XU, Chuncheng. The effect of cultivar, wilting and storage period on fermentation and the

clostridial community of alfalfa silage. **Italian Journal of Animal Science**, [S. l.], v. 17, n. 2, p. 336–346, 2018. DOI: 10.1080/1828051X.2017.1364984. Disponível em: <https://doi.org/10.1080/1828051X.2017.1364984>.

CHAPTER 1

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FERMENTATIVE PROFILE, CHEMICAL COMPOSITION AND IN SITU RUMEN DEGRADABILITY OF THE BRS CAPIAÇU GRASS SILAGE WILTED OR WITH ADDED CORNMEAL

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ABSTRACT -

The aim of this study was to evaluate the quality of *Cenchrus purpureus* (Schumach.) Morrone cv. BRS Capiaçú silage with the addition of cornmeal or after 3 or 5 days of wilting in terms of fermentative profile, chemical composition, and *in situ* degradation. A completely randomized design with four treatments and three replicates was used: Control (CON), ensiling with the addition of 8% ground cornmeal (SGC), wilting grass for three days (WI3), and wilting grass for five days (WI5), totaling 12 experimental silos. The experimental silos were opened after 120 days and analyzed for pH, volatile fatty acids, chemical composition, and *in situ* rumen degradability. For the *in situ* incubation, three rumen-cannulated lactating cows were used. Data were subjected to ANOVA, with means compared using Tukey's test $P < 0.05$. The SGC and WI3 treatments differed but showed similar results, with lower pH values (4.55, and 4.52, respectively), higher lactic acid production (2.32, and 1.57%), and lower butyric acid (0.27, and 0.33%) ($P < 0.001$ for both variables). The SGC and WI3 also showed higher of dry matter (257.2, and 318.3 g/kg), crude protein (63.8, and 58.5 g/kg), and lower values of neutral detergent fiber (700.2, and 765.8 g/kg), acid detergent fiber (453.3, and 504 g/kg), and lignin (82.1, and 88.4 g/kg) ($P < 0.001$ for all variables). For rumen degradability, there were significant differences in fraction "A" ($P < 0.001$) and in effective degradability of DM at rate of passage

of 5, and 8 %/hour ($P=0.001$), with SGC treatment having the greatest values. The addition of cornmeal and wilting grass for 3 days improved the chemical composition, and fermentative quality of the elephant grass silage cv. BRS Capiaçú. However, degradation was only improved with the inclusion of cornmeal.

Keywords: *Cenchrus purpureus*, conservation, forage

1. Introduction

The Brazilian livestock industry uses pastures as the main source of feed for ruminants (Sampaio et al., 2017). However, tropical regions present seasonal variations, reducing the availability and quality of pastures, and impacting the profitability of production systems (Millen et al., 2011). In this scenario, silage is a fundamental tool to maintain good production rates, particularly during periods of feed scarcity (Kemboi et al., 2020; Rodríguez-Blanco et al., 2021; Aranega and Oliveira, 2024).

Elephant grass cv. BRS Capiaçú (*Cenchrus purpureus* (Schumach.) Morrone cv. BRS Capiaçú) is a forage with high potential for biomass production, capable of producing up to 50 ton/ha/year of dry matter (DM) (Pereira et al., 2016). However, ensiling process of tropical grasses is associated with challenges, such as low DM concentration (<300 g/kg DM), low soluble carbohydrate content (<40 g/kg DM), and high buffering capacity (>40 g of lactic acid/kg DM), which affects the quality of the silage (Nussio, 2002; Gomes et al., 2021; Moraes et al., 2023).

To improve the quality of silage, additives such as bacterial inoculants or moisture sequestrant may be used (Borreani et al., 2018; Muck et al., 2018). Ground cornmeal, as a moisture sequestrant, reduces gas and effluent losses and increases DM recovery (Andrade et al., 2012; Bezerra et al., 2019; Paula et al., 2020). However, the addition of ground cornmeal can increase the cost of silage production.

Alternatively, wilting can achieve an adequate DM content (Barcelos et al., 2018; Ribas et al., 2021), improving fermentation quality (Marsh, 1979), and reducing losses due to gases and effluents (Ribas et al., 2021). Nevertheless, the quality of the silage can be impaired if the harvested forage is exposed to the sun for a prolonged period (Pahlow, 2003; Wilkinson and Davies, 2013; Brüning et al., 2018).

In this context, there is a lack of studies on the ensiling of elephant grass cv. BRS Capiáçu, particularly regarding ensiling methods. These include the use of moisture sequestrant and wilting over different periods, including 3 and 5 days. Therefore, it is necessary to develop efficient methods for the conservation of this forage to improve the quality of fermentation and thus the nutritional value of the silage produced.

This study was prepared under the hypotheses that: 1) the addition of ground cornmeal during the ensiling process promotes adequate fermentation of BRS Capiáçu elephant grass silage, resulting in a feed with better nutritional value, 2) the use of wilting grass for 3 or 5 days improves silage quality. Thus, the objective was to evaluate the effects of adding ground cornmeal as a moisture sequestrant or wilting grass for 3 or 5 days on the fermentation characteristics, chemical composition, and *in situ* degradation of BRS Capiáçu elephant grass silage.

2. Materials and Methods

All procedures involving animals were previously reviewed and approved by the Ethics Committee for the Use of Production Animals of the Federal University of Viçosa, under protocol number 44/2024.

2.1. Study location, design, and treatments

The study was carried out at the Teaching, Research, and Extension Dairy Farm of the Federal University of Viçosa (UFV). The region has a climate classified as Cwa (mesothermal) according to the Köppen classification (1936), characterized by hot and rainy seasons (spring-summer) from October to March and cold and dry seasons (autumn-winter) from April to September, with an average temperature of 20.4°C and an average annual rainfall of 1,251 mm (Climate-Data.Org, 2022). During the days in which the ensiling processes were carried out, the following data on total precipitation, average temperature, and average relative humidity were recorded (Table 1). These data were obtained by the automatic meteorological station in Viçosa, located 2.8 km away from the experiment (INMET, 2022).

The study was conducted in a completely randomized design evaluating four treatments with three replicates each: i) control (CON; grass ensiled immediately after harvesting); ii) grass ensiled after cutting with the addition of ground cornmeal (SGC; 8% in relation to the mass of natural matter); iii) grass ensiled after wilting for three days (WI3); iv) grass ensiled after wilting for five days (WI5).

2.2. Sample collection, processing, and ensiling

The elephant grass cv. BRS Capiacu was harvested in winter at about 150 days of age and an average height of 4 meters, which is within the recommended range to ensure good nutritional quality and productivity (Pere

ira et al., 2016), and it presented approximately 22% DM. The grass was planted in an area of 0.7 ha, with a between rows of 1.30 m, and the number of seedlings used for the study was 6 tons/ha. The ensiling of treatments WI3 and WI5 was carried out at predetermined times to ensure that both treatments reached the established wilting time.

All treatments were harvested manually with a sickle, with the cut being made at a height of about 15 cm above ground. The grass was chopped to 20 mm in a silage chopper (Guarnieri MG - 350), and then the Magniva Basic inoculant (Lallemand) was added according to the manufacturer's recommendations, at a rate of 100 g per 50 tons of forage. This inoculant consists of a combination of the *Pediococcus acidilactici* CNCM I-4622, with minimum guarantee levels of 2.5×10^{10} UFC/g and *Lactobacillus plantarum* CNCM I-3736, with minimum guarantee levels of 2.5×10^{10} UFC*/g strains. To evaluate the quality of the machine cut and mixtures with cornmeal, the Penn State method was used to check the size of the particles produced (Table 2) (Heinrichs, 2013).

In the SGC treatment, cornmeal was added at 8% by mass of the fresh matter and manually mixed, aiming to increase the DM content of the material to 25%, bringing it within the recommended range of 25 to 35% for ensiling (Kung et al., 2018). The wilting of elephant grass cv. BRS Capiacu was done by spreading the plant in thin layers, allowing air to circulate and promoting moisture loss. The exposure time of the grass under these conditions varied according to treatments WI3 (3 days) and WI5 (5 days), as described in Table 1.

After obtaining the material from each treatment, the material was ensiled in 10-litre experimental silos made of sealed plastic buckets. These experimental silos had a height of 29.5 cm, a top diameter of 24 cm and a bottom diameter of 22 cm. To ensure drainage of effluents produced during ensiling, 3.5 kg of fine sand was placed at the bottom of each mini silo. A layer of cotton was placed on top of the sand layer to prevent direct contact between the forage and the sand. The ensiled mass amounted to 4.5 kg and was compacted to achieve a density of almost 600 kg/m^3 (Liu et al., 2024), filling the remaining volume in the bucket.

The experimental silos were then closed with a lid and the seal was reinforced with

transparent adhesive tape stored in a closed room at room temperature for 120 days. After 120 days of fermentation, the experimental silos were opened and about 5 cm of the top layer of each silo was discarded to avoid possible contamination (Bezerra et al., 2019). The other part of the silage was homogenized and sampled for later analysis. This procedure ensured that representative samples were obtained from each treatment to assess silage quality.

2.3. Dry matter losses

The determination of total DM losses was calculated by determining the difference between the initial and final gross DM weight in the silos in relation to the amount of ensiled feed mass (Schmidt, 2006):

$$DM_{losses} = \frac{[(DM_i - DM_f)]}{DM_i} \times 100$$

where: DM_{losses} = total DM loss (%); DM_i = initial DM amount (weight of silo after filling (kg) – weight of empty set, without forage, before filling (dry tare) (kg) × DM content of the forage in silage (% DM)); DM_f = final DM quantity (weight of the full silo before opening (kg) – weight of the empty set, without forage, after opening the silos (wet tare) (kg) × DM content of the forage at opening (% DM)).

2.4. pH, organic acids, and chemical composition

To evaluate the pH and concentration of organic acids in the ensiled materials, an aqueous extract was prepared from 25 grams of ground silage in an industrial blender with 225 mL of distilled water for one minute. This extract was then subjected to pH

evaluation using a digital potentiometer (Tecnal, model Tec-3MP). The extract was then acidified 1:1 with H₂SO₄, diluted with distilled water and frozen for later analysis of the organic acids (lactic, acetic, and butyric acids).

To quantify the organic acids, the samples were treated with calcium hydroxide and copper sulfate and analyzed by HPLC (SPD-10 AVP, Shimadzu, OR, USA) according to the method described by Siegfried et al. (1984). The HPLC instrument was equipped with a refractive index detector and an Aminex HPX-87H column (BIO-RAD, CA, USA), where the mobile phase contained 0.005 H₂SO₄ and had a flow rate of 0.7 mL/min at 45 °C.

Sampling of the fresh material was carried out before ensiling to determine the DM content. After ensiling, the samples were partially dried at 55°C for 72 hours (method INCT-CA G-001/2) and then ground in a Willey-type knife mill with 2- and 1-mm sieves, respectively.

Samples ground to 1-mm were analyzed for DM (INCT-CA method G-003/1), crude protein (CP; INCT-CA method N-001/2), ether extract (EE; INCT-CA method G-005/2), and ash (INCT-CA method M-001/2) content (Detmann et al., 2021). In addition, the samples were analyzed for the content of neutral detergent fiber (NDF; INCT-CA method F-013/1), acid detergent fiber (ADF; INCT-CA method F-015/1), and lignin (INCT-CA method F-005/2) (Detmann et al., 2021). The samples ground to 2 mm were used to determine the indigestible neutral detergent fiber (NDFi) content (INCT-CA method F-009/2) as described by Detmann et al. (2021). The samples were incubated in the rumen of two lactating Holstein cows through a rumen cannula for a period of 288 hours, and the residual NDF was determined. Non-fibrous carbohydrate (NFC) was calculated using the equation proposed by Hall et al. (1999):

$$NFC = 100 - (NDF + CP + EE + Ash)$$

where: NFC = Non-fibrous carbohydrate (g/kg); NDF = Neutral detergent fiber (g/kg); CP = Crude protein (g/kg); EE = Ether extract (g/kg).

2.5. In situ rumen degradability

Three rumen-fistulated lactating Holstein cows with an average body weight of 685 ± 119.1 kg and an average milk production of 37 ± 5.3 kg were used for the *in situ* incubation, which were kept in a compost barn system with *ad libitum* access to feed and water. The same ratio of corn silage to concentrate (45:55) was maintained throughout the assessment period of *in situ* rumen degradability and the animals were adapted for 14 days (Machado et al., 2016).

For incubation, samples were ground through a 2-mm sieve and approximately 4.5 g of each dried sample was individually weighed into nylon bags (16 x 10 cm, 50 μ m pore size, Ankon Technology, Macedon, NY, USA). The samples were placed in the bags at a rate of 10 to 20 mg DM/cm² of the usable area of the bags (Nocek, 1988). The bags were placed in the rumen in the reverse order of the incubation times and removed at the same time. The incubation times used were 0, 3, 6, 12, 24, 30, 48, 72, 120, and 240 hours (Detmann et al., 2021). The number of nylon bags used varied depending on the incubation time to ensure a sufficient number of residual samples after the process, which is influenced by the specific degradation rate of each feed. Therefore, a larger number of bags were used for samples with longer incubation times.

The samples were incubated in the rumen by attaching the nylon bags to a steel chain (90 x 2 cm²) (Menezes et al., 2019) with a weight (300 g) at the end to ensure their immersion in the rumen contents. After removal, all bags were washed under running water to remove excess external residues and then washed in a washing machine (5

consecutive 1-minute washes) (Vanzant et al., 1998). The bags were then partially dried for 72 hours at 55°C in an oven with forced ventilation (INCT-CA method G-001/2) and then placed in an oven at 105°C for 2 hours to estimate the disappearance of DM in the rumen (Menezes et al., 2019; Silva et al., 2020).

After drying and weighing the bags, the residue of each sample per treatment was removed from the nylon bags, ground in a Wiley mill (Fortinox, model STAR FT 50/6) with a 1-mm sieve and placed in a plastic bag labeled to obtain a sample from each animal and its respective incubation/treatment time. Subsequently, the residual samples were analyzed for DM and NDF content according to the methodology described by Detmann et al. (2021) and used to estimate the parameters of rumen-induced degradation of DM and NDF.

To estimate the *in situ* degradability of DM and NDF, the first-order asymptotic model proposed by Orskov and McDonald (1979) was used, which utilizes the following equation:

$$Deg(t) = a + b(1 - e^{-ct})$$

where: Deg(t) = represents the degradability or disappearance of the nutrient (DM or NDF) from the feed, expressed as percentage; a = fraction of the feed that is soluble in water at time zero; b = fraction that is insoluble in water but potentially degradable in the rumen at a given time; c = rate of degradation of the potentially degradable fraction in the rumen (b); t = incubation time (hours).

The parameters a, b, and c of DM and NDF determined for each incubation period and each animal were organized for subsequent statistical analysis. In addition, the potentially degradable fraction and estimated degradation for passage rates of 2, 5, and

8%/hour were calculated as described below:

$$PD = a + b$$

$$Deg = a + (b \times c / (c + kp))$$

where: PD = represents the potentially degradable fraction; a = fraction of the feed that is soluble in water at time zero; b = fraction that is insoluble in water but potentially degradable in the rumen at a given time; Deg = represents the estimated degradable fraction according to the estimated parameters; c = degradation rate of the potentially degradable fraction in the rumen (b); kp = passage rate, which in this case can take a value of 2, 5, or 8%/hour.

3. Statistical Analysis

Data related to the fermentation profile and chemical composition were subjected to analysis of variance using the GLIMMIX procedure of SAS (SAS on demand for academics, 2025), using the normal distribution for all variables analyzed. The data on the *in situ* degradation parameters were subjected to an analysis of variance using the lm package of R (R Core Team, 2025). In all analysis, the F-test was used at a significant level of 5% according to the model below.

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

in which y_{ij} is the measured response variable that received the i^{th} treatment, μ is the general constant, α_i is the fixed effect of the i^{th} treatment, and ε_{ij} is the random error term.

To compare the means between treatments, the Tukey test was used and effects

were considered significant at $P \leq 0.05$ and trend at $0.05 < P \leq 0.10$.

4. Results

The mean values of pH, DM loss, and concentration of lactic, acetic, and butyric acids differed significantly among treatments ($P < 0.01$ for all variables; Table 3). The SGC and WI3 treatments had the lowest pH values, with 4.55 and 4.52, respectively. Additionally, SGC and WI3 treatments also had the lowest DM loss, with values of 1.69 and 1.64%, respectively. Lactic acid was higher in the SGC treatment, while the acetic acid had the lowest value in the CON treatment (Table 3). The butyric acid concentration was lower in the SGC and WI3 treatments, with 0.27 and 0.33%, respectively.

The contents of DM, ash, CP, EE, NDF, ADF, lignin, NFC, and NDFi were different among treatments ($P < 0.01$; Table 4). Treatments WI3 and WI5 presented the greatest DM values with 318.3 and 305.4 g/kg, respectively. Treatment WI5 presented the lowest CP value among treatments, with 51.4 g/kg, while the other treatments average 60.2 g/kg. Treatments CON and SGC had the greatest values of EE. When evaluating the NDF, ADF, and NDFi contents, the SGC treatment had the lowest values (700.2 g/kg, 453.3 g/kg, and 355.0 g/kg, respectively). The SGC and WI3 treatments had the lowest values of lignin, with 82.1 and 88.4 g/kg, respectively. The greatest value of NFC was observed in SGC treatment (138.6 g/kg), while the other treatments averaged 61.3 g/kg (Table 4).

For the *in situ* rumen degradability evaluation, only the fraction “a” of DM ($P < 0.01$) and the effective degradability of DM at passage rates of 5 and 8 %/hour ($P = 0.01$) showed significant differences between treatments and a tendency towards the rate of 2%/hour (Tables 5 and 6). The fraction “a” of DM of the SGC treatment was 289 g/kg, while the other treatments averaged 227 g/kg, which was about 21.2% lower (Table 5). Treatments WI3 and WI5 showed greater values for the fraction “a” of DM when

compared to the CON treatment (Table 5). No differences ($P>0.05$) were observed among treatments in terms of the potentially degradable fraction in the rumen (fraction b) and the rate of degradation of the potentially degradable fraction in the rumen (c) of the DM. Similarly, there were no significant differences ($P>0.05$) among treatments for the degradation of fractions “a”, “b” and the degradation rate of NDF (Table 5).

No significant differences ($P>0.05$; Table 5) were found between the treatments regarding the potential degradation of DM and NDF. The effective degradability of DM at rates of 5% and 8%/hour in the SGC treatment was greater than in the other treatments (Table 6).

5. Discussion

The material was harvested with 22% DM, which is below the range recommended by Kung et al. (2018) (25-35%) for the anaerobic fermentation of grasses at the time of ensiling. Tropical forages with a DM content lower than 25% have a higher potential for nutrient losses through gases and effluents, which affects the nutritional quality of the silage, as some of the carbohydrates and proteins are contained in the effluents (Kung et al., 2018; Batista et al., 2022).

The lower pH values found in the SGC and WI3 treatments are consistent with those of Kung et al. (2018), who prepared a review on the interpretation of the chemical, microbial, and organoleptic components of different silage types. For grass silage, the authors suggest that within a DM content range between 25 and 35%, the ideal pH range is between 4.3 and 4.7. According to these criteria, the SGC and WI3 treatments achieved values that were within the recommended range for better fermentation quality.

The pH values observed in the SGC and WI3 treatments could be due to the reduction in the moisture content of the grass, resulting in a concentration of soluble

carbohydrates that increased osmolarity of the silage. These factors probably promoted a reduction in buffering capacity and exacerbated the drop in pH (Tavares et al., 2009). Lowering the pH helps to prevent the growth of spoilage microorganisms such as yeasts, molds, and undesirable aerobic bacteria, thus helping to preserve the nutritional value of the ensiled material (González-Jartín et al., 2022).

The lower DM loss in the SGC and WI3 treatments could be related to the DM content of these treatments at the ensiling time. Tropical forages with a dry matter content lower than 25% may experience significant nutrient losses due to the release of gases and/or effluents, which negatively affect the nutritional value of the silages, as some of the carbohydrates and proteins present in the forages are released in the effluents during the fermentation process (Kung et al., 2018).

Amaral et al. (2020) characterized the population of lactic acid bacteria in the fermentation of elephant grass and selected promising lines for inoculants to evaluate their effect on silages of the BRS Capiacu variety harvested at 22% DM. These authors found DM losses between 3.8 and 12.3% in the different treatments. In the present study, lower DM losses were observed in the SGC and WI3 treatments, possibly due to the greater DM concentration at harvest, the addition of cornmeal, and the wilting process. Our results are consistent with those of Bezerra et al. (2019), who showed that the addition of ground cornmeal minimizes losses and suggest that adjustments to the ensiling material and substrate conditions can optimize lactic acid production, regardless of the initial lactic acid bacteria population.

According to Bates et al. (1989), DM loss in wilted silages may be increased due to less intensive fermentation characterized by lower acid production compared to non-wilted silages or silages that have been wilted for a shorter time. Our results confirm this observation and show that when comparing treatments WI3 and WI5, longer wilting

resulted in greater DM loss.

The greatest lactic acid concentrations were observed in treatments with greater DM content, which underlines the expected relationship between greater lactic acid production and greater DM content. In addition, the increase in lactic acid production could be due to the fact that the ensiled material had a greater amount of non-fibrous carbohydrates due to the addition of cornmeal, providing more substrate for lactic bacteria (Widyastuti, 2008; Silva et al., 2011; Borreani et al., 2018).

Kung et al. (2018) considered the ideal lactic acid concentration ranging from 6 to 10% for grass silage with a DM content of 25 to 35%. Therefore, none of our treatments had concentrations within this ideal range. This low lactic acid concentration may be directly related to the lower concentration of water-soluble carbohydrates (WSC) found in tropical forages. As WSC are the main substrate utilized by the lactic acid bacteria during the silage fermentation process (Piltz et al., 2022). During wilting, enzymatic respiration occurs, which leads to the loss of WSC (Muck et al., 2003), which also explains the lower concentration of lactic acid in treatments WI3 and WI5 compared to SGC. When comparing the CON treatment with WI3 and WI5, we found that the treatments that underwent the wilting process had greater lactic acid levels. Bates et al. (1989) and Umaña et al. (1991) indicate that wilting reduces water activity in the silage, making it difficult for *Clostridium* bacteria to multiply during fermentation. This environment favors lactic acid bacteria and gives them more time to produce sufficient amounts of organic acids, which are essential for effective preservation of silage.

According to Santos et al. (2008) and Ferreira et al. (2013), greater lactic acid production can lead to lower DM losses in grass silages. This is due to the fact that lactic acid fermentation only leads to minimal losses, while acetic and butyric acid fermentation is associated with secondary fermentations and DM losses in the form of gases. Regarding

acetic acid concentration, the values in all treatments were below the reference value proposed by Kung et al. (2018) for grass silages with a DM content between 25 and 35%, with the ideal range being 1 to 3% of DM. In contrast, the values found are greater than those observed by Ferrari Júnior and Lavezzo (2001) in wilted elephant grass silages or with the addition of cassava bran, which had an average of 0.47% acetic acid. Acetic acid plays an important role in the preservation of silage, especially after opening the silo, as it inhibits filamentous fungi, moulds, and yeasts in the silage and thus contributes to greater aerobic stability (Alencar et al., 2023).

It is worth mentioning that acetic acid also contributes to the preservation of ensiled material. However, greater concentrations indicate that undesirable changes may occur in the ensiling process. The ideal fermentation should take place with a greater amount of lactic acid to ensure a better quality of the fermented material (Mota et al., 2011). The lower concentration of butyric acid in the silage could be related to the decrease in pH, which may have inhibited the growth and proteolytic activity of microorganisms such as Clostridia (Arriola et al., 2011; Heinritz et al., 2012). When considering the butyric acid concentrations proposed by Kung et al. (2018), only the CON treatment showed production above the maximum limit of 1% recommended as a quality parameter for this type of silage.

According to Jobim et al. (2010), the ash content in silages can indicate losses of organic compounds due to contamination of the forage with sand during cutting, which normally occurs in the ensiling process. These losses lead to an increase in ash content and can have a negative effect on the pH buffering capacity of the silage. In addition, this increase in ash content may also be related to a dilution effect due to the lower water concentration of these treatments compared to the control, resulting in less dilution of this component.

Regarding CP, a similar result was observed by Zanine et al. (2006) and Paula et al. (2020). Paula et al. (2020) investigated the bromatological composition of BRS Capiaçú elephant grass silage with cornmeal added in proportions of 0, 5, 10, 15, and 20%. The authors found that the addition of ground corn to the silages had a linear effect, resulting in higher CP levels, as the cornmeal contained a greater proportion of this component compared to the elephant grass cv. BRS Capiaçú. In this study, the addition of 10% of cornmeal led to an increase of 0.93 percentage points in the CP content of the DM, while in our study the addition of 8% cornmeal led to an increase of 0.54 percentage points in the CP content of the DM. However, the SGC treatment CP was like similar with CON and WI3 treatments. The lower CP content in the WI5 treatment can be attributed to the prolonged wilting time. According to Henderson (1993), a wilting period of several days can result in a loss of water-soluble carbohydrates and a reduction in proteins due to the deamination of amino acids, which can lead to increased ammonia-nitrogen production during silage fermentation.

A similar result was observed by Paula et al. (2020) regarding the EE content, who found that despite the numerical increases in EE levels in the silage with the inclusion of ground cornmeal, there was no significant difference compared to the control treatment. The lowest EE content was observed in treatments WI3 and WI5, which can be attributed to wilting time. Studies suggest that wilting the material before ensiling reduces the EE content, resulting in significant losses of specific fatty acids, such as α -linolenic acid and linoleic acid (Boufaïed et al., 2003; Dewhurst et al., 2006; Van Ranst et al., 2009). These losses are associated with the lipoxygenase system, a plant defense mechanism that is activated in damaged tissues (Dewhurst et al., 2006).

The addition of 8% cornmeal in the SGC treatment decreased the fibrous fractions, with a reduction of 1.16%, 0.87%, and 0.82% for NDF, ADF, and NDFi, respectively, for

each 1% of cornmeal added. These results can be explained by a dilution effect, as cornmeal contains lower levels of these fractions compared to BRS Capiaçú grass (Paula et al., 2020). In contrast, the greater levels of these components observed in treatments CON, WI3, and WI5 may be related to the loss of WSC during silage fermentation (Mills and Kung, 2002). The NDF and ADF content is an indicator of the quantity and quality of fiber contained in the material, as a high NDF content may limit intake, while a low ADF content indicates fiber of good quality (Van Soest, 1994).

When evaluating the use of citrus pulp and wilting on the quality of elephant grass silage, Gomes et al. (2017) found that citrus pulp reduced the lignin content due to the dilution effect. On the other hand, wilting increased the lignin content, a change that was not observed in the WI3 treatment of the present study. In contrast, Carvalho et al. (2007) and Ribas et al. (2021) found no significant differences between wilted and non-wilted grasses. As plant tissue matures, secondary cell wall thickness increases, leading to an increase in NDF and lignin concentration at the expense of cell content (Van Soest, 1994; Wilson, 1994; Zailan et al., 2016).

When evaluating the rumen degradability, the fraction "a" of DM corresponds to the proportion of the feed that is readily available for the action of the microorganisms in the rumen. This increase in fraction "a" can be attributed to the inclusion of ground cornmeal, an ingredient with high values of the water-soluble fraction in its composition (Bezerra et al., 2015). The fraction "a" of DM for SGC treatment was 289 g/kg, a result similar to the found by Bezerra et al. (2015), who evaluated the *in situ* rumen degradability of elephant grass silages supplemented with corn bran and autochthonous microbiota inoculant using 60-day-old grass. These authors observed higher values of fraction "a" in the grass silage with the addition of ground cornmeal, with average values of 273 and 257 g/kg for the treatments without and with inoculant, respectively.

The values of the fraction “a” of DM for WI3 and WI5 treatments did not agree with the results of Ribas et al. (2021), who found no significant effects of wilting times on the rumen kinetics parameters of DM. The authors attributed this pattern to the decrease in CP and EE content with increasing wilting time. However, this pattern was not observed in the present study, because despite the reduction in CP and EE contents, the WI3 and WI5 treatments still showed greater values for the fraction “a” of DM compared to the CON treatment. This pattern could be due to the greater DM content in both treatments. According to Ridla et al. (2024), in their meta-analysis on the effects of wilting on silage quality, the authors concluded that during wilting, the concentration of carbohydrates, including WSC, increases as the forage loses moisture. In addition, wilting slows down the respiration of plant cells, which leads to a reduction in carbohydrate consumption. This reduction in respiration favors the conservation of carbohydrates, including WSC, which contributes to a greater content of soluble fractions in the forage (Borreani et al., 2018).

Regarding the NDF degradation rate, it is important to emphasize that according to Mertens (1993), the NDF degradation rate must be between 0.02 and 0.06%/h for bulky feeds to be considered of high quality, and only the SGC treatment was within this recommended range.

Ribas et al. (2021) reported an average potential DM degradability of 515.9 g/kg for BRS Capiaçú grass silage, a value that the authors classified as low and possibly related to the high iNDF content. This result is close to the average value of 571 g/kg found in our study. The greater effective degradability of the DM in the SGC treatment can be attributed to the better degradability of corn compared to elephant grass, as it has easily soluble components compared to the BRS Capiaçú variety (Passini et al., 2004).

It is worth noting that although the wilting of the forage was performed for 3 days and 5 days during the winter, the time required to reach the desired dry matter content

may vary depending on local climatic conditions. In warmer regions, with higher average temperatures, fewer days may be necessary to achieve the same dry matter. Therefore, it is important to consider other factors such as the dry matter content of the plant, local climate, and environmental conditions when adapting the wilting time for different regions, thus ensuring silage quality without compromising the efficiency of the process.

6. Conclusion

The wilting of BRS Capiaçú elephant grass for 3 days before ensiling or the addition of cornmeal with the aim to increasing the DM content are strategies that improve the fermentation quality of the ensiled material and enable better forage conservation. However, only the SGC treatment showed better degradation of dry matter. It is important to highlight that wilting is an advantageous technique, especially in situations where family labor is used, since the cost is lower, and the results of silage quality are similar those obtained with the addition of cornmeal. On the other hand, the addition of moisture sequestrants can improve silage quality without major issues caused by rainfall in the harvest. However, this can also significantly increase the cost of silage production.

Conflict of interest

The authors declare no conflict of interest.

Data availability

The entire dataset supporting the results of this study was published in the article itself.

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References

Andrade, AP; Quadros, DG; Bezerra, ARG; Almeida, JAR; Silva, PHS e Araújo, JAM 2012. Aspectos qualitativos da silagem de capim-elefante com fubá de milho e casca de soja. Semina: Ciências Agrárias 33:1209–1218, 2012. <https://doi.org/10.5433/1679-0359.2012v33n3p1209>

Alencar, AMS; Júnior, VRR; Monção, FP; Cordeiro, MWS; Santos, AS; Caldeira, LA; Oliveira, LIS; Ananias, JVA; Costa, MD; Souza, AS; Souza, AS e Santos, LCS 2023. Quality of mixed silages of sorghum, BRS Capiaçú grass, and cactus pear in a semiarid region of Brazil. Journal of Applied Animal Research 51: 719–728. <https://doi.org/10.1080/09712119.2023.2277256>

Amaral, RC; Carvalho, BF; Costa, DM; Morenz, MJF; Schwan, RF e Ávila, CLS 2020. Novel lactic acid bacteria strains enhance the conservation of elephant grass silage cv. BRS Capiaçú. Animal Feed Science and Technology 264:1-15. <https://doi.org/10.1016/j.anifeedsci.2020.114472>

Aranega, JPRB e Oliveira, CAF 2023. Occurrence of Mycotoxins in Conserved Grass and Legume Forages – A Systematic Review. Annals of Animal Science 24:3–11. <https://doi.org/10.2478/aoas-2023-0030>

Arriola, KG; Kim, SC e Adesogan, AT 2011. Effect of applying inoculants with heterolactic or homolactic and heterolactic bacteria on the fermentation and quality of corn silage.

Journal of Dairy Science 94:1511–1516. <https://doi.org/10.3168/jds.2010-3807>

Assunção, A. S 2017. Avaliação da variabilidade entre animais e de protocolos de incubação em estudos de degradação *in situ* em bovinos. Dissertação (Mestrado em Zootecnia). Universidade Federal de Viçosa, Viçosa.

Barcelos, AF; Carvalho, JRRD; Tavares, VB e Gonçalves, CCDM 2018. Valor nutritivo e características fermentativas da silagem de capim-elefante com diferentes proporções de casca de café. *Ciência Animal Brasileira* 19:27432. <https://doi.org/10.1590/1809-6891v19e-27432>

Bates, DB; Kunkle, WE; Chambliss, CG e Chambliss, CG 1989. Effect of Dry Matter and Additives on Bermudagrass and Rhizoma Peanut Round Bale Silage. *Journal of Production Agriculture* 2:91–96. <https://doi.org/10.2134/jpa1989.0091>

Batista, JSS; Alves, DD; Rigueira, JPS; Backes, AA; Silva, JTE; Silva, ÉTDJ e Monção, FP 2022. Elephant grass cv. BRS capiaçu silage with inclusion of different proportions of silk cotton. *Semina: Ciências Agrárias* 43:179–196. <https://doi.org/10.5433/1679-0359.2022v43n1p179>

Berchielli, TT; Pires, AV e Oliveira, SG 2011. *Nutrição de Ruminantes*. 2ª ed. FUNEP.

Bezerra, HFC; Santos, EM; Oliveira, JS; Carvalho, GGP; Pinho, RMA; Silva, TC; Pereira, GA; Cassuce, MR e Zanine, AM 2019. Fermentation characteristics and chemical composition of elephant grass silage with ground maize and fermented juice of epiphytic lactic acid bacteria. *South African Journal of Animal Science* 49:522–533. <https://doi.org/10.4314/sajas.v49i3.13>

Bezerra, HFC; Santos, EM; Oliveira, JS; Carvalho, GGP; Cassuce, MR; Perazzo, AF; Freitas,

DSS e Santos, VS 2015. Degradabilidade ruminal in situ de silagens de capim-elefante aditivadas com farelo de milho e inoculante da microbiota autóctone. *Revista Brasileira de Saúde e Produção Animal* 16:265–277. <https://doi.org/10.1590/S1519-99402015000200001>

Borreani, G; Tabaco, E; Schmidt, RJ; Holmes, BJ e Muck, RE 2018. Silage review: Factors affecting dry matter and quality losses in silages. *Journal of Dairy Science* 101:3952–3979. <https://doi.org/10.3168/jds.2017-13837>

Boufaïed, H; Chouinard, PY; Tremblay, GF; Petit, HV; Michaud, R e Bélanger, G 2003. Fatty acids in forages. I. Factors affecting concentrations. *Canadian Journal of Animal Science* 83:501–511. <https://doi.org/10.4141/A02-098>

Brüning, D; Gerlach, K; Weiss, K e Südekum, KH 2018. Effect of compaction, delayed sealing and aerobic exposure on maize silage quality and on formation of volatile organic compounds. *Grass and Forage Science* 73:53–66. <https://doi.org/10.1111/gfs.12288>

Buriol, LR; Torteli, SR; Gallina, G; Battiston, J e Lajús, CR 2021. Perfil granulométrico e digestibilidade do amido da silagem de milho submetida a diferentes processamentos. *Brazilian Journal of Development* 7:39680–39710. <https://doi.org/10.34117/bjdv7n4-433>

Carvalho, GGP; Garcia, R; Pires, AJV; Pereira, OG; Azevêdo, JAG; Carvalho, BMAD e Cavali, J 2007. Valor nutritivo de silagens de capim-elefante emurhecido ou com adição de farelo de cacau. *Revista Brasileira de Zootecnia* 36:1495–1501. <https://doi.org/10.1590/S1516-35982007000700006>

CLIMATE-DATA.ORG. Clima Viçosa: Temperatura, Tempo e Dados climatológicos Viçosa

2022. Disponível em: <https://pt.climate-data.org/america-do-sul/brasil/minas-gerais/vicosa-25021/>. Acesso em: 2 jul. 2024.

Comino, L; Pasinato, S; Revello-Chion, A; Chiavazza, E; Ferrero, F; Tabacco, E e Borreani, G 2024. Substitution of human edible feeds with integrated use of reduced fat wheat distillers and high-quality forages in a diet for high production lactating dairy cows. *Animal Feed Science and Technology* 312:115973. <https://doi.org/10.1016/j.anifeedsci.2024.115973>

Detmann, E; Silva, LC; Rocha, GC; Palma, MNN e Rodrigues, JPP 2021. Métodos para Análise de Alimentos – INCT - Ciência Animal. ed Independente. Viçosa, MG.

Dewhurst, RJ; Shingfield, KJ; Lee, MRF e Scollan, ND 2006. Increasing the concentrations of beneficial polyunsaturated fatty acids in milk produced by dairy cows in high-forage systems. *Animal Feed Science and Technology* 131:168–206. <https://doi.org/10.1016/j.anifeedsci.2006.04.016>

Ferrari Júnior, E e Lavezzo, W 2001. Qualidade da Silagem de Capim-Elefante (*Pennisetum purpureum* Schum.) Emurcheado ou Acrescido de Farelo de Mandioca. *Revista Brasileira de Zootecnia* 30:1424–1431.

Ferreira, DJ; Lana, RP; Zanine, AM; Santos, EM; Veloso, CM e Ribeiro, GA 2013. Silage fermentation and chemical composition of elephant grass inoculated with rumen strains of *Streptococcus bovis*. *Animal Feed Science and Technology* 183:22–28. <https://doi.org/10.1016/j.anifeedsci.2013.04.020>

Gomes, ALM; Auerbach, HU; Lazzari, G; Moraes, A; Nussio, LG; Jobim, CC e Daniel, JLP 2021. Sodium nitrite-based additives improve the conservation and the nutritive value of guinea

grass silage. *Animal Feed Science and Technology* 279:115033.
<https://doi.org/10.1016/j.anifeedsci.2021.115033>

Gomes, RDS; Almeida, JDC; Carneiro, JDC; Azevedo, FHV; Lista, FN; Elyas, ACW e Oliveira, TS 2017. Impacts of citrus pulp addition and wilting on elephant grass silage quality. *Bioscience Journal* 33:675–684. <https://doi.org/10.14393/BJ-v33n3-33790>

González-Jartín, JM; Ferreiroa, V; Rodríguez-Cañás, I; Alfonso, A; Sainz, MJ; Aguin, O; Vieytes, MR; Gomes, A; Ramos, I e Botana, LM 2022. Occurrence of mycotoxins and mycotoxigenic fungi in silage from the north of Portugal at feed-out. *International Journal of Food Microbiology* 365:109556. <https://doi.org/10.1016/j.ijfoodmicro.2022.109556>

Hall, MB; Hoover, WH; Jennings, JP e Webster, TK 1999. A method for partitioning neutral detergent-soluble carbohydrates. *Journal of the Science of Food and Agriculture* 79:2079–2086. [https://doi.org/10.1002/\(SICI\)1097-0010\(199912\)79:15<2079::AID-JSFA502>3.0.CO;2-Z](https://doi.org/10.1002/(SICI)1097-0010(199912)79:15<2079::AID-JSFA502>3.0.CO;2-Z)

Heinrichs, J. 2013. The Penn State Particle Separator. Disponível em: <https://extension.psu.edu/penn-state-particle-separator#section-1>. Acesso em: 17 mar. 2025.

Heinritz, SN; Martens, SD; Avila, P e Hoedtke, S 2012. The effect of inoculant and sucrose addition on the silage quality of tropical forage legumes with varying ensilability. *Animal Feed Science and Technology* 174:201–210.
<https://doi.org/10.1016/j.anifeedsci.2012.03.017>

Henderson, N 1993. Silage additives. *Animal Feed Science and Technology* 45:35–56.
[https://doi.org/10.1016/0377-8401\(93\)90070-Z](https://doi.org/10.1016/0377-8401(93)90070-Z)

INMET. Instituto Nacional De Meteorologia 2022. Dados históricos anuais. Disponível em: <https://portal.inmet.gov.br/dadoshistoricos>. Acesso em: 2 jul. 2024.

Jobim, CC; Junior, MC; Júnior, VHB e Oliveira, FCL 2010. Composição química e qualidade de conservação de silagens de grãos de milho (*Zea mays* L.) com diferentes níveis de grãos de soja (*Glycine max* Merrill). *Semina: Ciências Agrárias* 31: 773–782. <https://doi.org/10.5433/1679-0359.2010v31n3p773>

Jung, HG e Deetz, DA 1993. Cell wall lignification and degradability. In: Jung, HG; Buxton, DR; Hatfield, RD; Ralph, J. Forage cell wall structure and digestibility. American Society of Agronomy, p. 315-346.

Kemboi, DC; Antonissen, G; Ochieng, PE; Croubels, S; Okoth, S; Kangethe, EK; Faas, J; Lindahl, JF e Gathumbi, JK 2020. A review of the impact of mycotoxins on dairy cattle health: Challenges for food safety and dairy production in sub-Saharan Africa. *Toxins* 12: 222. <https://doi.org/10.3390/toxins12040222>

Köppen, W. Das geographische System der Klimate. In: KÖPPEN, W.; GEIGER, R. (Eds): Handbuch der Klimatologie. Berlin: Gebrüder Bornträger, 1936. Banda 1, Parte C, p. 1-44.

Kung Jr., L; Shaver, R D; Grant, RJ e Schmidt, RJ 2018. Silage review: Interpretation of chemical, microbial, and organoleptic components of silages. *Journal of Dairy Science*. *Journal of dairy Science* 101:4020-4033. <https://doi.org/10.3168/jds.2017-13909>

Liu, J; Hao, J; Zhao, M; Yan, X; Jia, Y; Wang, Z; & Ge, G 2024. Effects of different temperature and density on quality and microbial population of wilted alfalfa silage. *BMC microbiology*, 24: 380. <https://doi.org/10.1186/s12866-024-03510-2>

Machado, MG; Detmann, E; Mantovani, HC; Valadares Filho, SC; Bento, CBP; Marcondes,

MI e Assunção, AS 2016. Evaluation of the length of adaptation period for changeover and crossover nutritional experiments with cattle fed tropical forage-based diets. *Animal Feed Science and Technology* 222: 132–148. <https://doi.org/10.1016/j.anifeedsci.2016.10.009>

Marsh, R 1979. The effects of wilting on fermentation in the silo and on the nutritive value of silage. *Grass and Forage Science* 34:1–10. <https://doi.org/10.1111/j.1365-2494.1979.tb01441.x>

Menezes, ACB; Valadares Filho, SC; Pacheco, MVC; Pucetti, P; Pereira, JMV; Rotta, PP; Zanetti, D; Silva, BC; Silva, LFCE; Detmann, E; Neville, TL e Caton, JS 2019. Single point ruminal incubation times necessary to estimate rumen degradable protein content in concentrate feeds. *Translational Animal Science* 3:1686-1690. <https://doi.org/10.1093/tas/txz058>

Mertens, D. R 1993. Kinetics of cell wall digestion and passage in ruminants. Pages 535–570 in *Forage Cell Wall Structure and Digestibility*. H. G. Jung, D. R. Buxton, R. D. Hatfield, and J. Ralph, ed. American Society of Agronomy, Madison, WI. <https://doi.org/10.2134/1993.foragecellwall.c21>

Millen, DD; Pacheco, RDL; Meyer, PM; Rodrigues, PHM; Arrigoni, MB 2011. Current Outlook and Future Perspectives of Beef Production in Brazil. *Animal Frontiers* 1, 46–52. <https://doi.org/10.2527/af.2011-0017>

Mills, JA e Kung, L 2002. The effect of delayed ensiling and application of a propionic acid-based additive on the fermentation of barley silage. *Journal of Dairy Science* 85:1969–1975.

Monção, FP; Rocha Júnior, VR; Silva, JT; Jesus, NG; Marques, OFC; Rigueira, JPS; Sales, ECJ; Silva Júnior, AAG; Alves, DD; Carvalho, CCC; Gomes, VM e Leal, DB 2020. Nutritional Value of BRS Capiacu Grass (*Pennisetum purpureum*) Silage Associated with Cactus Pear. Iranian Journal of Applied Animal Science 10: 25–29.

Moraes, A; Auerbach, HU; Bragatto, JM; Piran Filho, FA; Silva, SMS; Nussio, LG; Jobim, CC e Daniel, JLP 2023. Effect of application rate of sodium nitrite and hexamine on the fermentation and the chemical composition of guinea grass silage harvested at different stages of maturity. Animal Feed Science and Technology 302: 115667. <https://doi.org/10.1016/j.anifeedsci.2023.115667>

Mota, ADS; Rocha Júnior, VR; Souza, AS; Reis, ST; Tomich, TR; Caldeira, LA e Menezes, GCC 2011. Perfil de fermentação e perdas na ensilagem de diferentes frações da parte aérea de quatro variedades de mandioca. Revista Brasileira de Zootecnia 40: 1466–1473. <https://doi.org/10.1590/S1516-35982011000700010>

Muck, RE; Nadeau, EMG; McAllister, TA; Contreras-Govea, FE; Santos, MC e Kung Jr, L 2018. Silage review: Recent advances and future uses of silage additives. Journal of Dairy Science 101: 3980-4000. <https://doi.org/10.3168/jds.2017-13839>

Muck, RE; Moser, LE e Pitt, RE 2003. Postharvest factors affecting ensiling. In: Silage Science and Technology; Buxton, D.R., Muck, R.E., Harrison, J.H., Eds.; American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America, Inc.: Madison, WI, USA.

Nocek, JE 1988. In situ and Other Methods to Estimate Ruminant Protein and Energy Digestibility: A Review. Journal of Dairy Science 71: 2051-2069.

Nussio, LG; Paziani, SDF e Nussio, CMB 2002. Ensilagem de capins tropicais. In Embrapa Pecuária Sudeste. In: Reunião Anual Da Sociedade Brasileira De Zootecnia, 39,2002, Recife, PE.

Orskov, ER e Mcdonald, I 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. The Journal of Agricultural Science 92: 499–503, 1979. <https://doi.org/10.1017/S0021859600063048>

Pahlow, G; Muck, RE; Driehuis, F; Oude-Elferink, SJWH e Spoelstra, SF 2003. Microbiology of ensiling. In: Buxton, D. R.; Muck, R. E. and Harrison, J. H., eds. Silage science and technology. American Society of Agronomy p.31-93, Madison, WI. <https://doi.org/10.2134/agronmonogr42.c2>

Passini, R; Laura, MOB; Ferreira, FA e Rodrigues, PHMR 2004. Degradabilidade no rúmen bovino de grãos de milho processados de diferentes formas. Pesquisa Agropecuária Brasileira 39: 271-276. <https://doi.org/10.1590/S0100-204X2004000300010>

Paula, PRP; Júnior, APN; Souza, WL; Abreu, MJI; Teixeira, RMA; Cappelle, ER; Tavares, VB 2020. Composição bromatológica da silagem de capim-elefante BRS Capiaçú com inclusão de fubá de milho. Pubvet 14: 1-11. <https://doi.org/10.31533/pubvet.v14n10a680.1-11>

Pedroso, ADF; Nussio, LG; Paziani, SDF; Loures, DRS; Igarasi, MS; Coelho, RM; Packer, HI; Horii, J e Gomes, LH 2005. Fermentation and epiphytic microflora dynamics in sugar cane silage. Scientia Agricola 62: 427-432. <https://doi.org/10.1590/S0103-90162005000500003>

Pereira, AV; Ledo, FJS; Morenz, MJF; Leite, JLB; Brighenti, AM; Martins, CE e Machado, JCB 2016. BRS Capiaçú: cultivar de capim-elefante de alto rendimento para produção de

silagem. Embrapa Gado de Leite.

Piltz, JW; Meyer, RG; Brennan, MA e Boschma, SP 2022. Fermentation Quality of Silages Produced from Wilted Sown Tropical Perennial Grass Pastures with or without a Bacterial Inoculant. *Agronomy* 12: 1721. <https://doi.org/10.3390/agronomy12071721>

Ribas, WFG; Monção, FP; Rocha, VR; Maranhão, CMA; Ferreira, HC.; Santos, AS e Rigueira, JPS 2021. Effect of wilting time and enzymatic-bacterial inoculant on the fermentative profile, aerobic stability, and nutritional value of BRS capiaçu grass silage. *Revista Brasileira de Zootecnia* 50: 1–13. <https://doi.org/10.37496/rbz5020200207>

Ridla, M; Albarki, HR; Risyahadi, ST e Sukarman, S 2024. Effects of wilting on silage quality: a meta-analysis. *Animal Bioscience* 37: 1185. <https://doi.org/10.5713/ab.23.0403>

Rodríguez-Blanco, M; Ramos, AJ; Sanchis, V e Marín, S 2021. Mycotoxins occurrence and fungal populations in different types of silages for dairy cows in Spain. *Fungal Biology* 125: 103–114. <https://doi.org/10.1016/j.funbio.2019.08.006>

Sampaio, RL; Resende, FD; Reis, RA; Oliveira, IM; Custódio, L; Fernandes, RM; Pazdiora, RD e Siqueira, GR 2017. The nutritional interrelationship between the growing and finishing phases in crossbred cattle raised in a tropical system. *Tropical Animal Health and Production* 49: 1015–1024. <https://doi.org/10.1007/s11250-017-1294-8>

Santos, EM; Zanine, AM; Ferreira, DJ; Oliveira, JS; Penteado, DCS e Pereira, OG 2008. Inoculante ativado melhora a silagem de capim-tanzania (“panicum maximum”). *Archivos de zootecnia* 57: 35–72.

Schmidt, P 2006. Perdas fermentativas na ensilagem, parâmetros digestivos e

desempenho de bovinos de corte alimentados com rações contendo silagens de cana-de-açúcar. Piracicaba. Tese (Doutorado em Agronomia). USP. Escola Superior de Agricultura Luiz de Queiroz, São Paulo.

Siegfried, VR; Ruckemann, H e Stumpf, G 1984. Method for the determination of organic acids in silage by high performance liquid chromatography. *Landwirtschaftliche Forschung*, v: 298-304.

Silva, BC; Pacheco, MVC; Godoi, LA; Silva, FAS.; Zanetti, D; Menezes, ACB; Pucetti, P; Santos, SA; Paulino, MF e Valadares Filho, SC 2020. *In situ* and *in vitro* techniques for estimating degradation parameters and digestibility of diets based on maize or sorghum. *The Journal of Agricultural Science* 158: 150-158. <https://doi.org/10.1017/S0021859620000271>

Silva, FF; Aguiar, MSMA.; Veloso, CM; Pires, AJV; Bonomo, P; Dutra, GS; Almeida, VS; Carvalho, GGP; Silva, RR; Dias, AM e Ítavo, LCV 2007. Bagaço de mandioca na ensilagem do capim-elefante: qualidade das silagens e digestibilidade dos nutrientes. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia* 59: 719-729.

Silva, TC; Silva, MVB; Ferreira, EG; Pereira, OG e Ferreira, CLLF 2011. Papel da fermentação láctica na produção de silagem. *Pubvet* 5: Art. 992-998.

Tavares, VB; Pinto, JC; Evangelista, AR; Figueiredo, HCP e Ávila, CLDS 2009. Efeitos da compactação, da inclusão de aditivo absorvente e do emurchecimento na composição bromatológica de silagens de capim-tanzânia. *Revista Brasileira de Zootecnia* 38: 40-49.

Umaña, R; Staples, RC; Bates, DB; Wilcox, CJ e Mahanna, W.C 1991. Effects of a microbial inoculant and(or) sugarcane molasses on the fermentation, aerobic stability, and digestibility of bermudagrass ensiled at two moisture contents. *Journal of Animal Science*

69: 4588–4601, 1991. <https://doi.org/10.2527/1991.69114588x>

Van Ranst, G; Fievez, V; De Riek, J e Van Bockstaele, E 2009. Influence of ensiling forages at different dry matters and silage additives on lipid metabolism and fatty acid composition. *Animal Feed Science and Technology* 150: 62–74, 2009. <https://doi.org/10.1016/j.anifeedsci.2008.08.004>

Van Soest, PJ; Robertson, JB e Lewis, BA 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74: 3583–3597, 1991. [https://doi.org/10.3168/jds.s0022-0302\(91\)78551-2](https://doi.org/10.3168/jds.s0022-0302(91)78551-2)

Van Soest, PJ 1994. *Nutricional ecology of the ruminant*. 2^a.ed. Cornell University Press. p. 476.

Vanzant, ES; Cochran, RC e Titgemeyer, EC 1998. Standardization of in situ techniques for ruminant feedstuff evaluation. *Journal of Animal Science* 76: 2717–2729.

Waldo, DR; Smith, LW e Cox, EL 1972. Model of Cellulose Disappearance from the Rumen. *Journal of Dairy Science* 55: 125–129. [https://doi.org/10.3168/jds.S0022-0302\(72\)85442-0](https://doi.org/10.3168/jds.S0022-0302(72)85442-0)

Widyastuti, Y 2008. Fermentasi silase dan manfaat probiotik silase bagi ruminansia. *Media Peternakan* 31: 225–232.

Wilkinson, JM e Davies, DR 2013. The aerobic stability of silage: Key findings and recent developments. *Grass and Forage Science* 68: 1-19. <https://doi.org/10.1111/j.1365-2494.2012.00891.x>

Wilson, JR 1994. Cell wall characteristics in relation to forage digestion by ruminants. *The*

Journal of Agricultural Science 122: 173–182.

Zailan, MZ; Yaakub, H e Jusoh, S 2016. Yield and nutritive value of four Napier (*Pennisetum purpureum*) cultivars at different harvesting ages. Agriculture and biology journal of north America 7: 213–219.

Zanine, AM; Santos, EM; Ferreira, DJ; Pereira, OG e Almeida, JCC 2006. Efeito do farelo de trigo sobre as perdas, recuperação da matéria seca e composição bromatológica de silagem de capim-mombaça. Brazilian Journal of veterinary Research and animal Science 43: 803-809. <https://doi.org/10.11606/issn.1678-4456.bjvras.2006.26560>

Tables

Table 1 - Data on maximum and minimum temperatures, average relative humidity, and daily rainfall from the weather station in Viçosa during the harvest and wilting periods.

Days	Activity performed	Max. temperature (°C)	Min. temperature (°C)	Air humidity (%)	Precipitation (mm)
	Harvesting of all treatments; Beginning of wilting of WI3 and				
1	WI5; Grinding and ensiling of grass from CON and SGC treatments	22.9	8.8	81.0	0
2	Wilting of grass in treatments WI3 and WI5	23.6	8.7	80.6	0.2
3	Wilting of grass in treatments WI3 and WI5	24.4	11.9	81.1	0
4	Grinding and ensiling of grass from WI3 treatment and wilting from WI5	24.2	12.9	79.0	0
5	Wilting of grass in treatments WI5	23.6	12.4	77.8	0
6	Grinding and ensiling of grass from the WI5 treatment	22.7	10	84.9	0.2

Table 2 - Particle distribution in Penn State evaluation methodology of *Cenchrus purpureus* (Schumach.) Morrone cv. BRS Capiaçú grass with the addition of cornmeal and different wilting periods.

Sieves	Treatments			
	CON	SGC	WI3	WI5
19 mm (%)	9.45	5.04	11.81	8.27
8 mm (%)	56.24	57.92	54.20	48.10
4 mm (%)	29.50	28.78	27.43	32.97
Pan (%)	4.81	8.26	6.56	10.66

Table 3 – pH, DM loss, and concentration of lactic, acetic, and butyric acid in *Cenchrus purpureus* (Schumach.) Morrone cv. BRS Capiçu silage with addition of cornmeal and different wilting periods.

Parameters	Treatments ¹				SEM ²	P-value
	CON	SGC	WI3	WI5		
pH	5.07 a	4.55 c	4.52 c	4.95 b	0.073	< 0.01
DM Loss (%)	3.16 a	1.69 b	1.64b	2.90 a	0.217	< 0.01
Lactic Acid (% DM)	0.83 c	2.32 a	1.57 b	1.65 b	0.161	< 0.01
Acetic Acid (% DM)	0.44 b	0.75 a	0.88 a	0.82 a	0.056	< 0.01
Butyric Acid (% DM)	1.20 a	0.27 c	0.33 c	0.54 b	0.113	< 0.01

¹CON = control; SGC = additional 8% of cornmeal; WI3 = wilting for 3 days; WI5 = wilting for 5 days.

² SEM = standard error of the mean.

Means followed by the same letter in the row do not differ from each other by Tukey's test at 5% probability.

Table 4 – Chemical composition of *Cenchrus purpureus* (Schumach.) Morrone cv. BRS Capiaçú silage with the addition of cornmeal and different wilting periods.

Items (g/kg) ¹	Treatments ²				SEM ³	P- Value
	CON	SGC	WI3	WI5		
Dry Matter	223.1 c	257.2 b	318.3 a	305.4 a	4.50	< 0.01
Ash	80.2 b	80.5 b	90.6 a	85.5 ab	1.59	< 0.01
Crude Protein	58.4 a	63.8 a	58.5 a	51.4 b	1.35	< 0.01
Ether Extract	16.7 a	16.7 a	9.9 b	7.5 b	1.05	< 0.01
NDF	792.7 ab	700.2 c	765.8 b	798.2 a	6.45	< 0.01
ADF	523.2 ab	453.3 c	504.0 b	540.5 a	7.26	< 0.01
Lignin	97.4 ab	82.1 c	88.4 bc	101.1 a	2.08	< 0.01
NFC	51.7 b	138.6 a	74.9b	57.2b	6.36	< 0.01
NDFi	420.4 a	355.0 b	394.5 a	414.9 a	7.49	< 0.01

¹ NDF = neutral detergent fiber; ADF = acid detergent fiber; NFC = non-fibrous carbohydrates; NDFi = indigestible neutral detergent fiber.

² CON = control; SGC = additional 8% of cornmeal; WI3 = wilting for 3 days; WI5 = wilting for 5 days.

³ SEM = standard error of the mean.

Means followed by the same letter in the row do not differ from each other by Tukey's test at 5% probability.

Table 5 - In situ degradation parameters of DM and NDF of *Cenchrus purpureus* (*Schumacher*.) Morrone cv. BRS Capiaçú silage with the addition of cornmeal and different wilting periods.

Items	Treatments ¹				SEM ²	P- Value
	CON	SGC	WI3	WI5		
DM parameters						
a, g/kg	209 c	289 a	240 b	234 b	4.95	< 0.01
b, g/kg	336	330	332	314	26.7	0.93
c, %/h	2.03	2.27	1.85	1.76	0.21	0.39
NDF parameters						
a, g/kg	149	162	160	173	7.63	0.27
b, g/kg	370	382	368	347	30.6	0.88
c, %/h	1.87	2.11	1.80	1.77	0.19	0.63
Potential degradation of DM, g/kg	545	619	572	548	25.6	0.22
Potential degradation of NDF, g/kg	519	544	528	520	31.6	0.93

¹CON = control; SGC = additional 8% of cornmeal; WI3 = wilting for 3 days; WI5 = wilting for 5 days.

² SEM = standard error of the mean.

Means followed by the same letter in the row do not differ from each other by Tukey's test at 5% probability.

Table 6 – Effective degradability of DM and NDF at three passage rates of *Cenchrus purpureus* (Schumach.) Morrone cv. BRS Capiaçú silage with the addition of cornmeal and different wilting periods

Items	Treatments ¹				SEM ²	P- Value
	CON	SGC	WI3	WI5		
Effective degradability of DM (g/kg)						
$K_p = 2\ %/h$	379 B	465 A	400 AB	381 B	20.7	0.06
$K_p = 5\ %/h$	307 b	393 a	330 b	316 b	13.6	0.01
$K_p = 8\ %/h$	278 b	362 a	303 b	291 b	10.2	0.01
Effective degradability of NDF (g/kg)						
$K_p = 2\ %/h$	329	359	335	336	25.1	0.85
$K_p = 5\ %/h$	251	276	258	264	17.3	0.77
$K_p = 8\ %/h$	221	243	228	236	13.8	0.70

¹CON = control; SGC = additional 8% of cornmeal; WI3 = wilting for 3 days; WI5 = wilting for 5 days.

² SEM = standard error of the mean.

Means followed by the same lowercase in the row do not differ from each other by Tukey's test at 5% probability, while means followed by the same uppercase in the row do not differ from each other by Tukey's test at 10% probability.

CHAPTER 2

Chapter formatted according to the scientific journal: Scientific reports

Current situation of milk producers affected by the collapse of the Fundão dam in Mariana (MG)

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ABSTRACT

Environmental disasters, such as dam failures, have caused great hardship, particularly for rural population in the affected regions. This study aimed to compare dairy farms affected by a dam disaster (AFD) with unaffected farms (UFD) in terms of management, management practices and socio-economic conditions. Sixty dairy farms in the municipalities of Mariana, Minas Gerais, served by the *Familia do Leite*

Program of the Federal University of Viçosa (UFV), were analyzed. Affected farmers received assistance from Vale, the mining company responsible for the disaster. Data collection included agronomic, productive, environmental and socio-economic indicators. Statistical analysis was performed using SAS UNIVARIATE for continuous variables and logistic regression with GLIMMIX for binary variables. Results showed that AFD were more likely to receive technical assistance, purchase forage, analyze the soil; however, they also had a higher likelihood of leaving the activity. At the same time, they were less likely to use exogenous oxytocin, have parasitic sadness, use pit water, and face road issues. These results highlight the significant differences in management practices and socio-economic conditions between AFD and UFD farms. These findings emphasize the need for targeted support to mitigate the long-term effects of environmental disasters on agriculture.

Keyword: Environmental disaster, milk production, mining, technical assistance, agriculture, contamination.

Introduction

Mining in Brazil has its origins in colonial times and was particularly intensive from the 17th century, the height of the “gold rush”. Due to its great geological diversity, the country is one of the largest mineral producers in the world¹. In 2023, mining accounted for 4% of national GDP², generated US\$ 51.3 billion and employed around 2.2 million people directly and indirectly^{3,4}. In this scenario, the state of Minas Gerais is not only the largest producer of metallic minerals in Brazil but also concentrates a large part of the country's mining activities. With 525 mining municipalities, mining is present in 62% of the state's territory ⁴.

However, the Brazilian economy, particularly that of Minas Gerais state, goes beyond mining and also includes agricultural production, with a focus on milk production. According to the Milk Yearbook of the Brazilian Agricultural Research Corporation – EMBRAPA⁵, 34.6 billion liters of milk were produced in Brazil in 2022, with Minas Gerais responsible for about 27% of this production⁶. In addition to its economic importance, the dairy industry also has a social and cultural importance, as it contributes to food security, nutrition, and income generation for many families⁷. More than 60% of the Brazilian dairy industry is made up of family farms⁸, and according to IBGE⁹, family farming is the leader in national milk production. Minas Gerais has

approximately 607.5 thousand agricultural establishments, of which 441.8 thousand family farms, behind only Bahia⁹.

In the Mariana region of Minas Gerais, agriculture, especially in the form of family farms, is part of the cultural framework of local communities. These activities are of great economic and social importance, as they offer the possibility of generating income in the region¹⁰. However, environmental disasters, such as dam failures, have caused great difficulties for these producers, as their land has been partially or completely damaged, affecting their ability to maintain production.

Despite its economic importance, mining has a significant environmental impact¹¹. Spoil dams, pose a high risk in the event of a breach, as demonstrated by the 2015 disaster with the breach of the Fundão dam in Mariana (MG), under the responsibility of the mining company Samarco Mineração S.A, currently under the control of the companies Vale S.A and BHP Billiton Brasil. As a result of the disaster, 55 million cubic meters of tailings were released into the environment¹², rendering around 1,430 hectares of land unproductive for agricultural activities such as dairy farming, being the biggest tragedy of its nature in the world¹³,

Following a similar disaster, the rupture of the Córrego do Feijão mine dam in the Brumadinho region in 2019, studies in the affected regions such as the Paraopeba River have shown an increase in the concentrations of several metals above the levels permitted by Brazilian legislation^{14,15}. Moreover, Miranda et al.¹⁶ assessed the physical and psychological impact on the population of Brumadinho after the tailings dam burst. According to the authors, the main health risks are the increased resistance of pathogens to antimicrobial agents, the possible toxicological effects and the risks to the general health of the population.

The hypothesis of this study is that dairy producers affected by the collapse of the Fundão dam in 2015 face a significantly more compromised production situation compared to producers who were not affected. The aim of this paper is therefore to describe the current situation of milk producers who were affected by the collapse of the Fundão dam in 2015 and to compare it with the situation of producers who were not affected.

Material And Methods

The data used in this study were provided by the *Familia do Leite* Program of the Federal University of Viçosa. The producers involved in the study were supervised

by this program, which allowed a structured and systematic data collection that corresponded to the reality of each dairy farm in the region. In addition, the producers agreed to make the data available for research purposes.

Data collection

The data used for this study were collected by the Família do Leite program from 60 dairy farms managed by the program and located in the municipalities affected by the Fundão dam collapse in Mariana (MG) (Figure 1). These data refer to properties in Barra Longa, Conselheiro Pena, Governador Valadares, Mariana, Naque, Ponte Nova and Tumiritinga, as recommended by the Renova Foundation, as these municipalities were the most affected, according to the institution. These properties were divided into two groups: affected farms (AFD), i.e. those whose dairy farming was totally or partially affected by the dam collapse, and unaffected farms (UFD), i.e. those that did not suffer any damage from the environmental disaster. Table 1 shows the relationship between the affected and unaffected farms and the municipalities to which they relate.

The affected producers received technical assistance from the Renova Foundation, created in 2016 in response to the collapse of the Fundão dam, owned by Vale, the mining company responsible for the disaster. The Foundation's goal is to support the recovery of the affected areas by bringing together technicians, specialists, and socio-environmental entities, with a focus on assisting producers and restoring normalcy to their operations.

The data collection was structured to collect information in several areas, including personal data, labor indicators and social aspects, agronomic, productive, milk quality, health, reproductive. and economic indicators. There are also indicators for environmental impact and land use. It is important to emphasize that the questionnaire was administered by the Família do Leite program before the start of any assistance activities, ensuring that the farms were evaluated prior to receiving any support. Although these properties were already receiving support from the RENOVA Foundation, the evaluation aimed to establish a baseline prior to the implementation of the specific interventions of this program.

The interviews with the producers took place during the months of April, May, June, and July of 2021. Since at that time the COVID-19 pandemic was on the rise, the team that conducted the interviews followed all the protocols recommended by

health authorities, such as the use of masks and hand sanitizer, social distancing from the producers, and laboratory tests, to ensure the safety of both the producers and the team members.

Data analytics

First, the descriptive statistics for the continuous variables were analyzed using the UNIVARIATE procedure from SAS¹⁷. The binary variables were analyzed by logistic regression using SAS GLIMMIX procedure, depending on whether or not each farm was affected or not by the disaster, using a binary distribution and logit link. These variables were further analyzed to determine the odds ratio (OR) for the occurrence of an event or situation in different situations. For the OR interpretation, the UFD were used as the reference group. In all analysis, differences were considered significant if the P-value was < 0.10 .

Results

The average age of the farmers in the AFD was 51 years and ranged from 24 to 69 years. In the UFD, the average age was 53.2 years and ranged from 26 to 81 years. In terms of length of service, farmers in the AFD had worked for an average of 24.9 years, ranging from 8 to 60 years. Farmers in the UFD had an average of 20.4 years' experience, ranging from 2 to 40 years (Table 2).

In terms of ownership areas, the AFD had an average area of 84.8 ha, with a minimum of 11 ha and a maximum of 500 ha. Within these areas, the average of pasture area was 40.2 ha, with a range of 0 to 250 ha; the cropland area was 3 ha, with a range of 0 to 15 ha; and the area of legal reserve had an average of 5 ha, with a range of 0 to 40 ha. The UFD had an average area of 79 ha, with a range of 3.6 ha to 360 ha. Pasture area averaged 37.6 ha, with values ranging from 0.3 ha to 192 ha; cropland area averaged 4.6 ha, with values ranging from 0 to 20 ha; and legal reserve area averaged 10.9 ha, with values ranging from 0 to 186 ha (Table 2). The average number of assistants in the AFD was 3, ranging from 1 to 9. On average, 1.2 of these assistants were family members, ranging from 0 to 9 people. In the UFD, the average number of assistants was 2.1 persons, ranging from 1 to 8 persons, and on average 1.2 were family members, ranging from 1 to 3 persons (Table 2).

The AFD had an average of 67.1 animals, with a variation between 13 and 208 animals. This included an average of 19.1 lactating cows, ranging from 3 to 78 animals. The ratio of lactating cows to dry cows on these farms averaged 59.7%, with a variation between 27.2% and 100%. The ratio of lactating cows to the entire herd averaged 30.2%, with a range of 11.5% to 50% (Table 3). The UFD had an average of 74.3 animals, with a variation between 6 and 200 animals. The average number of lactating cows was 21.8 animals, ranging from 3 to 80 animals. The average number of dry cows was 14.3, with a variation between 0 and 55 animals. The ratio of lactating cows to dry cows averaged 61.4%, with a range of 17.9% to 100%. The ratio of lactating cows to the entire herd averaged 30.7%, with a range of 12.6% to 74.4% (Table 3).

The AFD had an average milk production of 132 kg/day, with a variation between 20 and 600 kg/day. The average milk production per animal was 6.5 kg, with values ranging from 2 to 16 kg/day. The average number of milkings on these properties was 1.3, with a variation of 1 to 2 milkings per day. The average price per liter of milk was US\$ 0.3 with a minimum value of US\$ 0,2 and a maximum value of US\$ 0.4 (Table 3). The UFD produced an average of 227.8 kg milk/day, with a variation between 15 and 1300 kg/day. The average milk production per animal was 9.3 kg/day, with a range of 3 to 22.6 kg/day. The average number of milkings was 1.4, with a variation between 1 and 2 milkings. The average price of a liter of milk was US\$ 0.3, ranging from US\$ 0.3 to US\$ 0.4 (Table 3).

The AFD were 2.94 times more likely ($P = 0.08$; Table 4) to receive technical assistance than the UFD. In addition, there was a statistical difference ($P < 0.07$; Table 4), with the AFD being 4.80 times more likely to purchase forage than the UFD. The other resource management variables analyzed did not show a significant difference ($P > 0.10$) between the AFD and the UFD (Table 4). The AFD were 2.85 times more likely to use pre-dipping management compared to UFD ($P = 0.06$; Table 5). On the other hand, AFD had an OR of 0.406 ($P = 0.09$) for the use of oxytocin during milking. No significant differences ($P > 0.10$) were found between AFD and UFD for the other variables analyzed (Table 5).

The AFD showed an OR of 0.30 ($P = 0.04$; Table 6) for the occurrence of parasitic sadness compared to the UFD. No significant differences ($P > 0.10$) were found for the other variables analyzed (Table 6). None of the variables analyzed showed a statistically significant difference ($P > 0.10$; Table 7) between AFD and UFD in the assessment of reproductive management. When examining the availability of

water for human consumption, it was found that AFD had an OR of 0.387 ($P = 0.08$; Table 8) for the consumption of water from mines relative to UFD. No statistically significant differences ($P > 0.10$) were found between AFD and UFD for the other variables regarding water use, such as livestock consumption, use for agriculture, use for irrigation and protected areas (Table 8).

The AFD had an OR of 2.933 ($P = 0.05$; Table 9) for performing soil analysis than the UFD. There was no statistically significant difference ($P > 0.10$) between the AFD and the UFD for the other variables related to pasture, soil management, and planting (Table 9). None of the variables regarding the disposal of empty fertilizer, pesticide, and medicine packaging showed a statistically significant difference ($P > 0.10$; Table 10) between the AFD and the UFD. The AFD were found to have an OR of 3.051 (0.04; Table 11) for leaving the dairy activity. The AFD showed an OR of 0.333 ($P = 0.09$; Table 12) for problems related to roads in the logistics process. No statistically significant differences ($P > 0.10$) were found between AFD and UFD for the other variables (Table 12).

Discussion

Based on the data on the characteristics of the employees and the areas of the properties, it was possible to outline the profile of AFD and UFD as a result of the Fundão dam burst. In both AFD and UFD, around 60% of employees belonged to the family group, while on average only 40% were hired. In Brazil, the dairy industry consists mainly of small family-owned dairy farms¹⁸. These farms account for 81.2% of all dairy farms in Brazil and are responsible for 64.2% of the country's total milk production⁹.

The total area of the AFD and UFD averaged 82 ha. However, the total area is generally variable, especially in extensive and/or semi-intensive production systems, where not always the entire property area is used for livestock or food production⁷. Regarding the distribution of land areas, it was found that both AFD and UFD devoted, on average, about 48% of their total area to pasture. However, the UFD allocated a larger proportion of their land to crop cultivation, about 6%, while the AFD used only 4% for this purpose. Although the difference is not very significant, land size is an important variable as it affects both the amount of production and income¹⁹.

The analysis of zootechnical indices is a fundamental factor in the evaluation of farms, as this information can be used to understand the productivity and efficiency of

a given production system. The AFD and UFD had a similar number of animals, 71 on average, with an average of 21 lactating cows. The average daily production of AFD was 6.5 kg, while at UFD it was 9.3 kg. Both farms had milk production above the national average of 6.18 L/cow/day²⁰. However, most dairy farms in Brazil still operate at a low or medium level of technology and have a productivity below the potential that could be achieved in several regions of the country^{9,21}.

As far as the analysis of binary variables is concerned, the results show that AFD were more likely to receive technical assistance compared to UFD. This finding underscores the fundamental role that organizations, such as the Renova Foundation created by Vale, played in assisting farmers during the disaster. The Foundation was obligated to make regular visits and provide necessary supplies, such as feed, to help support the affected producers.

Despite its importance, the dairy industry faces persistent challenges that are exacerbated by the lack of adequate government support for disaster preparedness and response. This deficit leaves farmers vulnerable to extreme weather events, leading to food shortages, poor animal health, and fragile infrastructure²². Technical assistance programs are essential in these situations as they aim to train producers to improve farm productivity. In dairy farming, these trainings include both operational practices directly related to milk production and aspects of farm management, such as herd selection, feed management, health management, soil and pasture control, labor management, training and cost control^{23,24}. In addition, these programs help to strengthen the resilience of farms to environmental disasters.

In this study, we demonstrated the effects of technical assistance using variables such as forage purchase, use of pre-dipping, administration of oxytocin, and the occurrence of parasitic sadness. These variables showed statistically significant differences between AFD and UFD, emphasizing the direct impact of technical assistance on improving management practices. AFD were more likely to purchase forage, a practice supported by the Renova Foundation. This behavior may be partially explained by the effects of the dam breach, which affected approximately 1,587 ha of vegetation cover and potentially reduced forage availability for livestock²⁵. However, it may also reflect the influence of technical assistance, which guided producers in adopting improved animal nutrition practices²⁴.

In general, the areas affected by the spoil heaps were intensively used as cropland and pasture land before the disaster due to their topographical and chemical

characteristics. After the event, many of these areas were degraded and it was recommended to suspend the use of the affected soils for agricultural purposes due to the risks to vegetation and therefore to animal health²⁶. The need to buy feed may be due to resource constraints or insufficient stocking densities²⁷.

As far as milking practices are concerned, the greater likelihood of pre-dipping being performed by AFD, compared to UFD emphasizes the crucial role of technical support. Its application helps to reduce the prevalence of mastitis and the bacterial load of the milking environment²⁸. Therefore, the dissemination of knowledge through technical assistance is essential to improve management practices, which has a direct impact on milk quality²⁹.

On the other hand, AFD were less likely than UFD to use exogenous oxytocin during milking. This behavior may be attributed in part to the more frequent technical assistance provided by AFD, but also to the adoption of the practice of pre-dipping. Pre-dipping has a positive impact on milking performance by promoting milk let-down³⁰. To ensure its effectiveness, according to Bruckmaier³¹, high blood concentrations of oxytocin can be measured in dairy cows within 30 seconds of the start of stimulation. The reduced use of exogenous oxytocin in AFD could therefore be related to the fact that more time is spent on pre-milking practices, resulting in more effective stimulation closer to the time required for milk ejection.

Another possible explanation for the reduced use of exogenous oxytocin in AFD is related to the technical recommendation, as the continuous use of this drug can have negative consequences, such as increased stress in cows and the risk of disease transmission through the use of shared needles³². In addition, according to Faraz et al³³, the administration of exogenous oxytocin can affect milk quality and the reproductive health of dairy cows, which is why continuous use should be discouraged.

In calf rearing, AFD showed a lower probability of occurrence of bovine parasitic sickness (BPS) in calves compared to UFD. The BPS is an endemic disease of major importance in Latin America, caused by the parasites *Babesia spp.* and *Anaplasma marginale*. These parasites cause erythrocyte destruction through intracellular parasitemia, resulting in severe anemia, reduced performance and increased production costs^{34,35}. An effective strategy for the management and prevention of infections in dairy calves requires a multifactorial approach. This includes practices such as appropriate colostrum management, a balanced diet and the application of

strict hygiene measures, which have been shown to be essential in significantly reducing the risk of infection³⁶.

In terms of water consumption, this study has shown that AFD are less likely to use mine water for human consumption compared to UFD. This fact is directly related to the rupture of the tailings dam, since the rupture of a dam represents an interruption of the mass transport mediated by nature between the Earth's geological reservoirs, causing environmental damage that is detrimental to microbiota, flora, fauna, soil, and water³⁷.

The event increased environmental pollution in the region and the bioavailability of heavy metals and impaired water quality³⁸. An analysis of the water from the Rio Doce carried out two years after the event found levels of aluminum, nickel, arsenic, copper, manganese and lead above the limits established by Brazilian legislation³⁹. The presence of heavy metals poses a risk to public health, as these toxic elements can contaminate crops⁴⁰, milk⁴¹, and meat⁴².

Several studies indicate that prolonged intake of heavy metals can be associated with the development of gastrointestinal cancer⁴³ and neurological diseases^{44,45}, highlighting the serious consequences of this contamination for humans⁴⁶. Weber et al.⁴⁷ investigated the effects of tailings on liver histopathology and biomarkers of metal contamination in two native freshwater fish species (*Hoplias intermedius* and *Hypostomus affinis*) and found significant damage associated with exposure to heavy metals. Similarly, Gaeta et al.³⁷ evaluated the genomic characteristics of a multidrug-resistant and mercury-tolerant *Escherichia coli* from the environment recovered after a mining dam disaster in South America. They found that the presence of genes conferring resistance to heavy metals could be directly related to environmental pollution from mining activities.

However, some ruminant-specific bacteria have shown sensitivity to heavy metals in vitro studies. Species such as *Bacteroides succinogenes*, *Ruminococcus albus*, *Bacteroides amylophilus* and *Eubacterium ruminantium* have been shown to be sensitive to metals such as cadmium, mercury, copper, arsenic and chromium⁴⁸. It is widely recognized that the microorganisms present in the rumen play a crucial role in feed fermentation and in the production of metabolites that are important for the maintenance of homeostasis in ruminants⁴⁶.

Gaeta et al.⁴⁶ conducted a study to compare the prevalence of antimicrobial resistance (AMR) genes on a contaminated and an uncontaminated farm and to

evaluate the effects of prolonged exposure on the nasopharyngeal, ruminal and fecal microbiome. The main results showed that the differences in microbiota indicate that exposure to water contaminated with heavy metals can affect the microbiota of dairy cattle, which in turn affects animal productivity.

The quality of water on dairy farms is a crucial factor that affects both the health of the animals and the quality of the milk produced⁴⁹. To ensure animal health and productivity, it is important to identify and solve potential water-related problems and it is mandatory for dairy farmers to apply good agricultural practices, such as the use of clean and pure water⁵⁰.

In terms of soil management, AFD were more likely to carry out soil analysis compared to UF, a result directly related to the dam breach. The spoil wave covered the natural alluvial soils with a layer of spoil about one meter thick. After the disaster, the natural drainage recovered and the agricultural land began to restore its natural vegetation and pastures. During this process, the spoil heaps were mixed or covered with soil, increasing the differences in the composition of soil and spoil heaps⁵¹. As previously mentioned, these anthropogenic activities are responsible for the deposition of heavy metals in the environment.

Davila et al.⁵² assessed the heavy metals in the iron ore tailings and alluvial soils affected by the Samarco Dam collapse and concluded that the tailings do not represent a “ticking time bomb” for heavy metal contamination in the region, as they pose a low risk of release into nature. Similarly, Melo et al.⁵¹, when conducting an integrated environmental impact assessment of iron ore waste in the soils and plants of the floodplains after the Fundão Dam disaster, concluded that this waste has no potential for future contamination by heavy metals such as silver (Ag), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), tin (Sn), zinc (Zn), arsenic (As) and mercury (Hg).

However, it is controversial whether this material should be considered an “environmental time bomb” due to the risk of metal release in unfavorable environmental conditions such as waterlogging or pH fluctuations^{53,54}. In this context, soil analysis is crucial as it provides farmers with important information for planning and implementing appropriate nutrient management strategies on their land⁵⁵ and assists them in decision-making in the face of environmental and economic challenges.

Regarding the assessment of future intentions in relation to dairy farming, AFD were more willing to give up the activity than UFD. This behavior can be explained by

several factors, the most important of which is the challenges posed by environmental disasters. Environmental disasters disrupt feed supplies, increase costs and expose vulnerabilities in the supply chain⁵⁶. The ongoing changes associated with climate change, rising labor, feed and fertilizer costs, limited access to food during these events, and changing consumer preferences and attitudes may thus affect farmers' future prospects⁵⁷. In addition, as Ferjani et al.⁵⁸ have highlighted, several factors determine the exit of producers from agricultural activities, e.g. human capital, farm structure, structural environment, and socio-economic conditions.

As far as the impact of environmental disasters are concerned, it is important to consider not only the economic aspects, but also the impact on the mental health of the producers. Natural disasters often have a significant impact on the mental health of livestock producers, who face emotional and financial stress, reduced agricultural productivity and increased herd mortality⁵⁹. These impacts can be exacerbated when the lack of solutions to producers' problems and needs is compounded by uncertainties and insecurities about the future, both from government agencies and from the companies responsible for the disasters, adding to the emotional and psychological suffering⁶⁰. Hansen⁶¹ investigated the relationship between well-being and the intention to stay in or leave dairy farming and concluded that producers who intend to continue the activity have higher well-being than those who are considering or planning to leave dairy farming.

In addition, the age of farmers is an important factor to consider, as the older farmers get, the more likely they are to give up farming⁶¹. Reasons cited for quitting include loss of physical ability to work, farmers' awareness that their ability to manage the farm is limited, and unexpected incidents^{58,62}. On the other hand, younger successors migrate or show intentions to leave rural areas in the future⁶³. The combination of young people moving out of rural areas and aging farmers is seen as an obstacle to more sustainable agriculture and appropriate land use⁶⁴.

When evaluating the obstacles reported by the producers, the AFD had fewer problems with the roads compared to the UFD. This result can be explained by the efforts directed towards post-disaster infrastructure recovery, as the quick and efficient restoration of transportation systems is crucial⁶⁵ to minimize the negative impact on the affected socio-economic activities⁶⁶. This restoration includes the reconstruction of various transportation components, such as roads, bridges, sidewalks, tunnels and others⁶⁶.

Conclusion

In summary, environmental disasters such as the dam burst had a direct impact on the farming practices and living conditions of dairy farmers, as the use of water, soil and animal feed was restricted due to the high levels of heavy metal contamination. Technical assistance proved to be a crucial factor in mitigating these impacts, underlining its importance in the post-disaster recovery process. The study also highlights the need for effective public policies to minimize the impact of environmental disasters on the agricultural sector, which is often marginalized compared to the mining sector. Despite the contributions of this study, there are few works in the literature that address the relationship between the mining and agricultural sectors. Therefore, future research is needed to deepen the understanding of the impacts of these disasters, e.g. on plants and animals, and their effects on the food production chain in Brazil.

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References

1. Instituto Brasileiro de Mineração (IBRAM). *Informações Sobre a Economia Mineral Brasileira 2020 – Ano Base 2019*. (2020). <https://portaldamineracao.com.br/wp-content/uploads/2021/03/Economia-Mineral-Brasileira-IBRAM-2020.pdf> (2020).
2. Instituto de Pesquisa Econômica Aplicada (IPEA). Ipea e MME lançam estudo sobre a extensão da cadeia produtiva da mineração no PIB brasileiro. <https://www.ipea.gov.br/portal/categorias/45-todas-as-noticias/noticias/14835-ipea-e-mme-lancam-estudo-sobre-a-extensao-da-cadeia-produtiva-da-mineracao-no-pib-brasileiro> (2023).
3. Instituto Brasileiro de Mineração (IBRAM). Contribuição da indústria da mineração para o G20. https://ibram.org.br/wp-content/uploads/2024/11/IBRAM_Contribuicao-da-Industria-da-Mineracao-para-o-G20-Brasil-2024-2-1.pdf (2024).
4. Instituto Brasileiro de Mineração (IBRAM). Setor mineral 2024. https://www.ibram.org.br/wp-content/uploads/2025/02/DADOS_Setor-Mineral_2024_5FEV2025.pdf (2025).
5. Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA). Distribuição da produção de leite no Brasil. *ANUÁRIO Leite 2024 avaliação genética multirracial*. <https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1164754/1/Anuario-Leite-2024.pdf> (2024).
6. Instituto Brasileiro de Geografia e Estatística (IBGE). Pesquisa Trimestral do Leite. <https://www.ibge.gov.br/estatisticas/economicas/agricultura-e-pecuaria/9209-pesquisa-trimestral-do-leite.html> (2024).
7. Silveira, R. M. F. *et al.* Diversity in smallholder dairy production systems in the Brazilian semiarid region: Farm typologies and characteristics of raw milk and water used in milking. *J. Arid Environ.* **203**, (2022).
8. de Mendonça, B. S., Bánkuti, F. I., Pozza, M. S. D. S., Perez, H. L. & Siqueira, T. T. da S. A typology of corporate and family dairy farms in eastern Goiás, Brazil. *Cienc. Rural* **50**, 1–10 (2020).
9. Instituto Brasileiro de Geografia e Estatística (IBGE). Censo Agropecuário. <https://sidra.ibge.gov.br/pesquisa/censo-agropecuario/censo-agropecuario->

- 2017/resultados-definitivos (2017).
10. Messias, M. C. T. B. *et al.* Conhecimento Tradicional e Agroecologia Na Região Sudeste Do Quadrilátero Ferrífero. In: SINGULANO, M. A., VIANA, F. D. F.; MESSIAS, M. C. T. B. (eds). *Agricultura familiar e desenvolvimento territorial em uma região mineradora: o caso dos municípios de Mariana e Ouro Preto*. 1 ed. Ouro Preto: Editora UFOP, P. 53-77 (2023).
 11. Cota, G. E. M., Rosa, N. M. G., Romeiro, C. E., Mendes, I. A. da S. & Magalhães Júnior, A. P. ASPECTOS LEGAIS DA SEGURANÇA DE BARRAGENS DE REJEITO DE MINÉRIO: IMPLICAÇÕES PARA A QUALIDADE AMBIENTAL E USOS MÚLTIPLOS DA ÁGUA NO ALTO RIO DAS VELHAS (MG). *GEOgraphia* **21**, 32 (2019).
 12. Botelho, M. R., Faria, M. P. de, Mayr, C. T. R. & Oliveira, L. M. G. de. Rompimento das barragens de Fundão e da Mina do Córrego do Feijão em Minas Gerais, Brasil: decisões organizacionais não tomadas e lições não aprendidas. *Rev. Bras. Saúde Ocup.* **46**, 1–11 (2021).
 13. Lacaz, F. A. de C. *et al.* Tragédias brasileiras contemporâneas: o caso do rompimento da barragem de rejeitos de Fundão/Samarco. *Rev. Bras. Saúde Ocup.* **42**, 1–12 (2017).
 14. Vergilio, C. dos S. *et al.* Metal concentrations and biological effects from one of the largest mining disasters in the world (Brumadinho, Minas Gerais, Brazil). *Sci. Rep.* **10**, 1–12 (2020).
 15. Parente, C. E. T. *et al.* First year after the Brumadinho tailings' dam collapse: Spatial and seasonal variation of trace elements in sediments, fishes and macrophytes from the Paraopeba River, Brazil. *Environ. Res.* **193**, (2021).
 16. Miranda, D. M. de *et al.* Impactos físicos e psicológicos na população de Brumadinho após rompimento da barragem de rejeitos. *Rev. Médica Minas Gerais* **31**, (2021).
 17. SAS Institute. SAS OnDemand for Academics. at https://www.sas.com/en_us/software/on-demand-for-academics.html (2024).
 18. Silva, A. C., Laven, R. & Benites, N. R. Risk factors associated with mastitis in smallholder dairy farms in southeast brazil. *Animals* **11**, 1–10 (2021).
 19. Andersen, E., Verhoog, D., Elbersen, B., Godeschalk, F. & Boudewijn, K. *A Multidimensional Farming System Typology*. (2006).
 20. Instituto Brasileiro de Geografia e Estatística (IBGE). Produção da Pecuária

- Municipal 2023. 1–13.
https://biblioteca.ibge.gov.br/visualizacao/periodicos/84/ppm_2023_v51_br_informativo.pdf (2024)
21. Bánkuti, F. I., Damasceno, J. C., Schiavi, S. M., Kuwaraha, K. C. & Prizon, R. C. Structural features, labor conditions and family succession in dairy production systems in Paraná State, Brazil. *Cah. Agric.* **27**, 1–11 (2018).
 22. Elijah, V. T. & Odiyo, J. O. Perception of environmental spillovers across scale in climate change adaptation planning: The case of small-scale farmers' irrigation strategies, Kenya. *Climate* **8**, (2020).
 23. Ollé, M. D. A., Fluck, A. C. & Bermudes, R. F. Relação entre técnicos e produtores de leite no sul do Brasil. *Rev. Electron. Vet.* **18**, (2017).
 24. Ferreira, M., Macagnan, C., Vancin, D. & Toaldo, A. Technical assistance: A determinant of cooperative member loyalty. *Ann. Public Coop. Econ.* **92**, 649–668 (2021).
 25. Secretaria de Estado de Desenvolvimento Regional de Política Urbana e Gestão Metropolitana (SEDRU). Relatório: Avaliação dos efeitos e desdobramentos do rompimento da Barragem de Fundão em Mariana - MG. 287. https://www.agenciaminas.mg.gov.br/ckeditor_assets/attachments/770/relatorio_final_ft_03_02_2016_15h5min.pdf (2016).
 26. Aires, U. R. V., Santos, B. S. M., Coelho, C. D., da Silva, D. D. & Calijuri, M. L. Changes in land use and land cover as a result of the failure of a mining tailings dam in Mariana, MG, Brazil. *Land use policy* **70**, 63–70 (2018).
 27. Snider, M. A. *et al.* An overview of organic, grassfed dairy farm management and factors related to higher milk production. *Renew. Agric. Food Syst.* **37**, 624–632 (2022).
 28. Hohmann, M. F., Wente, N., Zhang, Y. & Krömker, V. Bacterial load of the teat apex skin and associated factors at herd level. *Animals* **10**, 1–19 (2020).
 29. Vieira, R. K. R. *et al.* The effects of implementing management practices on somatic cell count levels in bovine milk. *Animal* **15**, (2021).
 30. Leonel Gonçalves, J., Tomazi, T. & Veiga dos Santos, M. Rotina de ordenha eficiente para produção de leite de alta qualidade. *Rev. Acadêmica Ciência Anim.* **15**, 9 (2017).
 31. Bruckmaier, R. M. Oxytocin from the pituitary or from the syringe Importance and consequences for machine milking in dairy cows. *NMC Annu. Meet. Proc.* 4–11

- (2013).
32. Santos, M. V. Dos & Fonseca, L. F. L. Da. *Controle Da Mastite e Qualidade Do Leite - Desafios e Soluções*. (Pirassununga - SP, 2019).
 33. Faraz, A. *et al.* Impact of oxytocin administration on milk quality, reproductive performance and residual effects in dairy animals-A review. *Punjab Univ. J. Zool.* **35**, 61–67 (2020).
 34. Bock, R., Jackson, L., De Vos, A. & Jorgensen, W. Babesiosis of cattle. *Parasitology* **129**, (2004).
 35. Silva, J. B. *et al.* Prevalência sorológica e molecular de Babesia bovis e Babesia bigemina em búfalos (*Bubalus bubalis*) na Ilha de Marajó, Pará. *Pesqui. Vet. Bras.* **33**, 847–850 (2013).
 36. Robi, D. T., Mossie, T. & Temteme, S. A Comprehensive Review of the Common Bacterial Infections in Dairy Calves and Advanced Strategies for Health Management. *Vet. Med. Res. Reports Volume 15*, 1–14 (2024).
 37. Gaeta, N. C. *et al.* Genomic features of a multidrug-resistant and mercury-tolerant environmental Escherichia coli recovered after a mining dam disaster in South America. *Sci. Total Environ.* **823**, (2022).
 38. Aguiar, V. M. de C., Neto, J. A. B., Quaresma, V. da S., Bastos, A. C. & Athayde, J. P. M. de. Bioavailability and ecological risks of trace metals in bottom sediments from Doce river continental shelf before and after the biggest environmental disaster in Brazil: The collapse of the Fundão dam. *J. Environ. Manage.* **272**, (2020).
 39. Carvalho, M. S. de, Moreira, R. M., Ribeiro, K. D. & Almeida, A. M. de. Concentração de metais no rio Doce em Mariana, Minas Gerais, Brasil. *Acta Bras.* **1**, 37–41 (2017).
 40. Rai, P. K., Lee, S. S., Zhang, M., Tsang, Y. F. & Kim, K. H. Heavy metals in food crops: Health risks, fate, mechanisms, and management. *Environ. Int.* **125**, 365–385 (2019).
 41. Zhou, X. *et al.* Large scale study of the within and between spatial variability of lead, arsenic, and cadmium contamination of cow milk in China. *Sci. Total Environ.* **650**, 3054–3061 (2019).
 42. Wang, X. *et al.* Spatial analysis of heavy metals in meat products in China during 2015–2017. *Food Control* **104**, 174–180 (2019).
 43. Yuan, W., Yang, N. & Li, X. Advances in Understanding How Heavy Metal

- Pollution Triggers Gastric Cancer. *Biomed Res. Int.* **2016**, (2016).
44. Karri, V., Schuhmacher, M. & Kumar, V. Heavy metals (Pb, Cd, As and MeHg) as risk factors for cognitive dysfunction: A general review of metal mixture mechanism in brain. *Environ. Toxicol. Pharmacol.* **48**, 203–213 (2016).
 45. Bjorklund, G. *et al.* Metals and Parkinson's Disease: Mechanisms and Biochemical Processes. *Curr. Med. Chem.* **25**, 2198–2214 (2018).
 46. Gaeta, N. C. *et al.* A Cross-Sectional Study of Dairy Cattle Metagenomes Reveals Increased Antimicrobial Resistance in Animals Farmed in a Heavy Metal Contaminated Environment. *Front. Microbiol.* **11**, 1–15 (2020).
 47. Weber, A. A. *et al.* Effects of metal contamination on liver in two fish species from a highly impacted neotropical river: A case study of the Fundão dam, Brazil. *Ecotoxicol. Environ. Saf.* **190**, 110165 (2020).
 48. Forsberg, C. W. Effects of heavy metals and other trace elements on the fermentative activity of the rumen microflora and growth of functionally important rumen bacteria. *Can. J. Microbiol.* **24**, 298–306 (1978).
 49. Urseler, N., Bachetti, R., Biolé, F., Morgante, V. & Morgante, C. Atrazine pollution in groundwater and raw bovine milk: Water quality, bioaccumulation and human risk assessment. *Sci. Total Environ.* **852**, (2022).
 50. Soares, A. S., Miranda, C., Coelho, A. C. & Trindade, H. Occurrence of Coliforms and Enterococcus Species in Drinking Water Samples Obtained from Selected Dairy Cattle Farms in Portugal. *Agric.* **13**, 1–10 (2023).
 51. Melo, V. F. *et al.* Integrated environmental assessment of iron ore tailings in floodplain soils and plants after the Fundão Dam disaster in Brazil. *Integr. Environ. Assess. Manag.* **20**, 117–132 (2024).
 52. Davila, R. B., Fontes, M. P. F., Pacheco, A. A. & Ferreira, M. da S. Heavy metals in iron ore tailings and floodplain soils affected by the Samarco dam collapse in Brazil. *Sci. Total Environ.* **709**, 136151 (2020).
 53. Queiroz, H. M. *et al.* The Samarco mine tailing disaster: A possible time-bomb for heavy metals contamination? *Sci. Total Environ.* **637–638**, 498–506 (2018).
 54. Segura, F. R. *et al.* Potential risks of the residue from Samarco's mine dam burst (Bento Rodrigues, Brazil). *Environ. Pollut.* **218**, 813–825 (2016).
 55. Micha, E., Tsakiridis, A., Ragkos, A. & Buckley, C. Assessing the effect of soil testing on chemical fertilizer use intensity: An empirical analysis of phosphorus fertilizer demand by Irish dairy farmers. *J. Rural Stud.* **97**, 186–191 (2023).

56. Rasool, S. *et al.* The Impact of Natural Disasters on Livestock Sector: A Review. *J. Biomed. Res. Environ. Sci.* **2**, 669–674 (2021).
57. Celik, E., Bogueva, D., Phillips, C. J. C. & Marinova, D. A survey of Australian dairy farmers' attitudes to their business, its challenges and transitioning to alternative enterprises. *Sci. Rep.* **14**, 1–20 (2024).
58. Ferjani, A., Zimmermann, A. & Roesch, A. Determining Factors of Farm Exit in Agriculture in Switzerland. *Agric. Econ. Rev.* **16**, 1–26 (2015).
59. Okolo, E. C. *et al.* Preparedness , Response , and Communication Preferences of Dairy Farmers During Extreme Weather Events : A Phenomenological Case Study. 1–22 (2025).
60. de Freitas, C. M., Barcellos, C., Asmus, C. I. R. F., da Silva, M. A. & Xavier, D. R. From samarco in mariana to vale in Brumadinho: Mining dam disasters and public health. *Cad. Saude Publica* **35**, (2019).
61. Hansen, B. G. Stay in dairy? Exploring the relationship between farmer wellbeing and farm exit intentions. *J. Rural Stud.* **92**, 306–315 (2022).
62. Kimhi, A. & Bollman, R. Family farm dynamics in Canada and Israel: the case of farm exits. *Agric. Econ.* **21**, 69–79 (1999).
63. Chen, R., Ye, C., Cai, Y., Xing, X. & Chen, Q. The impact of rural out-migration on land use transition in China: Past, present and trend. *Land use policy* **40**, 101–110 (2014).
64. Morais, M., Borges, J. A. R. & Binotto, E. Using the reasoned action approach to understand Brazilian successors' intention to take over the farm. *Land use policy* **71**, 445–452 (2018).
65. Lou, Y. & Zhang, L. Defending transportation networks against random and targeted attacks. *Transp. Res. Rec.* 31–40 (2011) doi:10.3141/2234-04.
66. Rouhanizadeh, B. & Kermanshachi, S. Post-disaster reconstruction of transportation infrastructures: Lessons learned. *Sustain. Cities Soc.* **63**, 102505 (2020).

Tables

Table 1 – Municipalities visited and the relationship between the farms affected and unaffected by dam failure in Mariana.

Municipality	Number of properties		
	AFD	UFD	Total
Barra Longa	4	4	8
Conselheiro Pena	6	6	12
Governador Valadares	2	10	12
Mariana	4	4	8
Naque	2	2	4
Ponte nova	3	5	8
Tumiritinga	5	3	8
Total	26	34	60

AFD = affected farms; UFD = unaffected farms

Table 2 – Descriptive analysis of the collaborators and the area of the farms affected and unaffected by dam failure in Mariana.

Variables ¹	Mean	Median	Mode	Standard Deviation	Minimum	Maximum
Employee information						
AP (years)	51.0	52.0	60.0	10.8	24	69
TA (years)	24.9	25.0	30.0	12.4	8.0	60.0
NA (N° of people)	3.0	2.0	2.0	1.8	1	9
FA (N° of people)	1.9	2.0	1.0	1.8	0	9
Farm area information						
Farm area (ha)	84.8	53.3	19.0	104.4	11.0	500.0
Pasture area (ha)	40.2	18.5	3.0	53.7	0.0	250.0
Crop area (ha)	3.0	1.0	0.0	3.8	0	15
LRA (ha)	5.0	0.1	0.0	10.9	0.0	40.0
Unaffected farms						
Employee information						
AP (years)	53.2	56.0	62.0	13.8	26	81.0
TA (years)	20.4	24.5	30.0	11.5	2.0	40.0
NA (N° of people)	2.1	2.0	2.0	1.3	1	8
FA (N° of people)	1.2	1.0	1.0	0.7	0	3
Farm area information						
Farm area (ha)	79.0	44.0	24.0	92.2	3.6	360.0
Pasture area (ha)	37.6	16.0	0.7	47.5	0.3	192.0
Crop area (ha)	4.6	3.0	3.0	5.3	0	20
LRA (ha)	10.9	0.3	0.0	34.0	0.0	186.0

¹ AP = Age of producer; TA=Time in activity; NA=Number of assistants; FA=Family assistants; LRA=Legal reserve area.

Table 3 – Descriptive statistics of the productive indexes of the dairy activity of the the farms affected and unaffected by dam failure in Mariana.

Variables¹	Mean	Median	Mode	Standard Deviation	Minimum	Maximum
Affected farms						
Number of animals (units)	67.1	42.5	26.0	55.7	13.0	208.0
Cows in milk (units)	19.1	19.0	20.0	16.1	3.0	78.0
Dry cows (units)	16.3	8.0	0.0	20.7	0.0	80.0
Ratio of CM/DC (%)	59.7	61.5	100.0	23.2	27.2	100
Ratio of CM/TH (%)	30.2	28.6	-	11.7	11.5	50.0
Milk production (kg/day)	132.0	80.0	20.0	147.7	20.0	650.0
AMPC (kg/day)	6.5	7.5	5.0	3.2	2.0	16.0
Number of milkings (units)	1.3	1.0	1.0	0.4	1.0	2.0
PLM (US\$/L)	0.3	0.3	0.4	0.1	0.2	0.4
Unaffected farms						
Number of animals (units)	74.3	57.5	95.0	47.5	6.0	200.0
Cows in milk (units)	21.8	17.5	15.0	16.5	3.0	80.0
Dry cows (units)	14.3	12.0	10.0	11.5	0.0	55.0
Ratio of CM/DC (%)	61.4	62.0	100	20.3	17.9	100.0
Ratio of CM/TH (%)	30.7	30.6	32.0	12.9	12.6	74.4
Milk production (kg/day)	227.8	130.0	80.0	257.3	15	1300
AMPC (kg/day)	9.3	6.8	5.3	5.4	3.0	22.6
Number of milkings (units)	1.4	1.0	1.0	0.5	1.0	2.0
PLM (US\$/L)	0.3	0.3	0.4	0.1	0.3	0.4

¹ Ratio of CM/DC = Ratio of cows in milk/dry cows; Ratio of CM/ TH = Ratio of cows in milk/total herd; AMPC= Average milk production per cow; PLM= Price of a liter of milk.

Table 4 - Assessment of the management of the farms affected and unaffected by dam failure in Mariana.

Variables¹	OR	Lower limit	Upper limit	P - Value
Management				
Zootechnical bookkeeping	0.545	0.188	1.581	0.25
Use of MS	0.861	0.128	5.796	0.87
Receiving TA	2.940	0.871	9.919	0.08
Access to loans	0.380	0.119	1.212	0.10
Production and Sales				
Production of DP	0.627	0.192	2.054	0.43
Trades through cooperatives	2.042	0.625	6.672	0.23
Sells milk to dairies	0.581	0.183	1.846	0.35
Has contracts with dairies	0.623	0.156	2.499	0.49
Receipt for milk quality	0.857	0.289	2.539	0.77
Purchases of animals and inputs				
Purchases of animals	0.720	0.222	2.336	0.57
Purchases of fodder	4.800	0.850	27.106	0.07

¹ MS= management software; TA= technical assistance; DP= dairy products.

Table 5 - Assessment of technical assistance, breeding system and milking management practices on the farms affected and unaffected by dam failure in Mariana.

Variables¹	OR	Lower limit	Upper limit	P - Value
Animal breeding system	0.677	0.237	1.930	0.45
Performing milk control	0.848	0.207	3.484	0.81
Performing analysis of MC	0.635	0.179	2.254	0.47
Has a tank	0.568	0.190	1.698	0.30
Mechanical milking machine	0.652	0.221	1.924	0.43
Use of pre-dipping	2.850	0.952	8.529	0.06
Use of post-dipping	0.713	0.227	2.241	0.55
Administration of oxytocin	0.406	0.138	1.193	0.09
Presence of Mastitis	0.821	0.285	2.360	0.70
Use of Antibiotics (Dry Cow)	0.540	0.187	1.564	0.25
Destination of MWA	2.074	0.601	7.158	0.24

¹ MC= milk composition; MWA= Milk with Antibiotics.

Table 6 - Assessment of management practices in raising calves on the farms affected and unaffected by dam failure in Mariana.

Variables¹	OR	Lower limit	Upper limit	P - Value
Calf feeding system	1.322	0.276	6.322	0.72
Colostrum supply	0.758	0.043	13.498	0.84
Navel healing	1.562	0.127	19.210	0.72
Average daily gain	0.978	0.192	4.975	0.97
Occurrence of diarrhea	1.182	0.405	3.447	0.75
Occurrence of pneumonia	1.055	0.246	4.528	0.94
Occurrence of BPS	0.300	0.094	0.954	0.04
Fate of males	1.005	0.347	2.908	0.99

¹ BPS = bovine parasitic sadness

Table 7 - Assessment of reproductive management practices on the farms affected and unaffected by dam failure in Mariana.

Variables ¹	OR	Lower limit	Upper limit	P - Value
Implementation of a protocol	0.364	0.098	1.356	0.12
Use of bull or AI	1.048	0.364	3.016	0.93
Performance of PD	1.469	0.493	4.376	0.48
Occurrence of abortion	1.146	0.389	3.375	0.80
Performance of RV	0.321	0.059	1.760	0.18

¹ AI= artificial insemination; PD= pregnancy diagnosis; RV= reproductive vaccine

Table 8 - Assessment of water availability for human and animal consumption and agricultural use on the farms affected and unaffected by dam failure in Mariana.

Variables¹	OR	Lower limit	Upper limit	P - Value
Human Consumption				
Mine water	0.387	0.132	1.131	0.08
Well water	0.756	0.257	2.228	0.60
Animal Consumption				
Mine water	0.652	0.228	1.864	0.41
Well water	0.429	0.134	1.372	0.15
River water	1.107	0.367	3.340	0.85
Reservoir water	1.348	0.240	7.563	0.73
Use for Agriculture				
Mine water	0.503	0.113	2.240	0.36
Well water	0.413	0.039	4.436	0.45
River water	2.042	0.625	6.672	0.23
Reservoir water	0.640	0.052	7.868	0.72
Use for Irrigation	1.357	0.461	3.999	0.57
Preservation Areas				
PPAs fenced and preserved	1.571	0.484	5.106	0.44
PRF near the river	1.664	0.509	5.440	0.39

¹ PPAs= permanent preservation areas; PRF= preserved riparian forest.

Table 9 - Assessment of pasture areas, soil management and planting on the farms affected and unaffected by dam failure in Mariana.

Variables	OR	Lower limit	Upper limit	P - Value
Pasture				
Pasture condition	0.432	0.143	1.303	0.13
Leasing	0.600	0.183	1.972	0.39
Use of Brachiaria in pasture	0.722	0.201	2.598	0.61
Use of Panicum in pasture	1.667	0.452	6.144	0.43
Soil management and planting				
Soil analysis	2.933	0.996	8.641	0.05
Soil preparation	1.913	0.553	6.621	0.30
Soil correction	0.825	0.288	2.360	0.71
Direct planting	0.381	0.102	1.426	0.14

Table 10 - Assessment of the disposal of empty fertilizer, pesticide and medicine packaging on the farms affected and unaffected by dam failure in Mariana.

Variables	OR	Lower limit	Upper limit	P - Value
Fertilizers				
Fertilization of pastures	1.240	0.433	3.550	0.68
Use of chemical fertilizers	0.518	0.175	1.536	0.23
Use of organic fertilizers	0.532	0.105	2.710	0.44
Agricultural pesticides				
Use of Agricultural pesticides	0.650	0.219	1.925	0.43
Use of herbicides	0.630	0.211	1.879	0.40
Use of insecticides	1.381	0.244	7.827	0.71
Disposal of fertilizer packaging				
Burning	1.067	0.342	3.323	0.90
Collection	0.884	0.277	2.827	0.83
Disposal of agricultural pesticide packaging				
Burning	1.067	0.342	3.323	0.91
Collection	0.591	0.152	2.293	0.44
Disposal of Medication				
Burial	0.640	0.052	7.868	0.72
Burning	1.107	0.367	3.340	0.85
Collection	0.792	0.274	2.291	0.66

Table 11 - Assessment of intentions regarding dairy farming activities on the farms affected and unaffected by dam failure in Mariana.

Variables¹	OR	Lower limit	Upper limit	P - Value
Exclusive dependence on DF	0.596	0.203	1.744	0.33
Intention to leave DF	3.051	1.030	9.041	0.04

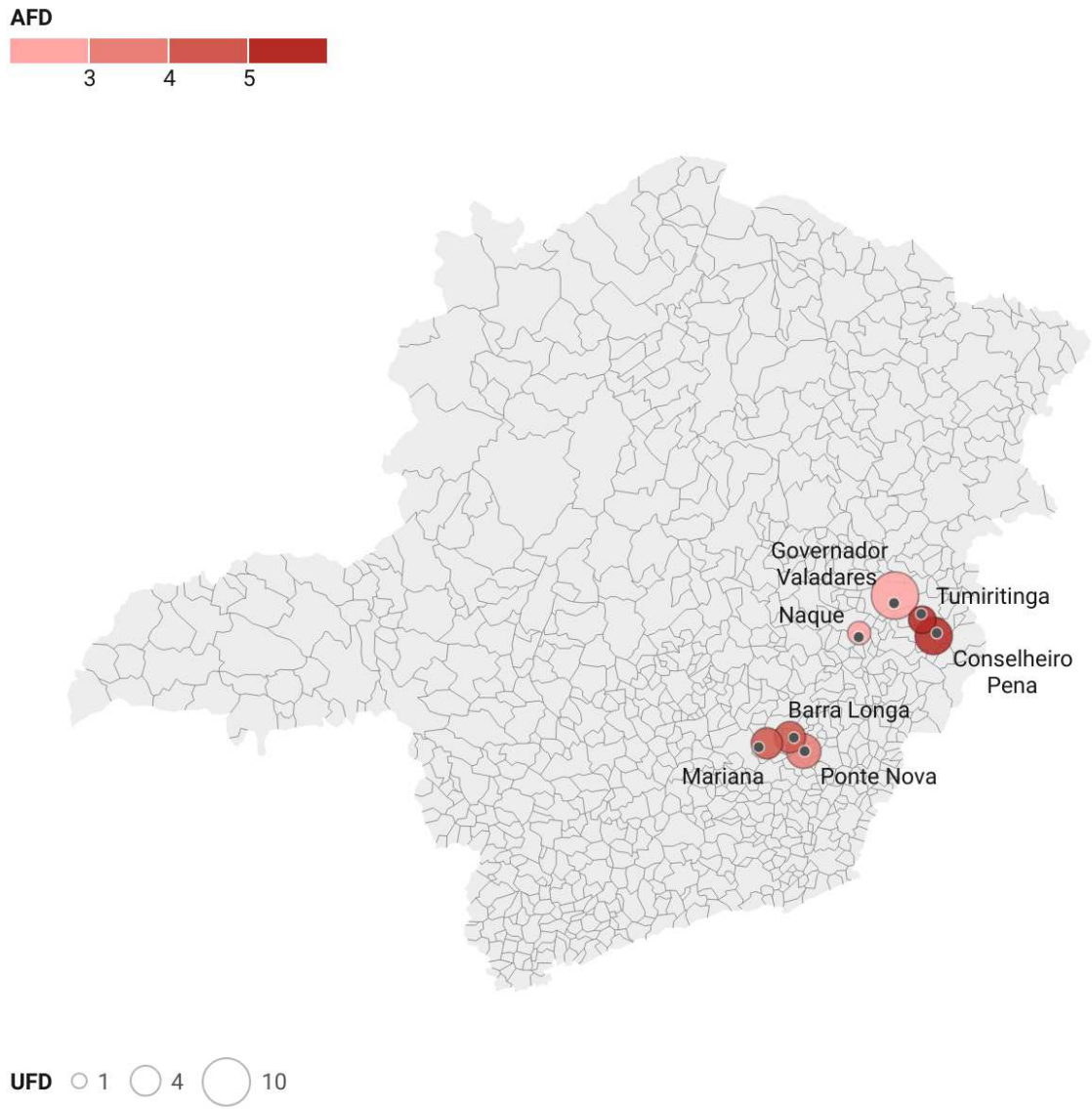
¹DF= dairy farming;

Table 12 - Obstacles reported by the farms affected and unaffected by dam failure in Mariana.

Variables¹	OR	Lower limit	Upper limit	P - Value
Problems with WS	3.100	0.673	14.280	0.14
Difficulties with TA	2.460	0.513	11.796	0.25
Challenges in MP	2.750	0.224	33.829	0.42
Difficulties in ARC	0.861	0.128	5.796	0.87
Difficulties with labor	1.107	0.367	3.340	0.85
Problems with RC	0.333	0.090	1.228	0.09
Impact of PPOB	1.679	0.573	4.916	0.33
Difficulty in AI	4.310	0.450	41.298	0.20

¹ WS= water supply; TA= technical assistance; MP= marketing products; ARC= accessing rural credit; RC= road conditions; PPOB= product prices on business; AI= acquiring inputs

Figure



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Figura 1- Location of the municipalities affected by the rupture of the Fundão dam in Mariana (MG).

GENERAL CONCLUSION

The two chapters of this dissertation highlight important strategies for improving silage quality and the significant impact of environmental disasters on agricultural practices. Techniques such as the wilting of BRS Capiapu elephant grass or the addition of cornmeal help to improve the fermentation of the ensiled material, allowing better preservation of the forage and, consequently, better food quality. The addition of water-binding agents does not pose any risks when it rains, even though the costs may be higher. Environmental disasters, such as dam failures, have a direct impact on agricultural practices, especially in the dairy sector, and affect the use of resources such as water, soil, and pasture due to contamination with heavy metals. Technical assistance proved to be essential in mitigating these impacts and supporting post-disaster recovery, underlining the need for and importance of public action in such situations. The study also highlights the lack of studies addressing the impact of these disasters on the affected sectors, particularly agriculture, and points to the need for further research to deepen the understanding of the consequences of these events.