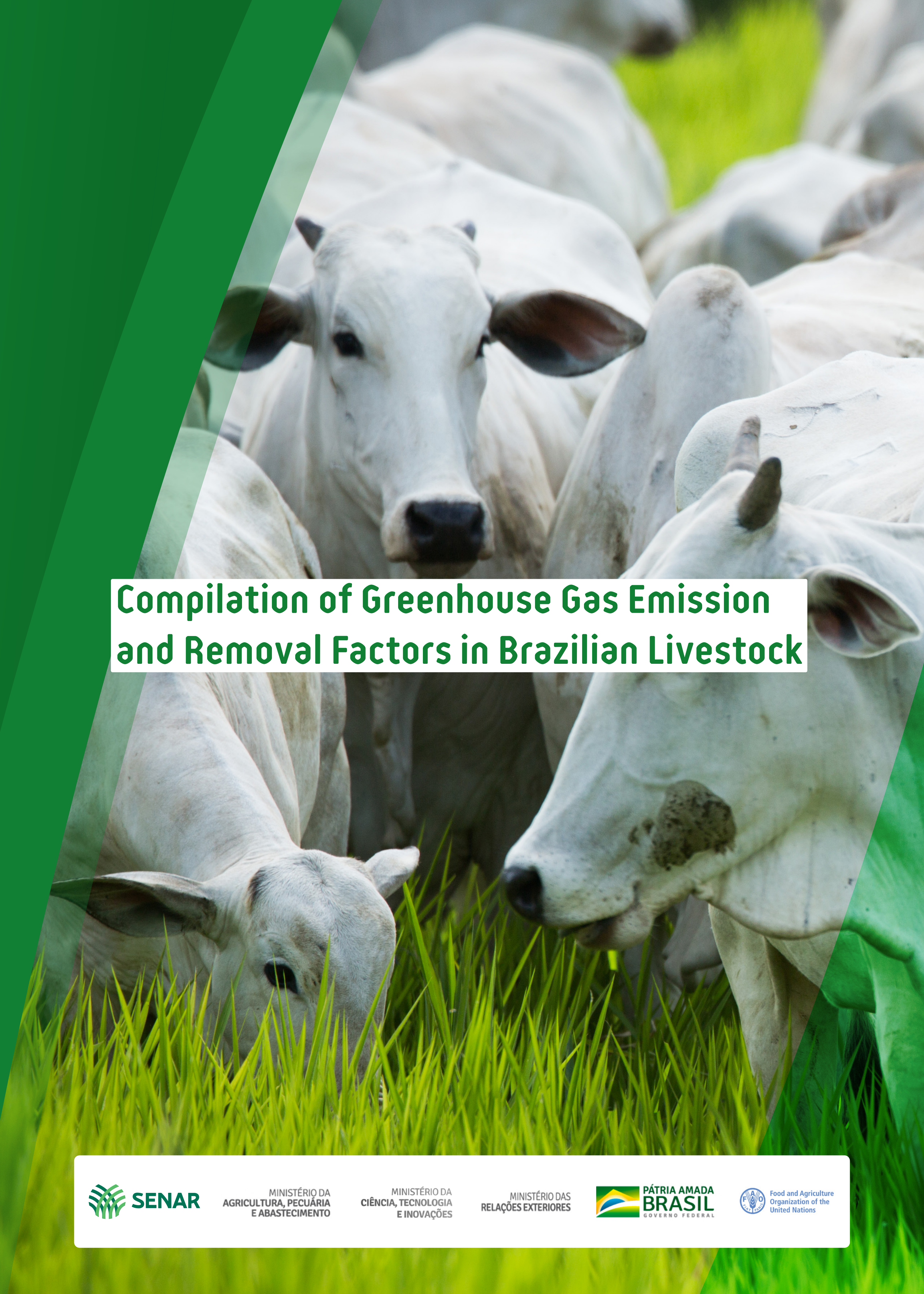


Compilation of Greenhouse Gas Emission and Removal Factors in Brazilian Livestock

SENAR
MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
MINISTÉRIO DAS RELAÇÕES EXTERIORES
PÁTRIA AMADA BRASIL GOVERNO FEDERAL
Food and Agriculture Organization of the United Nations

President of Brazil
Jair Messias Bolsonaro

Minister of Agriculture, Livestock and Food Supply
Tereza Cristina Corrêa da Costa Dias

Executive Secretary
Marcos Montes Cordeiro

Secretary for Innovation, Rural Development and Irrigation
Fernando Silveira Camargo

Deputy Secretary for Innovation, Rural Development and Irrigation
Cleber Oliveira Soares

Director for Sustainable Production and Irrigation
Mariane Crespolini dos Santos

General Coordinator for Climate Change, Forestry and Conservation Agriculture
Fabiana Villa Alves

Ministry of Agriculture, Livestock, and Food Supply

Compilation of Greenhouse Gas Emission and Removal Factors in Brazilian Livestock

MAPA's mission

To promote the sustainable development of agriculture and livestock, and it's subproducts

Brasília
MAPA
2021

1st Edition.
run: 1,000

Coordination: Eleneide Doff Sotta, Elvison Nunes Ramos, Fernanda Garcia Sampaio, Juan Vicente Guadalupe Gallardo, Juliana Bragança Campos, Kátia Marzall, Mirella de Souza Nogueira Costa, Sidney Almeida Figueira de Medeiros.

Publishers
Dr. Eleneide Doff Sotta, Dr. Fernanda Garcia Sampaio and Mirella de Souza Nogueira Costa.

Scientific reviewers
Chapter 1 – Dra. Diana Signor
Chapter 2 – Dr. Alexandre Berndt and Dra. Patrícia Perondi Anchão Oliveira
Chapter 3 – Dra. Ana Paula Packer, Dra. Leidiane Ferronato Mariani and Juliana Bragança Campos

Collaborators
Adilson Oliveira Farias, Aline Czezacki, Andréa Nascimento de Araújo, Cleber Oliveira Soares, Danielly Godiva Santana Molleta, Eduardo Mansur, Fabiana Villa Alves, Fernando Sardenberg Zelner Gonçalves, Francisco Basílio Freitas de Souza, Giovanna Lunkmoss de Christo, Gustavo Chianca, Ily de Miranda Barbiéri, João Francisco Adrien Fernandes, João Nicanildo Bastos dos Santos, Juliana Cristina Lopes, Lidiane Rocha de Oliveira Melo, Mariane Crespolini dos Santos, Martial Bernoux, Mateus Moraes Tavares, Mirella Salvatore, Pedro Alves Correa Neto, Rafael Zavala, Ricardo Kobal Raski, Roberto Soares Rocha, Sergio Dorfler e Tiago Queiroz de Menezes

Cataloging in Source

Dados Internacionais de catalogação na Publicação (CIP)
Biblioteca Nacional de Agricultura – BINAGRI

Brazil. Ministry of Agriculture, Livestock and Food Supply.
Compilation of Greenhouse Gas Emission and Removal Factors in Brazilian Livestock / Eleneide Doff Sotta, Fernanda Garcia Sampaio, Mirella de Souza Nogueira Costa (organizers). – Brasília : MAPA, 2021.
164 p. : il. color.
ISBN 978-65-86803-59-4

1. Sustainable Agriculture 2. Tropical Agriculture and Livestock Production. 3. Climate Change 4. Brazilian Livestock. 5. Agriculture and livestock. I.Secretariat of Innovation, Rural Development and Irrigation. II. Title.

AGRIS E14

Kelly Lemos da Silva CRB1-1880

ACKNOLEGMENTS

We would like to acknowledge the support received from the project 'Brazil Sustainable Production in Areas Previously Converted to Agricultural Use Project (ABC Cerrado Project)' funded by the Forest Investment Program (FIP/SCF/CIF) towards the World Bank. We also acknowledge the support received from the project 'Supporting the Implementation of the Koronivia Joint Work on Agriculture Roadmap' funded by the Federal Ministry of Food and Agriculture of Germany.

PRESENTATION

The Sectoral Plan for the Mitigation and Adaptation to Climate Change for the Consolidation of a Low Carbon Economy in Agriculture (ABC Plan) was created to implement Brazil's National Policy on Climate Change - PNMC (Law No. 12,187/2009) in the agricultural sector. The ABC Plan is one of the most important tools in Brazil's current agricultural policy. With the aim of expanding the adoption of sustainable production systems, the ABC Plan represents the sector's solid commitment to tackling climate change and other factors, by monitoring the results of actions to control agriculture and livestock-related greenhouse gas emissions (GHG).

Agriculture and livestock production play a fundamental role in food security. Furthermore, the progress observed after the adoption of sustainable agricultural production systems is also fundamental to foster an appropriate balance between income generation, economic sustainability, environmental conservation, and the provision of ecosystem services. Currently, the agriculture and livestock sector play an important role in national efforts to tackle climate change and in fulfilling Brazil's commitment to the United Nations Framework Convention on Climate Change (UNFCCC). Thanks to its solid scientific and technological base, strategy and effective public policy tools, as well as an inclusive management team that deeply involved the productive sector, the ABC Plan has been showing expressive results with regard to the increase of agricultural production, aligned with gross greenhouse gas (GHG) emission control. The implementation of the ABC Plan has made it possible for emissions associated to the agriculture and livestock sector to remain well below the initially defined targets, and certainly well below the projected emissions growth, without the need for interference from public policy. Thanks to the ABC Plan, the Ministry of Agriculture, Livestock and Food Supply (MAPA) has been able to fulfill its role in strengthening more sustainable agriculture enabling the reduction of GHG emissions, ensure security in food production, reduce vulnerability to climate change, strengthen resilience and the ability to adapt to growing climate uncertainties, thereby contributing sustainably to the increase of productivity in Brazilian agriculture and livestock.

Each nation has its own history, economy, and developmental trajectory, which are all linked to certain GHG emission levels. This is the basis behind the principle of common but differentiated responsibilities, which takes into account each country's economy, as established by the UNFCCC. At the same time, it emphasizes the importance of determining specific emission factors that reflect the reality of environmental and technological conditions in each country. Establishing national and sectoral emission factors is essential for more accurate quantification of GHG emissions, enabling the disclosure of appropriate information to national and international stakeholders, and above all, to guide the correct design for the national sector's national policy to combat climate change.

Emission estimates, and, consequently, their reduction, control, and removal capacity, are currently still elaborated with a high level of uncertainty. Although we cannot completely eliminate the intrinsic uncertainty in this very dynamic process, we can certainly improve the accuracy of these estimates by applying better data and appropriate methodologies according to each sector's specific characteristics. To this end, determining emission factors that are specific to the nature of each activity and appropriate for national circumstances is essential (IPCC, 2000).

Currently, there are several studies in Brazil that have been developed by universities and research institutions, aiming to establish specific emission factors for national agricultural systems. However, many stakeholders and partners are not aware of a large part of this data, given the difficulty of access to it. Consequentially, it makes it more difficult to recognize the potential that the results of these studies and related information may have for calculating national emissions. This scenario has frequently forced Brazil to adopt IPCC standard emission factors for its GHG emissions calculations. Although valid on a global scale, these factors were developed from edaphoclimatic and technological realities that are different from the tropical and subtropical reality that characterizes the diversity of Brazilian agricultural and livestock production systems. Therefore, the potential for the removal and control of GHG emissions by national agriculture and livestock activities is not necessarily reflected in the figures obtained.

In order to promote dialogue between the various national actors, MAPA prepared the present "Compilation of Greenhouse Gases Emission Removal Factors in Brazilian Livestock", with the participation of several Brazilian researchers dedicated to the topic.

This publication presents an objective, albeit unexhaustive, picture of the current state of research towards creating a definition of both specific emission factors aimed at the main crops and production systems in the country, and the management alternatives to mitigate GHGs.

The information collected in this Compilation comes from scientifically based inputs aimed at strengthening the ABC Plan strategies for sustainable livestock, as well as improving methodologies for quantifying GHG emissions and removals in the agricultural sector.

We would like to thank all the collaborators and institutions that contributed to this strategy and wish them a pleasant read!

Tereza Cristina Corrêa da Costa Dias
Minister of Agriculture, Livestock and Food Supply

TABLE OF CONTENTS

Transparency and reporting mechanisms of the United Nations Framework Convention on Climate Change and modulations of its norms. 18

The influence of herd management in mitigating livestock emissions 22

1. EMISSION AND REMOVAL FACTORS FOR SMALL RUMINANTS 26

Factors for emission and removal of greenhouse gases from the production of small ruminants in the national territory 28

Greenhouse Gas Emissions (GHG) and carbon balance in a caprine production system in the Caatinga Biome 32

Greenhouse Gas Emissions (GHG) in lamb production systems for meat in southern Brazil 34

Enteric methane emissions from sheep and goats in caatinga biome production system 36

2. EMISSION AND REMOVAL FACTORS FOR LARGE RUMINANTS 38

Evaluation Of Emission And Removal Factors Of Large Ruminants And Their Integration In The Brazilian Agricultural Policy 40

Quantification On Enteric Methane Emission Factors In Grazing Cattle 48

Tannins As A Food Additive To Mitigate Methane Emissions In Taurine And Zebu Cattle 50

Methane Emissions from cattle In integrated livestock crop systems (ILCS) 52

Enteric Methane Emission from Crossbred Canchim, Angus, And Charolais Cattle, Finished In Confinement Feedlots 54

Greenhouse Gas Emission In Cattle Production Systems In Southern Brazil 56

Methane Mitigation Opportunities In Meat Production Through Animal Breeding 58

Rotational Grazing with Elephant-Grass for Dairy Cows: Grazing Strategies, Animal Productivity and Enteric Methane and Nitrous Oxide Emissions 60

Carbon Neutral Beef: Testing The Guidelines In A Case Study 63

Greenhouse Gas Balance And Carbon Footprint Of Beef Cattle In Three Different Pasture Management Systems In Brazil 64

Emission Factors For Nitrous Oxide From Cattle Urine And Dung In Pastures Of The Brazilian Subtropic 66

Quantification Of Direct And Indirect Nitrous Oxide Emission Factors 68

+ Precoce - Efficiency And Innovation In The First-Calf Chain Integrating The Pantanal And Cerrado Biomes 70

Methane Levels And Energy Losses In Beef Cattle, Supplemented Or Not, In Mombas A Grass Pastures (*Panicum Maximum Cv. Mombasa*) 72

Data Of Methane Emission Factors From The Enteric Fermentation Of Beef And Milk Cattle In Brazil 74

PECUS RESEARCH NETWORK - DYNAMICS OF GREENHOUSE GASES IN BRAZILIAN AGRICULTURE AND LIVESTOCK PRODUCTION SYSTEMS 78

Pecus network 79

Enteric methane emissions by canchim steers in integrated systems of production compared to exclusive production systems for rearing and fattening 82

Enteric methane emissions from beef cattle on natural pasture with different levels of intensification 84

Enteric methane emissions for cattle in integrated systems in the brazilian mid-north 86

Methane emissions from beef cattle on temperate pastures and integrated agricultural systems 88

Enteric methane emissions in buffaloes in eastern 90

Amazon: tier2 methodology and sulfur hexafluoride (SF_6) Enteric methane emission in buffaloes supplemented with palm kernel cake in the amazon biome 92

Nitrous oxide emission in tropical pastures of beef cattle production systems 94

Modeling nitrous oxide emissions from pure grass pastures and intercropped grass and legumes in the western brazilian amazon 96

Greenhouse gas dynamics and their interface with efficiency, food quality and sustainability in agricultural production systems of the atlantic rainforest bioma 98

Organic carbon stock and soil greenhouse gas emissions in a natural grassland area of the pampa biome 100

Pastoral soil carbon stocks for dairy production systems 102

Soil carbon stocks in integrated systems in the atlantic forest biome 104

Carbon stocks and soil humidification in pastures with different levels of intensification in Brazil 106

Soil quality indicator in an integrated livestock system with low carbon emission in the amazon biome 108

Statistical modeling of soil carbon in specialized integrated-crop-livestock-forest producution system in paragominas-pa 110

Biomass and carbon stock from eucalyptus trees in integrated livestock production systems 112

Sustainable production systems, crop-livestock integration and crop-livestock-forest integration systems 114

Potential of environmental services using eucalyptus in integrated production systems 116

Enteric methane emissions from nellore heifers in integrated and extensive systems 117

Greenhouse gas emissions from soils from different animal production systems in the brazilian cerrado 118

Soil carbon content in crop-livestock-forest integration systems 119

3. EMISSION AND REMOVAL FACTORS FOR NON- RUMINANTS 120

Factors for emission and removal of greenhouse gases from the production of non-ruminants in the national territory 122

Emission of greenhouse gases (GHG) in technological arrangements for the production and use of biogas 130

Nitrous oxide emissions from pig farming 132

Greenhouse gas and ammonia emissions from broiler breeding with multiple bed reuse 134

Greenhouse gas emissions during broiler housing on reused litter 138

Modeling carbon dioxide emissions in broiler production 140

Effects of the intensity and production scale on environmental impacts on the poultry meat production chain: life cycle assessment of french and brazilian scenarios - of bird production 142

Environmental impacts from the broiler production process 144

Strategies to mitigate nitrous oxide emissions after the application of animal waste and urea in no-tillage in southern Brazil 146

Understanding greenhouse gas (GHG) emissions and removals in net tank fish farming in reservoirs 150

Emission or removal: the enigma of mariculture in the blue carbon balance 152

ANNEX - BIBLIOGRAPHIC CONTINUATION **154**

ACRONYMS

LCA	Life Cycle Assessment
AND	Designated National Authority
BTRs	Biennial Transparency Reports
BUR	Biennial Update Reports
CBDR	Common but Differentiated Responsibilities
CNBB	Carbon Neutral Brazilian Beef
CH_4	Methane
DMI	Dry Matter Intake
CO_2	Carbon Dioxide/Carbon Gas
COP	Conference of the Parties
ETF	Enhanced Transparency Framework
EXT	Extensive System (Extensive Farming)
BNF	Biological Nitrogen Fixation
ERF	Emission and Removal Factor
GHG	Greenhouse Gases
DWG	Daily Weight Gain
IHS	Irrigated Pasture with High Stocking Rate
EI	Emission Intensity
ILA	Integrated Landscape Approach
CLIS	Crop-Livestock Integration System

ICLFS	Integrated Crop-Livestock-Forest System
IPCC	Intergovernmental Panel on Climate Change
MAPA	Ministry of Agriculture, Livestock and Food Supply
MCTI	Ministry of Science, Technology and Innovation
SOM	Soil Organic Matter
N_2O	Nitrous Oxide
NATCOM	National Communications
NH_3	Ammonia
GWP	Global Warming Potential
PECUS	Greenhouse Gas Dynamics Project in Brazilian Agricultural Production Systems
PNMC	National Policy on Climate Change
SF_6	Sulfur Hexafluoride (tracer gas)
IAPS	Integrated Agricultural Production Systems
SISAVE	Greenhouse Gas Sampling System in No-Till (NT) Poultry Farming
CWT	Carcass Weight Equivalent
UNFCCC	United Nations Framework Convention on Climate Change
Ym	Methane Conversion Factor/Enteric Fermentation

INTRODUCTION

In 2020, the Climate Change Mitigation and Adaptation Sectorial Plan for the Consolidation of a Low Carbon Economy in Agriculture, known as the ABC Plan, celebrates ten years since its creation. The ABC Plan has become a reference for public policies that promote sustainability in the agricultural sector, especially during a period in which environmental issues are at the forefront of concerns. These concerns are further reinforced, as the lack of adequate environmental conditions threatens the very maintenance of agricultural production capacity. The action strategy in the ABC Plan led to the implementation of initiatives that aim to ensure fundamental economic gains to Brazilian farmers, in a manner intrinsically aligned with the establishment of production systems that allow them to increase their resilience, ensuring their ability to adapt in face of external impacts while also controlling greenhouse gas (GHG) emissions associated with the sector. The ABC Plan, considering its objectives and contexts, is also aligned with the concerns of strengthening sustainability in the national process of development, especially, when responding to the challenges proposed internationally through the Sustainable Development Goals, in particular SDG-2 (Zero Hunger and Sustainable Agriculture) and SDG-13 (Action to combat Global Climate Change)[1].

Partnering closely with the scientific community, and promoting the most efficient sustainable production technologies, the ABC Plan has become a world reference in terms of public policy for adapting to climate change and for controlling GHG in systems of agriculture and livestock production in the context of the climate change debates. The ABC Plan is built on a solid scientific base, and results from over 40 years of consistent investment in research, incorporating groundbreaking proposals for innovation and sustainable technologies in tropical agriculture.

Transformation of the productive process in the field took place thanks to the promotion and adoption of ABC technologies highly accepted by the productive sector, allowing the sector to reach the goals proposed for the period from 2010 to 2020. Much of the success achieved is a reflection of the innovative territorial policy, allowing for local partnerships, which established State Management Groups for the creation of state ABC Plans in all Federal units.

In order to communicate the results of mitigating GHG emissions related to the adoption of ABC systems and technologies, accounting for GHG emissions and removals is a must. Official communication reported through the National Inventory must follow the guidelines of the Intergovernmental Panel on Climate Change (IPCC). Under the United Nations Framework Convention on Climate Change (UNFCCC), agricultural emissions are accounted for, mainly, in two sectors: the 'Agricultural Sector' (AS) and the 'Land-Use Change Sector '[2]. For these sectors,

1 Goal 2. SDG 2: End hunger, enhance food and nutrition security, and promote sustainable agriculture; Take urgent action to mitigate climate change and its impacts

2 More details on this process are described in the texts by Mozzer & Bueno (p. 16) and Christo & Santos (p. 20).

the assessment categories are predetermined within the scope of the guidelines that guide the respective national inventories.

Accuracy in estimating GHG emissions depends on both the availability and the quality of the data on activity and their emission and removal factors (ERF). Estimates from the 'Agricultural Sector', in the last National Inventory, were still carried out using mainly IPCC standard emission factors (EF) (2006), which introduce an important level of uncertainty in the estimates from the agricultural sector as they are the result of studies carried out in temperate climate farming systems.

In order to improve the accuracy of estimates in the agricultural sector, several research institutions in the country have been working on the development of specific EF for tropical conditions. However, the information generated through the different surveys is very scattered and is often little known or accessed by official government agencies responsible for agricultural sector policy.

The General Climate Change Coordination (CGMC), of the Department of Sustainable Production and Irrigation, of the Secretariat of Innovation, Rural Development and Irrigation, of the Ministry of Agriculture, Livestock and Food Supply (MAPA), within the scope of the ABC Cerrado Project and with the purpose of contributing to the reduction of these uncertainties, prepared this compilation, entitled "Compilation of Emission and Removal Factors of Greenhouse Gases from Brazilian Agriculture and Livestock."

Thus, this Compilation aims to bring together advances in scientific knowledge related to the generation of EFs specific to the national conditions and also the strategies or alternatives proposed by researchers for controlling GHG emissions in production systems, in different regions of the country. Researchers and national research groups were invited to present their data according to a guiding script, generating information in more technical and less scientific language, and also containing notes on solutions and challenges related to the subject. The research compiled provides data on GHG emissions and removals for the different enteric fermentation processes of small and large ruminants, monogastric organisms, as well as the determination of GHG flows in areas where fish, oysters and mussels are grown. The Compilation was then organized considering the large groups of animal production, resulting in the following chapters: I. Small Ruminants (sheep and goats); II. Large Ruminants (cattle and buffaloes); and III. Non Ruminants (poultry, pigs, fish and bivalve mollusks), in which the results obtained and implemented in different projects and initiatives are presented. The document compiles valuable scientific-based information, which, in addition to enriching the knowledge base on the topic of GHG estimates in the agricultural sector, aims to strengthen interinstitutional discussion processes for the construction and/or improvement of policies aimed at guaranteeing sustainable agriculture.

The information gathered demonstrates that there is a greater concentration of studies for large ruminants, with cattle being the group with the greatest contribution of research, covering more than 70% of the papers received. Due to the intense cattle farming in national agriculture and the weight given to enteric fermentation processes in accounting for emissions proposed in the IPCC guidelines, efforts aimed at improving the understanding of GHG emissions in tropical production systems are essential. Research with beef cattle considers different production systems, the main breeds reared and the different regions in Brazil. It is important to highlight the enormous contribution from the Pecus Project, which under Embrapa's coordination, gathered a significant amount of research, creating a sub-chapter within the chapter on large ruminants. The Pecus Project's efforts and the establishment of the Pecus Research Network and other work on the subject, allowed Brazil to advance in understanding GHG dynamics in livestock, improving the calculation of factors and making it much more accurate. Accuracy in accounting has made it possible to better represent gains in efficiency for Brazilian livestock and the reduction in emissions per head of cattle. There is also a clear trend in studies accounting for emissions and removals in integrated production systems considering not only animal emissions, but also the GHG balance of the production system as a whole.

Also noteworthy is the excellent contribution of research on sheep and goat breeding carried out in the semi-arid region and in the south of the country, generating important information that may allow Brazil to report emissions closer to the local realities. The important advances in the contributions seen for swine and broiler chickens and the pioneering efforts in understanding the processes of emission and removal in malaco-culture are also highlights of the Compilation.

The particularities in determining national emission factors when considering production systems and management conditions, environments and different regions of Brazil, demonstrate the importance of defining emission factors for the main livestock activities. Thus, contributing to eliminate the uncertainties derived from the use of EFp in the IPCC and, consequently, improve the accuracy of the national livestock sector GHG estimates.

This context shows that it is important to continue investing resources for the development of research related to GHG mitigation strategies and, specifically, to the generation of EF, in order to consolidate the current knowledge base and, above all, expand it through implementing new research projects.

The results presented come from studies carried out in different Brazilian realities and biomes. The diversity of the studies presented and their national scope allow us to verify the breadth of how the matter is being treated in Brazil, as well as the efforts which have already been made and the volume of material available on the subject. We know, however, that this Compilation does not exhaustively represent all existing research dedicated to the topic and that other research groups are also committed to contributing to this process.

Despite recent advances in research, there is still a great demand for data obtained by methods recognized by the scientific community and by those who can technically subsidize the best strategies aimed at the sustainable development of agriculture and livestock. This compilation proposes to disseminate information in a way that is simple and accessible to the public, stimulating questions and suggestions of new strategies, as well as the use of scientific data as subsidies for data driven decision-making.

Although the results of this survey of information do not cover the entire universe of research being carried out in the country, they signal some aspects of great importance regarding the state of scientific production, which may prove to be an important input for the development of policies for sustainable agriculture. These aspects are related to the regionalization or geographic concentration of the research, focused on the subject being followed and with the range of GHG EF values for the same emission category within a specific region.

This publication is a MAPA initiative, supported by the Ministry of Foreign Affairs (MRE), the Ministry of Science, Technology and Innovation (MCTI), in partnership with the World Bank, the Brazilian Agricultural Research Corporation (Embrapa) and the National Service of Rural Apprenticeship (Senar), carried out within the scope of the ABC Cerrado Project. It was only made possible thanks to the effective participation of researchers who shared their work, with a view to contributing to the sustainability of the Brazilian agriculture and livestock sector.

Enjoy your reading!

Transparency and reporting mechanisms of the United Nations Framework Convention on Climate Change and modulations of its norms

Gustavo Barbosa Mozzer[1]; Adriana Mesquita Corrêa Bueno[1]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa

Brazil was the first country to sign the United Nations Framework Convention on Climate Change (UNFCCC), the result of the United Nations Conference on Environment and Development, held in Rio de Janeiro in June 1992, which was then ratified by the National Congress in 1994. Likewise, it was the first country to establish a National Designated Authority (AND) for supervising the Convention - the Ministry of Science, Technology and Innovation (MCTI).

The main commitment arising from the UNFCCC is the need for transparency and reporting, which translates into the structuring of a national system for the periodic elaboration of National Communications (NATCOM) and National Inventories of Anthropogenic Emissions from Sources and Removals by Sinks of Greenhouse Gases (GHG) not controlled by the Montreal Protocol (according to art. 4 and art. 12 of the Convention). This system is also essential to storing the database and recalculations and for the implementation of a continuous process of improvement and refinement, which allows the dynamic advance in the quality of inventories aligned with the development of scientific knowledge and the availability of data.

In order to allow transparent and reliable technical reviews, the Convention stipulates that inventories should preferably use comparable methodologies, which are proposed by the Intergovernmental Panel on Climate Change (IPCC) and agreed on by the Conference of the Parties (COP). Developed countries, referred to as Annex I in the context of the UNFCCC, have an additional commitment to present their inventories annually, in addition to undergoing a thorough review process that includes systematizing the data necessary to estimate national GHG emissions in the form of a common tabular format: the CRF (Common Reporting Format). The argument for the different additional levels of commitment from developed countries, agreed in the context of the Convention, was justified due to the historical difference in the contribution of Annex I countries when compared to Non-Annex I (developing countries) in GHG emissions according to the principle of common but differentiated responsibilities (CBDR), stipulated in art. 3. That is, although there is a commitment by all Parties to make efforts to stabilize GHG concentrations in the atmosphere, Annex I countries have a greater responsibility than that of Non-Annex I countries.

The Intergovernmental Panel on Climate Change (IPCC) is made up of scientists from 195 countries and, over the past 31 years, has developed three improvements to the methodological guidelines for the elaboration of national inventories: i) the IPCC Guidelines for National Greenhouse Gas Inventories; ii) the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and iii) the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. In addition, it produced other documents and two good practice handbooks on uncertainty and land and forest use (LULUCF). In 2019, the IPCC proposed a revision of the 2006 Guidelines, entitled 2019 Refinement to the 2006 IPCC Guidelines on National Greenhouse Gas Inventories1[1].

The inventory structure is basically composed of: institutional arrangements, documentation of methods and data, description of quality assurance and control procedures (QA/QC), description of the file system, analysis of key category (KCA) and improvement plan. In addition, the inventory is divided into four sectors: energy; industrial processes and product use (IPPU); waste treatment and agriculture, forests and land use (AFOLU). To measure emissions and removals, a country must identify the activities that contribute to GHG emissions or removals and estimate, by using emission or removal factors, the size of each of these contributions, in addition to potential sinks that contribute to the GHG removal.

Activity data is a quantitative measure of an activity level that contributes to GHG emissions; the emission or removal factors are coefficients that relate the activity data to the inherent emissions or removals. The general principle of the methodological guides is to allow extrapolation from activity data and emission or removal factors, resulting in GHG emissions or removals associated with a process or an operation.

Calculations of emissions and removals involve three hierarchical levels of methods that vary in complexity from standard data and simple equations to the use of specific data and models that accommodate each country's national circumstances. The first level, or Tier 1, represents the first step in this roster and has the fundamental objective of enabling the estimation of emissions when very little or even no information is available. The calculation of emission estimates using Tier 1 represents, without a doubt, the vast majority of the estimates presented in greenhouse gas inventories and its use is considered adequate except for categories classified as key2[2] due to the level (relative value of emissions) or trend. In any of these cases the use of more sophisticated methods is recommended.

The calculation of emissions using Tier 1 was designed by the IPCC to make conservative estimates3[3] of greenhouse gas emissions feasible for relevant sectors of the economy. In the 2006 methodological guidelines, the decision trees presented in each of the chapters must be carefully followed in the methodological choice process and also during the subsequent review phase. For this same reason, removal estimates cannot be made using Tier 1 methods, since the most conservative posture, in this case, is not to account for any removal in the inventory.

Tier 2 represents the methodological level at which activity data or domestic emission factors are used to estimate emissions. The use of a Tier 2 method implies the replacement of the conservative assumptions adopted at the previous level (Tier 1) with data that is reliable and representative of the national reality. In this case, Tier 2 represents the gateway to an avenue of complexification and breakdowns that can be made according to the existence of domestic data and the country's interest. Tier 3, on the other hand, represents a more sophisticated level of analysis4[4] that will vary according to the sector and category, but, in general, it can be represented by emission estimates based on data from mathematical models or estimates based on data collected at the unit level at installed factories or plants.

---

1 The updated methodology contributes to improving the transparency and reporting process, ensuring that the methodology used to determine these inventories is based on the latest science.

2 Key Category Analysis(KCA) is a fundamental exercise in preparing the inventory. This subject will be detailed below.

3 Conservative estimates from the perspective of the UNFCCC for greenhouse gas inventories mean, in the context of the data distribution curve, the upper fringe containing the observations with the most significant emissions.

4 The use of Tier 3 methods, in cases where emission estimates are calculated based on models, is notoriously a way to preserve sensitive data, thus avoiding the open exposure of emission factors inherent to the application of the Tier 2 method.

Five structuring principles determine how GHG inventories should be developed, in specifically, how emission and removal factors should be established, as well as how activity data should be structured. These principles also govern the way in which the entire review process is operated[5]. They are: Transparency, Accuracy, Consistency, Comparability and Completeness (TACCC); i) Transparency concerns the clarity of the premises and methodologies that must be clearly explained and documented; ii) Accuracy involves the precision of estimates of emissions and removals, including all measures adopted to reduce uncertainties; iii) Consistency is related to the nature of the data set, with a consistent historical series in which, preferably, the same methodologies and assumptions are used in the time series[6]; iv) Comparability describes the need to ensure that the estimates calculated in an inventory are comparable to the estimates published by other Parties of the Convention in their respective inventories, and v) Completeness determines that all sources of GHG emissions are inventoried and reported.

Each country must establish a focal point to develop a national inventory system and produce NATCOMs; in Brazil, the General Climate Coordination[7](CGCL), of the MCTI, plays this role[8]. It is the role of this focal point to structure the institutional arrangements for the establishment of a technical team capable of ensuring the preparation, storage and organization of the databases. The file system[9] should allow access to the historical series and ensure the application of quality control procedures (QA/QC)[10] , key category analysis (KCA) and the inventory improvement plan[11].

The establishment of a robust filing system that dynamically allows access to all references, methodologies, expert opinions, reviews and calculations for the entire historical series of the inventory, is essential to ensure transparency and consistency of data being reported. KCA, in turn, is fundamental to point out the need to prioritize efforts and, in particular, to identify areas that should be inventoried using activity data and specific emission or removal factors for the country. Executing QA/QC is essential for the implementation of a continuous process of improving the inventory.

Brazil has given strategic importance to the commitment to present its national communications; so far, it has already submitted three NATCOMs (2004[12], 2010[13] e 2016[14]), with the National Inventory attached. As part of the institutional arrangements established for the development of Brazilian national inventories, the Ministry of Agriculture, Livestock and Food Supply (MAPA) and the Brazilian Agricultural Research Corporation (Embrapa) play a fundamental role in research and data collection aimed at the establishment of activity data and emission and removal factors. The compilation of these elements and the initial preparation of the agriculture chapter of the National Inventory are also the responsibility of MAPA and Embrapa, institutions which also support the focal point of the inventory in aspects related to the other sectors, when necessary and opportune.

5 Reviews are conducted annually by expert teams (ERT) organized in a balanced way between representatives of Annex I and non-Annex I countries. There are three models of review: Centralized Reviews, in which teams meet at the UNFCCC headquarters in Bonn, to review multiple inventories at once; On-site reviews (in country) in which a team of reviewers meets in the country to review the inventory and the national system in detail; and Desk Reviews, when for any reason one of the reviewers cannot participate in one of the previous modalities.

6 Temporal series start in the base year, determined by the country, or can alternatively start at any time if emissions in this category are not present in the base year.

7 Available at:https://www.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/index.html.

8 A key category is one that is prioritized in the national inventory system because its estimate significantly influences a country's total GHG inventory in terms of absolute level, trend or uncertainty in emissions and removals (IPCC, 2006).

9 In Brazil, the file system is called the National Emissions Registry System (SIRENE) and is coordinated by MCTI. Available at:https://www.mctic.gov.br/mctic/opencms/textogeral/sirene.html.

10 What differentiates QA (quality assurance) from QC (quality control) is that the first is carried out by evaluators external to the inventory team, while the QC is performed routinely by the team responsible for preparing the national inventory.

11 The improvement plan aims to increase the quality of the calculations and data used in compiling the inventory and contributes to the aforementioned continuous process of improving inventories.

12 1st NATCOM - single volume Available at: https://unfccc.int/documents/66128.

13 2nd NATCOM - volumes 1 and 2 Available at: https://unfccc.int/documents/69067.

14 3rd NATCOM - volumes 1, 2 and 3 and Executive Summary Available at: https://unfccc.int/documents/66129.

Over the years, the negotiation process has tried to modulate the original way in which the issues of Transparency and Comparability were dealt with in the context of the Convention and, in this sense, COP 13, through the Bali Road map[15], established the biennial reports update (BUR) in 2007. The BUR aims to report actions developed at the domestic level to control GHG emissions, as well as reporting on needs and received support. Annex I countries are assessed through international evaluation and review (IAR)16[16]; and for Non-Annex I countries, the process is done through international consultation and analysis (ICA)17[17]. Since then, Brazil has presented three BURs: in 201418[18],201719[19] and 201920[20].

With the Paris Agreement[21] entering into force in 2020, a new cycle of modulation will again seek to increase the Transparency and Comparability of the reporting mechanism of the Convention, this is the Enhanced Transparency Framework (ETF). This new process reduces the gap between Annex I and Non-Annex I countries in terms of review obligations, by establishing a single model of technical expert review (TER). The new standard should unify the reporting model in a common database, defining compatible criteria under which inventories will be tabulated according to a Common Tabular Format (CTF). In addition, the process of enhancing global ambition (GST), structured by the Paris Agreement, will aim to improve global governance, imposing dynamism to a continuous process of increasing ambition, thus exerting pressure for the Nationally Determined Contributions (NDCs) to reflect the global need for ambition and stimulate the increase of domestic efforts.

By January 2022, Parties to the Convention must submit their latest BURs, which will be reviewed by the beginning of 2024, the year in which the reporting model will transition to the Enhanced Transparency Framework. Thereafter, all countries should periodically start presenting their Biennial Transparency Reports (BTRs). In the coming years, the political impacts arising from the GST and the implementation of the Paris Agreement will mark the transition to the ETF, which will translate into new inventory and scrutiny obligations of the national system for Non-Annex I. countries. Therefore, it is important that Brazil be robustly prepared to continue to implement improvements to its inventory, consolidate the national system, generate and systematize activity data and specific emission and removal factors, conforming to the CTF, plan a continuous inventory improvement process and prepare itself for ETF technical review cycles.

References

IIPCC – Intergovernmental Panel on Climate Change. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Program, Eggleston HS, Buendia L., Miwa K., Ngara T. and Tanabe K. (eds.). Japan: IGES, 2006.

Author information

Dr. Gustavo Mozzer
Secretariat of Intelligence and Strategic Affairs;
mail: gustavo.mozzer@embrapa.br

Dra. Adriana Mesquita Corrêa Bueno
Secretariat of Intelligence and Strategic Affairs;
mail: adriana.bueno@embrapa.br

---

15 Available at: https://unfccc.int/process/conferences/the-big-picture/milestones/bali-road-map.
16 International Assessment and Review Available at: https://unfccc.int/IAR.
17 International Consultation and Analysis Available at: https://unfccc.int/ICA.
18 1st BUR Available at: https://unfccc.int/documents/ 180611.
19 2nd BUR Available at: https://unfccc.int/documents/ 180612.
20 3rd BUR Available at: https://unfccc.int/documents/ 193513.
21 Available at: https: //unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreem.

The influence of herd management in mitigating livestock emissions

Giovanna Lunkmoss de Christo[1]; Mauro Meirelles de Oliveira Santos[1]

1 Programa das Nações Unidas para o Desenvolvimento/Ministério da Ciência, Tecnologia e Inovações

Brazil instituted the National Policy on Climate Change (PNMC), through Law No. 12,187/2009, which defines the voluntary national commitment to adopt mitigation actions with a view to reducing its greenhouse gas (GHG) emissions between 36.1% and 38.9% in relation to projected emissions for 2020. According to Decree 7,390/2010, which regulates1[1] the PNMC, the projection of GHG emissions for 2020 was estimated at 3,236 Gt CO_2. Thus, the reduction corresponding to the percentages established for that year is between 1,168 Gt CO_2 and 1,259 Gt CO_2 respectively.

As a signatory country to the United Nations Framework Convention on Climate Change (UNFCCC), and in order to comply with the National Policy on Climate Change, one of Brazil's main obligations is the elaboration and periodic updating of the National Inventory of Anthropogenic Emissions by Sources and Removals by Sinks of Greenhouse Gases Not Controlled by the Montreal Protocol. The Ministry of Science, Technology and Innovation (MCTI) is the body responsible for preparing, updating and reporting on national GHG emissions.

The preparation of the inventory follows as a basic technical guideline, the Intergovernmental Panel on Climate Change (IPCC), which provides methodological guidelines for the preparation of national inventories. Within the Inventory, emissions from five sectors are counted: Energy, Industrial Processes and Product Use (IPPU), Agriculture, Land Use, Land Use Change and Forests (LULUCF) and Waste, bproviding an overview of emissions from main economic sectors in the country. A prominent sector is the Agriculture and Livestock sector, which in 2015 represented 31% of national emissions in terms of $CO_2$and[2].

Emissions from the Agricultural sector comprise the emissions of methane (CH_4) and nitrous oxide (N_2O) from five sub-sectors, which are: Enteric Fermentation, Waste Management, Rice Cultivation, Managed Soils and Burning of Agricultural Waste, not counting indirect GHGs[3]. From the Fourth National Inventory, which will follow the 2006 IPCC methodologies, two more sub-sectors will be incorporated: Liming and Application of Urea, responsible for carbon dioxide (CO_2) emissions. The first was accounted for in the LULUCF sector; the second, in the chemical industry sub-sector, within the Industrial Processes and Product Use (IPPU) sector. Ingeneral, the estimates of the Agriculture and Livestock sector are calculated from national data such as population and animal characterization, consumption of synthetic and organic fertilizers, production of agriculture, technologies used for manure management, among others. Most of

1 Replaced by Decree 9.578, of 2018.
2 Metric used: GWP/SAR. Data from the 5th Edition of Estimates, which can be accessed at: https: // sirene. mctic.gov.br/portal/opencms/publicacao/index.html.
3 Carbon monoxide (CO), nitrogen oxides (NOx) and non-methane volatile organic compounds (NMVOC) (IPCC, 2006).

the historical data sets are acquired from official sources, such as from the Brazilian Institute of Geography and Statistics (IBGE).

The most relevant subsector within the Agriculture and Livestock sector is Enteric Fermentation, which in 2016 contributed 57% of the total emissions of the Sector, and 19% of the country's total emissions are modulated, mainly, by the quantity of cattle heads (BRAZIL, 2019). Enteric fermentation is a natural part of ruminant animals' digestive process- cattle, sheep, goats, buffaloes; non-ruminants - equines, donkeys, mules; and monogastrics - pigs. Fermentation of food nutrients is an anaerobic process carried out by the ruminal microbiota (bacteria, protozoa and fungi), which converts cellulosic carbohydrates into short-chain fatty acids (AGCC), mainly acetic, propionic and butyric acids, producing methane, which is expelled through the animal burp. There is a direct, but complex, relationship between the amount of methane expelled by the animal and the quantity and quality of its food, which will influence its weight, its productivity and its digestibility, among other factors.

Brazil has been advancing in estimates of bovine enteric fermentation, the most representative animal category for the country, using more refined and more detailed methods for calculating emissions. In order to accomplish this, data on digestibility rate, live weight of the animal, daily weight gain (which depends on the animal's life stage), pregnancy rate and milk fat content (for dairy cows), hours of labor (which does not apply to Brazil), to obtain the amount of energy ingested by the animal, by calculating the amount of energy used for maintenance, feeding, lactation, work, gestation and growth. Another factor that directly influences emissions, in the last phase of the calculation, is the methane conversion factor (Ym), which means the fraction of the consumed energy converted to methane during animal enteric fermentation. This fraction varies from 2 to 12% and will depend on the combination of food consumption and type of animal (IPCC, 2006).

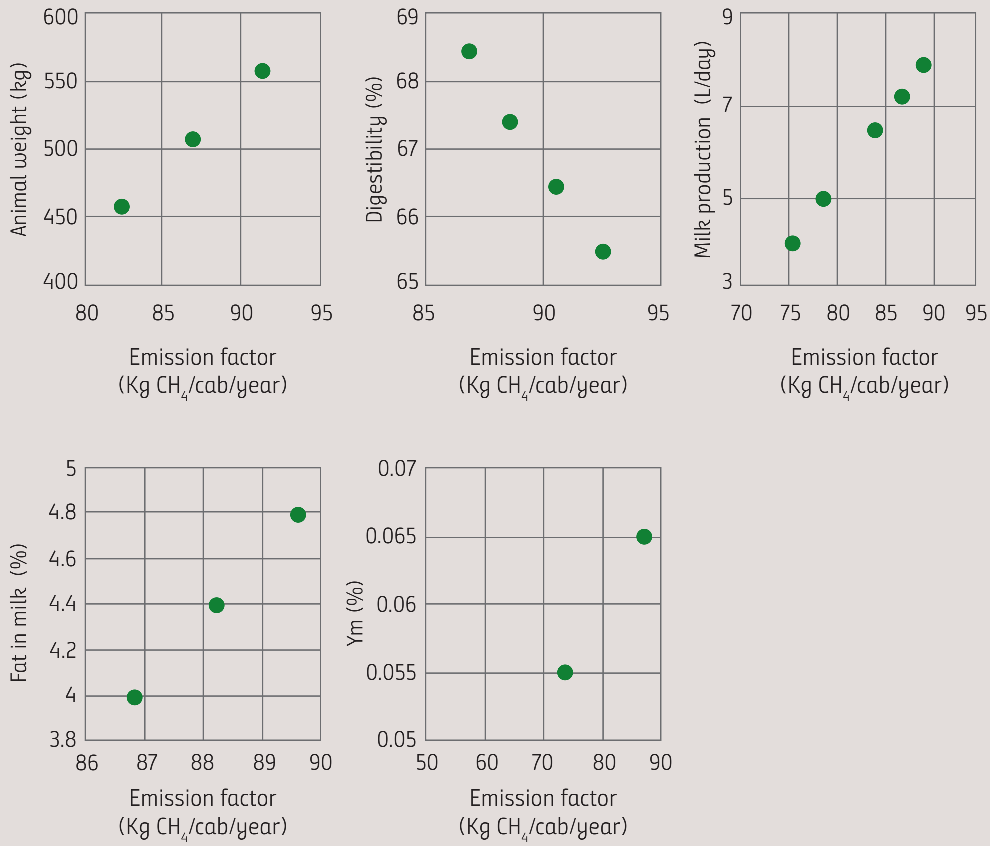
As a way of exemplifying the relationship between the parameters that influence the calculation of the enteric fermentation emission factors, we started by analyzing the variation of some parameters[4] used in the Fourth National Inventory[5], basing off of the animal category "high production dairy cows in the State of Minas Gerais", in 2016 (Emission Factor calculated: 86.8 kg CH_4/head/year).

The graphs illustrate the relationship between each parameter and the emission factor, with the other parameters kept constant. It can be observed that the greater the weight, the milk production, the fat in the milk and the Ym6[6] factor, the greater the corresponding emission factor. On the other hand, the increase in digestibility decreases it. This analysis, in qualitative terms, also applies to other classes of cattle (males, females and other ages), however, what is not perceived here is the direct relationship between the parameters.

4 The following values were considered, based on data from the national inventory: Digestibility (DE): 68.4%; Weight (W): 508 kg; Pregnancy rate (PR): 60%; Milk production (MP): 7.24 L/day; Milk fat (MF): 4.0%; Daily weight gain (WG): 0 kg/day; Mechanical working hours (H): 0 h; Methane conversion factor (Ym): 6.5%.

5 For Methodology used to estimate Enteric Fermentation emissions in the Fourth National Inventory, based on the (2006) IPCC, and which provides some methodological updates in relation to previous editions. The IPCC (2006) recommends the use of a 6.5% Ym factor for the conversion of energy consumed in methane for cattle that graze normally, but when fed in the trough with a diet of more than 90% concentrate, this factor drops to 3.0%. The IPCC warns that there is sparse data for this factor considering tropical pastures, as is the case in Brazil.

Figure: Analysis of the impact of the variation of some parameters (individually) used to calculate the enteric fermentation emission factor, based on the animal category of high production dairy cows, from the state of Minas Gerais in 2016



The exercise carried out in the example raises the question: "Would productivity be linked to lower emissions?" If increases in weight, milk production and percentage of fat in milk - which means greater productivity - are linked to higher emissions, the key may be to be concerned with digestibility and the Ym factor. It is necessary to consider how much the increase in digestibility (which influences the decrease in emissions) will increase the factors weight, milk production and percentage of fat in the milk (which influence the increase in emissions), in order to have a clear relationship between productivity and emissions. In addition, further research is needed in Brazil on how the Ym factor is affected by the other parameters, in the Brazilian reality.

It is true that the productivity of livestock systems is strongly related to animal digestibility and this, in turn, is influenced by the quantity and quality of the pasture consumed by each animal. Thus, degraded pastures, in addition to needing a larger area for animal use, are generally less useful. Still, the total equation between productivity and emission reductions needs to consider the cost factor. What investment is needed to increase productivity and reduce emissions? What would be the optimum for each type of cattle management?

Regardless of these doubts, Brazil has been committed to and advanced in increasing animal productivity and in improving the transparency of estimated emissions in each edition of the National Inventory, always incorporating new research, use of factors and parameters that reflect regional conditions, application of more up-to-date methodologies and elaboration of more complete reports, thus allowing greater accuracy of national emissions and stimulating the continuity of scientific advances on the part of other researchers, contributing to national and worldwide scientific development.

References

BRASIL. Ministério da Ciência, Tecnologia, Inovações e Comunicações. Secretaria de Políticas para a Formação e Ações Estratégicas. Coordenação-Geral do Clima. Estimativas anuais de emissões de gases de efeito estufa no Brasil. 5. ed. Brasília: Ministério da Ciência, Tecnologia, Inovações e Comunicações, 2019.

IPCC – Intergovernmental Panel on Climate Change. IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H. S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Japan: IGES, 2006.

Author information

Giovanna Lunkmoss de Christo – Ministério da Ciência, Tecnologia e Inovações; mail: giovana.christo@mctic.gov.br

Mauro Meirelles de Oliveira Santos – Ministério da Ciência, Tecnologia e Inovações; mail: mauro.santos@mctic.gov.br

1 EMISSION AND REMOVAL FACTORS FOR SMALL RUMINANTS

Factors for emission and removal of greenhouse gases from the production of small ruminants in the national territory

Mirella Nogueira de Souza [1]; Diana Signor [2]; Eleneide Doff Sotta [3,4]; Katia Marzall [4]; Fernanda Garcia Sampaio [3,4].

1 Autonomous Consultant - Specialist in Climate Change and Agriculture;2 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Semiárido; 3 Empresa Brasileira de Pesquisa Agropecuária – Embrapa; 4 Ministério da Agricultura, Pecuária e Abastecimento.

Goat and sheep farming is a widespread activity throughout the national territory, with an especially high concentration of goat herds in the Brazilian semi-arid region. In Brazil, about 90% of the goat herd and around 60% of the sheep herd is located in the Northeastern Region, which comprises 92.5% of the country's semi-arid area.

According to the 2017 Agriculture Census of the Brazilian Institute of Geography and Statistics (IBGE), Brazilian goat farming reached a herd of 8.26 million heads, a 60% herd increase, when compared to the 2006 Census (IBGE, 2006, 2017). The largest herds of goats in the Northeast are in the states of Bahia, Piauí, Pernambuco and Ceará. The national sheep herd, according to the 2017 Census, is 13.7 million heads, showing a 2.8% reduction when compared to the 2006 Census. In the same region, sheep farming is concentrated in Bahia, Ceará and Piauí.

Due to the climatic characteristics of the Brazilian semi-arid region and the rusticity of goats and sheep, animal husbandry is the great vocation of the rain-dependent regions. Herds, mainly of small ruminants, are bred basically in extensive production livestock systems based on grazing in Caatinga areas in the rainy season, associated with the use of cultivated pastures adapted to the region's climatic conditions, during the dry season (VOLTOLINI *et al*., 2011). Thus, the animal production systems developed in the semi-arid region are based on silvopastoral environments. In addition, Voltolini *et al.* (2011) indicate that, in the Brazilian semi-arid region, the cultivation of legumes for the production of hay or silage to feed animals during the dry season of the year is also an important strategy for the coexistence of these production systems with drought. Alternatives like this can also translate into low-carbon livestock farming, thus aligning with the process of modernizing management practices that are already being observed in other regions of Brazil.

According to the 3rd National Inventory of Anthropogenic Emissions by Sources and Removal by Sinks of Greenhouse Gases (IN), sheep and goats participate in GHG emissions through enteric fermentation and the animal waste disposed in the soil. Also, according to the 3rd IN, sheep and goats are classified in the "other animals" category, for which emissions were estimated using the IPCC standard emission factors (EFp). According to the "IPCC Guide to National Inventories of Greenhouse Gases" (IPCC, 2006), the EFp Tier 1 for enteric fermentation of goats and sheep for developing countries is equivalent to 5kg CH_4/head/year, with the average weight for sheep and goats being 45 and 40 kg, respectively. However, it is worth mentioning that the IPCC itself points out an uncertainty in the order of 30 to 50% for these emission factors. For calculations of emission from waste deposits (feces and urine), CH_4 emissions according to the IPCC (2006), should be estimated using the following EFp: 0.22 kg CH_4 / head/ year for goats and 0.20 kgCH_4/head/ year for sheep, with uncertainties in the order of 30%. As for N_2O, the IPCC Guide proposes that emissions be estimated to be equivalent to 1% of the nitrogen deposited in the soil via feces and urine from goats and sheep, although the confidence interval varies from 0.1 to 3%.

Signor and Morais (p. 32) assessed GHG emissions from native Caatinga, Caatinga under goat grazing and grazed buffel grass, in the Brazilian Semiarid, and claim to have registered the highest $CO_2$and N_2O flows and the lowest CH_4 flows in the soil in association with rainfalls. The authors also investigated emission factors resulting from the deposit of goat manure on the soil, not observing significant changes in the CO_2, N_2O and CH_4, fluxes, due to the fact that low humidity in the soil in the Semi-Arid environment limits the decomposition of waste and the production of these gases.

Monteiro *et al.* (p. 34) evaluated different lamb and sheep production systems in southern Brazil, studying summer and winter pastures and their effects on enteric methane emissions, as well as the effect of sheep waste deposition on GHG soil emissions. Preliminary results show that the daily gross emission for weaned and supplemented lambs is around 14 g CH_4 day^{-1}, while for lambs finished without weaning and without supplementation, the daily gross emission ranges from 10g CH_4 day^{-1}(in winter pastures) to 6 g $CH_4 day^{-1}$(in summer pastures). Weaned, lactating and pregnant sheep were also evaluated. In this case, the daily gross emission varied between 18 g $CH_4 day^{-1}$ 1 (weaned sheep) and 20 g CH_4 day^{-1} (nursing sheep), in winter pastures. Thus, they claim that, in general, the breeding systems influence the different categories regarding the emission of enteric methane, which is also related to the animal's total dry matter consumption.

In the Brazilian semiarid, Voltolini *et al.* (p. 34) measured the emission of enteric methane by male goats, not castrated, reared in confinement and fed with different proportions of roughage/concentrate in the diet. CH_4 emissions ranged from 4.4 to 11. kg CH_4 $year^{-1}$. The authors concluded that methane emission per unit of body weight, metabolic weight and dry matter consumption decreased linearly with the increase in concentrate in the diet, results that show the influence of food management on the enteric emissions of goats.

Also in the semi-arid region, Voltolini *et al.* (p. 36) evaluated enteric methane emissions by Lacaune x Santa Inês ewes at the beginning of lactation, in three management systems: I) pasture without supplementation; II) pasture with ground corn grain supplementation; and III) grazing with cottonseed supplementation. In this case, the concentrate supplementation strategies did not promote a reduction in the sheep's enteric methane emissions. The authors deduce that good quality pastures contribute to lower enteric methane emissions. According to the authors, during the dry season in the Brazilian semiarid region, enteric methane emissions by adult goats of the Canindé and Repartido breeds, receiving supplementation and pasture, were similar and ranged from 18 to 51 g $CH_4 day^{-1}$.

Although responsible for the highest methane emissions to the atmosphere, ruminant animals can have the production of this gas managed, and may decrease emissions through factors related mainly to feeding.

Generally, foods with high digestibility lead to lower CH_4 emissions, compared to diets with low digestibility, which are more fibrous and have low levels of crude protein. Thus, the opportunity to consume better quality pastures can optimize rumen microbial growth, which positively affects fermentation efficiency and decreases gas production per unit of ingested and fermented carbohydrates (Berchielli *et al.*, 2012). This is an important aspect for sheep and goat production in Brazil, since most herds are raised on pasture as an important source of food. Furthermore, in the semiarid region, supplementation with better quality food during highest emission periods (dry period) and adjusting the quantity of animals to the forage offer are strategic tools for mitigating enteric CH_4 emissions by small ruminant herds.

In a context of climate change and an increase in extreme drought events in other regions of Brazil, this information will become increasingly strategic for the sustainability of agriculture, not only in the Northeast, but also in the rest of the country.

References

BOGGLIA, A.; PAOLOTTI, L.; CASTELLINI, C. Environmental impact evaluation of conventional, organic and organic- plus poultry production systems using life cycle assessment. World's Poultry Science Journal, v. 66, p. 95-114, 2010.

IBGE, Censo Agropecuário, 2006. The data can be accessed at: https://biblioteca.ibge. gov.br/visualizacao/periodicos/51/agro_2006.pdf

IBGE, Censo Agropecuário, 2017. The data can be accessed at: https://censoagro2017. ibge.gov.br/templates/censo_agro/resultadosagro/pecuaria.html.

IPCC Guidelines for National Greenhouse Gas Inventories, 2006. Available at: https://www.ipcc- nggip.iges.or.jp/public/2006gl/.

MCTI – Ministério da Ciência, Tecnologia e Inovação. Terceira Comunicação Nacional do Brasil à Convenção – Quadro das Nações Unidas sobre Mudança do Clima. – Volume III. Brasília: Ministério da Ciência, Tecnologia e Inovação MCTI, 2016. v. 3.

VOLTOLINI, T. V; SANTOS, P. M; CAVALCANTE, A.C.R; PEZZAPANE, J. R.M; MOURA, M.S.B; SILVA, T.G.F; BETTIOL, G.M; CRUZ, P.G. (2011). Mudanças Climáticas Globais e a Pecuária: Cenários Futuros para o Semiárido Brasileiro. Revista Brasileira de Geografia Física 06. pg 1176-1196.

GREENHOUSE GAS EMISSIONS (GHG) AND CARBON BALANCE IN A CAPRINE PRODUCTION SYSTEM IN THE CAATINGA BIOME

Diana Signor [1]; Salete Alves de Moraes [1].
1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Semiárido

This research comprised two actions: I) the monitoring of CO_2, CH_4 and N_2O emissions by the soil in the Caatinga-Buffel-Leguminosa (CBL) silvopastoral system, recommended by Embrapa Semiárido; II) the determination of the N_2O emission factors by the deposition of goat waste (feces and urine) in the soil. During the first phase, the emissions of three Greenhouse Gases (GHGs) were monitored in the areas grazed by animals in the CBL system were monitored: grazed Caatinga and Buffel grass. For comparison purposes, the emissions of the same GHGs in native Caatinga area were also monitored. Evaluations took place during a year, contemplating a dry season and a rainy season. During the second phase, two experiments were carried out, one in the rainy season (March and April) and the other in the dry season (October) to determine the N_2O emission factors due to the deposition of feces and urine of Canindé and Repartido goats on the soil. The first experiment compared N_2O emissions from the deposition of different doses of urine and feces on the soil (0%, 50%, 100% and 150% of the quantities produced per urination and goat defecation event). In the second experiment, emissions were compared using only the dose corresponding to 100% of the quantities produced per goat urination and defecation event.

RESULTS

Monitoring GHG emissions in the CBL silvopastoral system

- CO_2 flows in the areas ranged from -19.98 to 179.12 mg C-CO_2 m^{-2} h^{-1} and were similar across areas for most of the year, with differences only in the wettest months, with the lowest in these conditions being observed in the grazed Buffel grass area;
- CH_4 flows ranged from -24.17 to 113.87 μgC-CH_4 $m^{-2} h^{-1}$ and were similar between uses throughout the year;
- N_2O flows ranged from -510.79 to 343.15 μg N-$N_2O m^{-2}$ h^{-1} and there were also no differences between areas;
- The highest flows of CO_2 and N_2O and the lowest flows of CH_4 are associated with precipitation events, demonstrating that soil moisture is the main limiting factor for GHG emissions in the Brazilian semiarid region;
- The accumulated emissions of the three GHGs evaluated in areas under anthropic uses (Buffel and Caatinga grazed) were lower than those in the native area during the evaluation period.

Experimental testing of goat manure emission factors

- No differences were observed between the N2O, CH4 and CO2 flows of the soil due to the urine and feces treatments applied in neither of seasons evaluated;
- The amounts of nitrogen added via feces and urine in these experiments, as well as the soil moisture, were not sufficient to guarantee the production and emission of significant quantities of the studied gases;
- Therefore, the soil moisture conditions typical of the Caatinga limit the decomposition of manure and the production of these gases;
- It is likely that, due to the low humidity in the soil in the semi-arid environment, a longer observation time in studies of this nature is necessary for the conversion of organic N to mineral N in the soil during the decomposition of goat manure and then the denitrification process, allowing the observation and measurement of changes in soil GHG emissions.

CHALLENGES

- Monitoring long term GHG emissions in the production systems of the Brazilian semiarid region;
- Understand the mechanisms of GHG formation and their relationship with microbial soil communities in the production systems of the Brazilian Semiarid;
- Generate and validate livestock production models that are more productive, promote lower GHG

emissions and contribute to the adaptation to climate change of production systems in the Brazilian semi-arid region;

- Implement public policies and actions that favor the mitigation of GHGs in livestock production systems in the Brazilian Semiarid.

SOLUTIONS

- Structure laboratories, institutions and research groups for the determination of GHG emissions in the production systems of the Brazilian Semiarid region;
- Implement and monitor more efficient and sustainable production systems;
- Provide the research results for the formulation of public policies.

DATA PUBLISHED IN:

MEDEIROS, T. A. F. Gasesdeefeitoestufadosoloemumsistemasilvipastoril de caprinos de corte no sertão pernambucano. 2016. Dissertação (Mestrado em Ciências Veterinárias no Semiárido) – Universidade Federal do Vale do São Francisco, Petrolina, 2016.

SIGNOR, D.; MEDEIROS, T. A. F.; MORAES, S. A.; CORRÊA, L. C.; TOMAZI,

M.; MOURA, M. S. B. Soil greenhouse gases emissions in a goat system production in dryland Caatinga Biome, Brazil. Artigo em preparação (2019)

Figure: Chamber for monitoring greenhouse gas emissions in the soil in an area of Buffelgrass.

Crédit: Diana Signor.

PROJECT COORDINATORS

Dra. Salete Alves de Moraes

Embrapa Semiárido

e-mail: salete.moraes@embrapa.br

Dra. Diana Signor Deon

Embrapa Semiárido

e-mail:diana.signor@embrapa.br

GREENHOUSE GAS EMISSIONS (GHG) IN LAMB PRODUCTION SYSTEMS FOR MEAT IN SOUTHERN BRAZIL

Alda Lúcia Gomes Monteiro[1]; Claudio José Araújo da Silva[2]; Alexandre Berndt[3]; Henrique Mendonça Nunes Ribeiro Filho[4]; Ana Cláudia Ruggieri[5]; Cimélio Bayer[6]; Paulo César de Faccio Carvalho[6]; Leonardo Deiss[7]; Jonatas Tiago Piva[8]; Teresa Cristina Moraes Genro[9].

1 Universidade Federal do Paraná; **2** Universidade Tuiuti do Paraná; **3** Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pecuária Sudeste; **4** Universidade do Estado de Santa Catarina; **5** Universidade Estadual Paulista Júlio de Mesquita Filho; **6** Universidade Federal do Rio Grande do Sul; **7** Ohio State University; **8** Universidade Federal de Santa Catarina; **9** Empresa de Pesquisa Agropecuária – Embrapa Pecuária Sul.

This project included evaluations of sheep enteric methane emissions and soil gas flow, seeking to measure and understand the gas flow dynamics in sheep production systems most commonly used by farmers in order to calculate, in the medium term, carbon balance and net global warming potential in sheep production systems. Regarding the animal's methane emission, the objective was to evaluate the different finishing systems of pasture lambs, how and if they interfere in the sheep's methane emission and produce emission values for different animal categories (lambs - around 60 days old and 25 kg average weight - weaned ewes, lactating ewes and pregnant ewes). The experimental protocols were carried out in the years 2012, and between 2014 and 2017. The animals were organized in a randomized block design, ewes and lambs submitted to two treatments. The treatments (production systems) were: lambs weaned at 60 days and supplemented after weaning until slaughter (1) and lambs who were not weaned or supplemented until slaughter (2). These production systems are commonly used in southern Brazil. The ewes that were mothers of the weaned lambs were assessed in separate paddocks, where the same pasture was considered. The predominant forage species were black oats (Avena strigosa) and annual ryegrass (Lolium multiflorum Lam.) in addition to Tifton 85 and Paspalum spp, during some periods of the year. The CH_4 gas, measured using the SF_6 tracer gas technique, was collected through vacuum-emptied cylinders, with a collection tube adjusted to the animal's head and body. The CH_4 and SF_6 analyses were determined by gas chromatography conducted in one of the associated laboratories, at the Federal University of Rio Grande do Sul (2012) and at the Sao Paulo State University in Jaboticabal (2014-2018). Individual and per kg of animal product emissions are described in the theses and dissertations published, in detail, below. In addition to the emission of animal gases, GHG emissions from animal waste deposited in the soil were also measured along with the flow of N2O and CH4 gases from the soil in pastoral areas in the two lamb production systems, which are also described in the results (productive cycles from 2015 to 2018). Based on this, the results on carbon and nitrogen stocks in the soil are being assessed, as well as the estimated net global warming potential. In general, it can be said that the lamb production systems influence the ingestive behavior, the dry matter intake and the emission of enteric methane from lambs and ewes in the different categories. The set of soil gas emission data is still under analysis.

RESULTS

The daily gross emission of methane for lambs weighing around 20 kg, weaned and supplemented with concentrated feed after weaning, was around 10 to 15 g (in summer and/or winter pastures), due to the concentrated feed consumption supplementing systems. For lambs finished without weaning and without supplementation, the daily gross emission was around 6 g. In the case of ewes, the daily gross methane emission varied between 18 g (weaned ewes) and 20 g (suckling ewes) in winter pastures. Summer and winter foraging species, influenced the levels of emission. It was observed for both categories, ewes or lambs, that the emission was strongly related to the total dry matter intake.

CHALLENGES

- Limited resources available, especially in equipment (permanent material);
- Challenge in the application of methodology to measure the methane emission of animals in pastures, with the use of SF6 (sulfur hexafluoride); the methodology is subject to many factors related to the environment, generating variable results;
- High cost of carrying out field research and laboratory analysis;
- Limited resources for publishing in high impact international journals;
- Recent limitation in number of doctoral and postdoctoral fellowships for Federal Universities, which limits the work of the team that develops the projects, which are highly demanding in terms of high quality human resources.

SOLUTIONS

- The solution that made the research feasible, given the limited resources for consumable materials, permanent material and scholarships, was to work in collaboration with teams from other universities and with Embrapa:
- Embrapa Pecuária (Livestock) Sudeste, São Carlos - SP;
- State University of Santa Catarina (UDESC), Laboratório de Análises Químicas e Bromatológicas, Lages – SC;
- Universidade Federal de Santa Catarina (UFSC), Curitibanos – SC;
- Universidade Estadual Paulista (Unesp), Jaboticabal campus, Animal Nutrition Laboratory, where all chromatographic analyses of samples of SF_6 collected in the field (more than 300 analyses) were carried out;
- Universidade Federal do Rio Grande do Sul, Laboratório de Biogeoquímica Ambiental, Departamento de Solos, where all chromatographic analyses for the samples of the gases (methane (CH_4),carbon dioxide (CO_2),and Nitrate (N_2O) from the soil were carried out.

DATA PUBLISHED IN:

FARO, A. M. C. F. Consumo de forragem e emissão de metano entérico em sistemas de produção de cordeiros em pastagens. 2017. Tese (Doutorado em Agronomia) – Programa de Pós-Graduação em Agronomia, Universidade Federal do Paraná, Curitiba, 2017.

HENTZ, F. Avaliação de produtividade e emissão de metano, resultado econômico e validação de sistemas de terminação de cordeiros. 2015. Tese (Doutorado em Agronomia) – Programa de Pós-Graduação em Agronomia, Universidade Federal do Paraná, Curitiba, 2015.

PERES, M. T. P. Padrão de pastejo e emissão de metano ruminal por ovinos em sistemas de terminação em pastagens. 2018. Dissertação (Mestrado em Agronomia) – Programa de Pós-Graduação em Agronomia, Universidade Federal do Paraná, Curitiba, 2018.

Continued in Annex

Figure: Sheep in the non weaned production system

Crédit: Mylena T. P. Peres.

PROJECT COORDINATORS

Dra. Alda Lúcia Gomes Monteiro

Federal University of Paraná

e-mail: aldaufpr@gmail.com

ENTERIC METHANE EMISSIONS FROM SHEEP AND GOATS IN CAATINGA BIOME PRODUCTION SYSTEM

Tadeu Vinhas Voltolini[1]; Salete Alves de Moraes[1]; Diana Signor Deon[1].

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Semiárido

This line of research comprised three experimental trials. The first with the objective of evaluating the productive performance, the consumption and digestibility of nutrients and the methane emission of goats in feedlots fed with different proportions of roughage/concentrate in their diets. The second, aiming to evaluate the consumption of food and nutrients, ingestion, milk production and methane emission from sheep raised in Tifton 85 grass pastures and subject to different supplementation strategies. And the third trial, where the consumption, digestibility and methane emission of goats grazing in the Caatinga in the dry and rainy periods of the year were evaluated. In experimental trial 1, five proportions of roughage/concentrate (100/0, 80/20, 60/40, 40/60 and 20/80) were used, based on dry matter and 40 un castrated male goats with initial average body weight of 13.3 kg distributed in a completely randomized design, with five treatments and eight repetitions. Tifton 85 hay was used as fodder and ground corn and soybean meal were used as concentrate. The sulfur hexafluoride tracer gas technique was used to estimate methane emissions. The experimental period lasted 72 days, including 15 days of adaptation. Assessments of the methane emission estimate were initiated on the 36th day of confinement. 10 animals were used (2 per treatment) to estimate the methane. Sampling was carried out for five consecutive days, with the change of tubes every 24 hours. Experimental trial 2 observed twelve Lacaune x Santa Inês ewes during the 11th week of lactation, weighing 43.1 kg at the beginning of the study, kept in Tifton 85 irrigated pasture, in a 3x3 quadruple Latin square experimental design with 12 animals, totaling 36 observations for each variable, lasting for three 21-day experimental cycles. The 3x3 double Latin square with six animals and 18 observations was used only to determine the enteric methane emission. The experimental period lasted 63 days divided into three 21-day subperiods. Three diets were evaluated, being: I) Pasture: irrigated Tifton 85 grass without supplementation; II) C. Corn: Pasture of irrigated Tifton 85 grass with concentrated supplementation based on ground corn; III) C. Cotton: Pasture of irrigated Tifton 85 grass with concentrated supplementation based on cottonseed. In this study, the sulfur hexafluoride tracer gas technique was also used to estimate methane emissions. The third experimental trial, observed 24 adult goats, 12 of the Canindé breed and 12 of the Repartida ecotype distributed in an experimental design arranged in subdivided plots, with the genotype (Canindé and Repartida) being the plot and the time of year (dry and wet seasons) the subplot, where every treatment was repeated three times. In the dry season the goats were supplemented with concentrate. The sulfur hexafluoride tracer gas technique was used to estimate the methane emission.

RESULTS

Experimental trial 1

- The increase in the proportion of concentrate in the diet provided greater weight gain and feed efficiency for goats;
- The methane emission per unit of body weight, metabolic weight and dry matter consumption decreased linearly with the increase in concentrate in the diet;
- Methane emissions from feedlots were estimated at 12.1 to 31.0 g/day.

Experimental trial 2

- Supplementation strategies promoted similar total dry matter consumption. The ewes fed exclusively with pastures showed higher forage consumption when compared to supplemented ones;
- Supplementation strategies (concentrates based on corn or cottonseed) did not influence the enteric methane emission of the sheep;
- Methane emissions from sheep in pastures of Tifton 85 grass without supplementation or receiving concentrate were estimated at 32.2 to 33.9 g/day.

Experimental trial 3

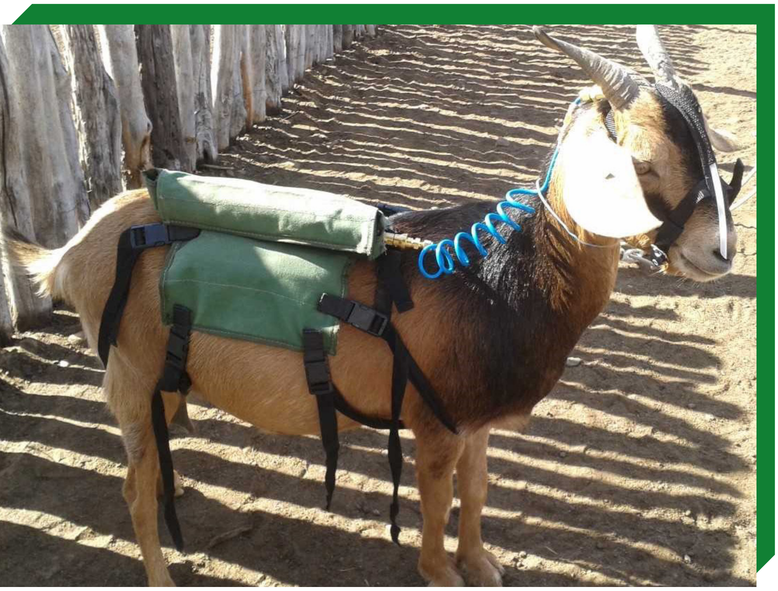
- Diet intake and digestibility were similar for the two goat genotypes evaluated. Consumption of dry matter, organic matter and neutral detergent fiber were higher in the dry period. On the other hand, the digestibility of dry and organic matter was higher in the rainy season;

- Methane emissions were similar for goats of the Canindé and ecotype Repartida breeds, in the dry and rainy seasons as well;
- Methane emissions from goats grazing in the Caatinga ranged from 18 to 51 g/day.

CHALLENGES

- Structuring laboratories, institutions and research groups to determine methane and other GHG emissions in the production systems of the Brazilian semiarid region and promoting actions that encourage the training of human resources in the area;
- Generating and validating livestock production models that are more productive, promote lower GHG emissions and contribute to Brazilian production systems' adaptation to climate change in the semi-arid region;
- Implementing public policies and actions that favor the mitigation of GHGs in livestock production systems in the Brazilian Semiarid.

Figure: Goat with apparatus for estimating methane emissions.



Crédit: Layse Gordiano

SOLUTIONS

Experimental trial 1

- Increasing concentrate in the diet improves productive performance and reduces the emission of methane from goats in feedlots;

Experimental trial 2

- The supply of 500 g of corn grain or cottonseed concentrate did not promote a reduction in the methane emission of sheep grazing in Tifton 85 grass pastures. Good quality pastures already contribute to lower methane emissions;

Experimental trial 3

- Canindé and Repartida breed goats grazing in the Caatinga in the dry and rainy periods have similar methane emissions.

DATA PUBLISHED IN:

BARBOSA, A. L.; VOLTOLINI, T. V.; MENEZES, D. R.; MORAES, S. A.; NASCIMENTO, J. C. S.; RODRIGUES, R. T. S. Intake, digestibility, growth performance, and enteric methane emission of Brazilian semiarid non-descript breed goats fed diets with different forage to concentrate ratios. Tropical Animal Health and Production, v. 50, n. 2, p. 283-289, 2018.

GORDIANO, LA Methane emission by goats grazing in the caatinga, in the dry and rainy periods. 2015. Dissertação (Mestrado em Ciência Animal) – Universidade Federal do Vale do São Francisco, Petrolina, 2015.

NOGUEIRA, G. H. M. S. M. F. Produção de leite e emissão de metano entérico de ovelhas mantidas em pastagens com diferentes suplementos. 2019. Dissertação (Mestrado em Ciências Veterinárias no Semiárido) – Universidade Federal do Vale do São Francisco, Petrolina, 2019.

PROJECT COORDINATORS

Dr. Tadeu Vinhas Voltolini

Embrapa Semiárido

e-mail: tadeu.voltolini@embrapa.br

Dra. Salete Alves de Moraes

Embrapa Semiárido

e-mail: salete.moraes@embrapa.br

Dra. Diana Signor Deon

Embrapa Semiárido

e-mail: diana.signor@embrapa.br

2 EMISSION AND REMOVAL FACTORS FOR LARGE RUMINANTS

Evaluation of emission and removal factors of large ruminants and their integration in the Brazilian agricultural policy

Mirella Nogueira de Souza[1]; Patrícia Perondi Anchão Oliveira[2]; Alexandre Berndt[2]; Eleneide Doff Sotta[3,4]; Mariane Crespolini[4]; Katia Marzall[4]; Fernanda Garcia Sampaio[3,4]

1 Autonomous Consultant - Specialist in Climate Change and Agriculture; 2 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pecuária Sudeste; 3 Empresa Brasileira de Pesquisa Agropecuária – Embrapa; 4 Ministério da Agricultura, Pecuária e Abastecimento.

Social and economic relevance

Agriculture is an extremely relevant sector for the Brazilian economy, contributing 21% of the 2019 national GDP. In addition to the importance in GDP, in the same year, more than 43% of Brazil's total exports were of agriculture and livestock products. As a result, more than 18.2 million people were employed, of which 45.3% worked on rural properties (Cepea, 2020).

Livestock production is fundamental in this context, contributing 31.5% of the sector's GDP (Cepea, 2020). It is also very relevant in exports. Initially a shy exporter in the mid-90s, Brazil is currently leading in beef exports. It is important to note that less than 25% of everything that is produced is destined to the international market and, even so, the country exports 60% more than Australia, which is the second largest exporter in the world, with almost 70% of production dedicated to exports (Abiec, 2020).

In the last two decades, beef and dairy cattle production has been transformed positively. From 1997 to 2015, the longest comparison when compared with the last year of available data, the total herd of cattle grew 33%, reaching 213.5 million heads. Beef production increased 124.7% and milk production 125.2% (IBGE, 2020). In the same period, the pasture area grew by only 9% (Lapig/UFG, 2020). As a result, comparing Lapig data with IBGE data, livestock productivity when assessed by area used for beef cattle production grew 107%.

In this brief introduction, it should be noted that when comparing 1997 with 2015, enteric fermentation increased 31% (Sirene/MCTIC, 2020). In other words, the increase in emissions resulting from the production of beef cattle and milk was very closely aligned to the growth of the herd. However, when comparing official databases, it appears that there was a large reduction in total emissions per kilo of meat or per liter of milk.

Providing products that ensure food security, in line with major global trends for the sector, such as climate change, is very strategic. Thus, this Compilation contributes greatly to science by bringing together diverse research, in different regions of a continental country like Brazil, presenting the factors responsible for the reduction in emissions from livestock production.

Advances in accounting for emissions

Due to the natural processes of rumination, cattle emit methane (CH_4) to the environment. CH_4 is the most relevant gas in accounting for emissions in the agricultural sector. As a result, enteric fermentation is one of the most representative activities in the national greenhouse gas emission (GHG) inventories of producing countries.

In countries where herd size is significant and also where livestock is an important economic activity, a significant contribution of methane of enteric origin is expected in total accounting for GHG emissions.

It is also worth mentioning that although CH_4 has a high GWP - Global Warming Potential , it remains in the atmosphere for a much shorter time than other GHGs. In addition, enteric CH4 is a biogenic gas (of non-fossil origin). Therefore, it is a carbon that can naturally reintegrate into the system through photosynthesis.

In order to comply with the processes established in the IPCC Guidelines for accounting for emissions in national inventories, emissions resulting from enteric fermentation can be accounted for with different methodologies, varying: i) the multiplication of the size of the herd (in heads) versus EFp (Factors Emissions), used mostly by countries that do not yet have defined EFs (Tier 1); ii) more accurate and precise accounting taking into account the national conditions, which consider, among other factors, the animal categories, the breeding condition, the purpose of production and digestibility (Tier 2); or iii) the measurement of emissions in controlled chambers or by experimental apparatus used in natural conditions (pastures, for example), in which the volume of gas issued by an animal is measured under different conditions (Tier 3).

In addition to enteric CH_4, livestock emissions also directly account for CH_4 resulting from the decomposition of animal waste (feces and urine) under anaerobic conditions, which vary according to their treatment or disposition, and nitrous oxide(N2O) arising from direct deposition of waste in the soil.

Indirect emissions of manure in livestock, resulting from leaching, are also accounted for, but represent a smaller portion. An example is the calculation of direct urine deposits in pastures and, indirectly, the use of animal waste as fertilizers deposited in crop farming areas. As with enteric fermentation, livestock manure management accounting may use IPCC standards or be specific to national conditions, varying according to data available in the country.

According to the IPCC Guides (2006), for calculation in the national GHG inventories, the EFp of CH_4 for beef cattle is 56 kg of CH_4 per animal per year, considering a 430 kg animal as reference for body weight. For N_2O the EFp direct form is: 1% of the N applied in the form of fertilizers lost as N_2O (EF1) and 2% of the N excreted via urine and feces emitted in the form of N_2O (EF3). While in the indirect form they are: 1% of the volatilized N lost as N_2O (EF_4) and 0.75% of the N leachate emitted as N_2O (EF5).

The IPCC EFp percentages refer to values established by experts based on surveys that were carried out up to 2006. However, it is recommended that each country determine its local FEs by climate region and specific production systems in order to correctly estimate GHG emissions.

Brazil in recent years has been working on improving its EF focusing on understanding the influence of herd management and the adoption of different particular technologies for tropical agriculture. Subsidized by many studies from researchers and research groups in different institutions, with their respective scientific production. Results of these surveys have allowed progress to be made in improving the accounting for national emissions.

The papers received for the chapter on large ruminants show a diversity of results from studies carried out throughout the national territory. In addition to the definition of EF, the work also demonstrates the influence of strategies that manage GHG emissions, delivering valuable material that will allow Brazil to continue making progress in improving the efficiency of production systems, contributing to the sustainable growth of national livestock production, while also reducing and controlling GHG emissions.

Scientific contributions to understanding the dynamics of emissions from cattle farming

The contributions received for the chapter on large ruminants in the Compilation were relevant in evaluating the enteric CH_4 and N_2O emissions from beef and dairy cattle as well as buffalos. Due to the wide variety of factors and elements influencing emissions and/or removals of gases in each production system, the contributions for this chapter made it possible to identify some of the issues and gaps in knowledge regarding the real contribution of Brazilian livestock production systems to GHG emissions.

Sakamoto *et al*. (p. 54) emphasize that, due to the diversity of production systems, bovine breeds, genetic groups and diets, it is difficult to establish average technical coefficients that represent all of Brazil. The authors studied the intensity of CH_4 emissions for crossbred Canchim, Angus and Charolais cattle in confinement during finishing phase, showing that the different classification by heterozygosis influences both CH_4 emissions and animal performance.

A close look at the research presented shows that studies are being carried out for different production systems in different regions of the country. For example, in the interior of São Paulo, Reis *et al.* (p. 46) has been quantifying enteric CH_4 emissions in animals reared on pastures with different supplements and supplementation strategies. The authors present studies in which they evaluated enteric CH_4 emissions for beef cattle grazing and receiving mineral supplementation. They found that CH_4 production obtained, both in relation to pasture management and residual food consumption, was similar to the IPCC's EFp.

On the other hand, in the Cocais Maranhenses region, Middle North of Brazil, Frota *et al.* (P. 84) evaluated the enteric emissions of ½ Curraleiro-Pé-Duro breed x ½ Nellore breed cattle in silvopastoral systems of Mombasa grass and babassu palms and compared them to cattle grazing in monoculture. The authors concluded that methane emissions, in general, vary according to the time of year, being influenced by the quality of the pasture and by animal consumption, reporting emissions of 45 kg of CH_4 year^{-1} in the dry season and 70 kg of CH_4 year^{-1} in the rainy season. The study also highlights that, in relation to systems in the rainy season, the emission intensity in silvopastoral systems was three times lower than in full sun, an effect potentiated even more in the dry period.

The relation with the time of year was also studied by Ribeiro-Filho (p. 54), who presents a set of studies on GHG emissions in different beef and milk production systems in the south of the country. In work evaluating the inclusion of annual winter and summer pastures in dairy cow diets. The results suggest that the inclusion of annual winter pastures in diets of Holstein × Jersey dairy cow crossbreeds, ingesting total mixed ration of corn silage, reduced CH_4 emissions by more than 25% due to the quality of the forage produced. Under these same conditions, the inclusion of annual summer pastures increased the intensity of CH_4 emissions by less than 5%.

Supplementation with Acacia mearnsii extract is also explored by several authors. Ribeiro-Filho (p. 54) found that this supplementation for dairy cows reduced the emission intensity by approximately 40%. Meanwhile, Perna Junior *et al*. (p. 50) evaluated the use of different levels of tannins (*A. mearnsii*) as a food additives for female Nellore and Holstein cattle and found that the levels of the additive caused a linear reduction in ruminal CH_4 production in both breeds, reaching a 26% reduction for the highest doses of tannin. Despite the authors pointing out the possibility of using the A. mearnsii extract as an additive, in low dosages, to reduce ruminal CH_4 production for Taureans and Zebu cattle, they point out that the reduced digestibility of the diet with increased levels of tannin contributes negatively to feed efficiency. They also highlight the importance of finding a food additive that reduces emissions while promoting improvements in animal performance.

Although less representative of the total Brazilian herd, studies involving buffaloes have also been carried out in Brazil, mainly in the Northern region. Amaral Junior *et al.* (p.90) evaluated the enteric CH_4 emissions of buffaloes in the eastern Amazon consuming different levels of palm kernel pie, and observed a decreasing linear effect in the estimate of CH_4 emission due to the inclusion of the supplement.

In order to set up a database of individual records of enteric methane emission (CH_4, g/day), average daily gain (AWG, kg/day), dry matter consumption (CMS, kg/day) and live weight (PV, kg), of Nellore cattle after weaning, Mercadante *et al*. (p. 58) presented a series of studies of individual means of enteric methane emission in Nellores (weight ranging from 365 to 468 kg) in supplemented pasture and feedlot systems. The authors state that there is a negative relation between performance characteristics and feed efficiency and methane emission values.

The evaluation of integrated production systems has contributed to the understanding of interactions and compensations within the system itself. Figueiredo *et al.* (p. 64) argues that the conversion of degraded pastures to well-managed pastures and the introduction of ILPF can reduce GHG emissions associated with the production of beef cattle on pastures, in terms of kg of CO_2eq emitted per kg live weight produced. This reduction is mainly due to the improvement of pastures and increases in livestock production and the favoring of the technical potential for sequestering C in soil and in biomass.

However, there are still issues of livestock production in integrated systems that require further studies. Guimarães Junior *et al.* (p. 114) point out that integrated systems, based on first year pasture, were more efficient, as they presented lower values for the indicators for energy loss from the diet via enteric fermentation and CH_4 emission per kg of DM ingested. The authors analyzed sustainability indicators for Nellore heifer production systems (279 kg ± 21.4 live weight) in the Cerrado biome in the following systems: crop-livestock, crop-livestock-forest and degrading pasture. Heifers raised in ICLF emitted more methane per kilo of dry matter ingested and, consequently, presented greater losses of crude energy in the form of methane (6.15% in the drought and 8.65% in the rainy season) compared to the other systems studied. Emissions of enteric methane were affected by the periods of the year, with higher gross emissions (g/day and kg/year) in the rainy season.

Likewise, Pontes *et al.* (p. 88) evaluated the balance between GHG emissions and carbon accumulation in two integrated crop livestock production systems (ICLS): crop-livestock integration (ICL) vs. crop-livestock-forest integration (ICLF), with two doses of nitrogen fertilization. The CH_4 emission per unit area varied significantly due to variations in animal load. In terms of CO_2eq, the study found values below what is found in the literature on CLI and CLF systems, suggesting a greater productive efficiency of the systems. The research also highlights the potential for sequestering C in the trees, neutralizing the CH_4 emission in the integrated systems studied.

It is important to highlight the great contribution of the study that evaluates GHG emissions in integrated production and pasture systems. Bergier *et al.* (p.70) affirm that enteric emissions of Nellore cattle grazing in farm pastures located in flood plains (like the Pantanal) can be considered null due to the balance of landscape emissions.

In native fields in the south of the country, Genro *et al.*(p.84) evaluated the CH_4 emissions of Hereford beef steers during rearing and finishing, grazing in natural pastures, with different levels of intensification. The authors point out that the average amounts of CH_4 emissions per animal are below the amounts proposed by the IPCC for this animal category, which is 70 kg/year.

Regarding this, Oliveira *et al*. (2020) carried out an experiment to investigate the C balance (tCO_2e./ha.year), the intensity of C emission (kg CO_2e./kg live weight or carcass), and the C footprint (tCO_2e./ ha.ano) in pastoral beef cattle production systems, inside the farm, considering the necessary inputs in adopting the technologies of the different degrees of intensification evaluated. The results obtained were used to calculate the amount of trees that should be planted in the production systems to mitigate GHG emissions in each evaluated system. GHG emissions and the C balance were calculated using the GHG global warming potential proposed in AR4 (IPCC, 2007) and AR5 (IPCC, 2013) for two years. Forty-eight garrote cattle were allocated to the four pastoral production systems: DP (Degraded Pasture), IAL (Irrigated with high stocking), SAL (Rainfed with high stocking), and SML (Drying with medium stocking). The rainfed systems (SAL and SML) presented the following smaller C footprints (-1.22 and 0.45 tCO_2e./ha.year, respectively), with C credits for SML, when using AR4 GWP. The IAL system showed less favorable results for the C footprint per unit area (-15.71 t CO_2e./ha.year), but when the results wereexpressed by annual weight gain they were much more favorable (-10.21 kgCO_2e./kg live weight) because of the high weight gain obtained per unit area in these production systems. Although the degraded pasture system showed an intermediate result for the C footprint (-6.23 tCO_2e./ha.year), the result was the worst when the index was expressed in relation to the annual live weight gain (- 30.21CO_2e./kg Live Weight), because in addition to animal's GHG emissions in this type of pasture, there was still GHG emission due to the loss of soil organic matter and C stock. As a result of these results, the SML and SAL presented a C credit equivalent to the growth of 6.27 and 1.08 eucalyptus trees per garrote cattle head, while the degraded and irrigated systems would require the planting of 63.89 and 29.11 trees per head to mitigate their emissions.

According to Oliveira *et al*. (2020), livestock systems based on degraded pastures should be avoided. They have low productivity and high environmental impact, especially when considering the intensity of the C footprint. In addition, these systems do not use the land rationally. The recovery and intensification of pastures in livestock systems simultaneously improve C sequestration and GHG mitigation, and, in addition, have a land-saving effect.

Volk *et al.* (p. 98) conducted research activities that characterize the carbon and organic nitrogen stock and the GHG soil emissions as well as the relationship with vegetation and animal management. Emissions in a native field area with Hereford steers in natural pasture, fertilized natural pasture and fertilized natural pasture with ryegrass were evaluated. The researchers found that there is a positive relationship between the C and N stock in the soil and the root mass, indicating that the correct animal grazing management leads to an increase in the production of roots and the stocks of organic C and N in the soil.

The same is observed by Segnini *et al*. (p.106) demonstrating the potential for mitigating GHG emissions due to the intensive management of tropical pastures, stating that the humification indexes showed the presence of more labile C in pastures with a higher accumulation of C, indicating the recent accumulation of C organic matter resulting from adequate pasture management.

In relation to N_2O emissions the climatic conditions of the seasons are again pointed out as an important factor in defining EF. Ruggieri *et al.* (p. 68) analyzed the emissions in cattle farming systems on tropical pastures considering the effect of seasons, type of excreta, pasture management and fertilization strategies.

Experts point to the difference in emission factors depending on the type of excreta (feces or urine) and the influence of the climatic season on the urine emission factors, being that emissions are higher in the rainy season, than in the dry season. The authors also suggest the urine emission factor of 0.67% and feces of 0.41% of the applied N, well below the 2% recommended by the IPCC.

Diekcow *et al*. (p. 66) quantified nitrogen EF in the form of bovine urine and manure N_2O (Holstein and Jersey dairy cows) applied to pastures of kikuyu (*Pennisetum clandestinum*), brachiaria (*Brachiaria humidicola*) and aries grasses (*Panicum maximum*) in Cambissolo Háplic Cambissoil in the South of Brazil (Pinhais-PR), and found that the manure EF was lower than the urine EF. The authors point out the need to revise the 2% EFp (EF3) for urine and manure for the subtropics since there is a difference between urine and manure EF, thus demanding disaggregation.

The various studies gathered here demonstrate the importance of joining efforts to more quickly progress in obtaining results that represent the variety of systems that exist in the country. The difficulty in accessing financial resources to cover the expenses in developing such studies, as well as the reduced number of human resources, were obstacles that authors recurrently mentioned throughout studies. Despite this, these difficulties have led the countless researchers, spread across the country, to work in groups to optimize the use of equipment and trained labor.

Main challenges and solutions

Research in several areas should be promoted in order to leverage strategies that increase livestock productivity and sustainability, while contributing to the reduction of GHG emissions. The main challenges pointed out by the different research groups were related to the methods of determining GHG emissions, the high costs and the requirement for technical capacity.

Thus, it is worth noting that the studies presented, coming from several research institutions, demonstrate that Brazil needs to continue investing resources to continue and improve research and innovation in the area. In addition, other challenges were pointed out, such as the need to find additives that reduce ruminal methane emissions without decreasing animal performance or influencing waste emissions. The need for additional efforts was also highlighted in order to better understand more intensive pasture management, in different productive systems and their potential for sequestering C in biomass and soil; the need to include analysis of the sequestration and carbon stock in the soil to obtain more accurate estimates of the carbon balance; and to carry out studies in the different conditions and regions of the country.

One of the great contributions of the works presented in this Compilation are notes of technological solutions that contribute to improving the productivity of the agricultural production system, in addition to mitigating GHG emissions. Among the available solutions, we can highlight the genetic improvement and adequate management of pastures as strategies that allow an increase in the productivity and the efficiency of the herds.

Adequate pasture management was pointed out as a crucial element to controlling cattle GHG emissions. According to Congio *et al.* (p. 60) strategic pasture management, represented by the pre-grazing goal, determines the best food value of tropical pastures, higher milk productivity, better land use and additionally, mitigates enteric CH_4 and N_2O emissions from the soil. The same authors point to monitoring the height of pastures as a practical, easy, cheap and reliable solution to increasing profitability of production systems and reducing emissions.

The recovery of degraded pastures and adoption of appropriate management technologies was also pointed out by Figueiredo *et al*. (p. 64) which highlights that the introduction of ICLF systems in recovered areas can reduce the associated GHG emissions emitted per kg of livestock produced. Pasture management techniques are also important for natural pastures, which when well managed have the potential to produce quality meat with lower CH_4 emission values (Genro *et al*.; p.84).

Alternatives to intensify production systems, with a minimum and rational increase in the use of inputs and natural resources, through nutritional management strategies for the animals' diet (use of concentrated feeds, additives and supplements, among others) and pasture (introduction of legumes in production systems, efficient use of fertilizations, genetic improvement seeking better quality forage), can optimize the use of forage and the consumption of digestible dry matter in order to improve the use of natural resources and at the same time mitigate environmental impacts.

Furthermore, the correct management of soil conservation and fertilization are fundamental to promote the increase in the production of biomass from plants, a practice that stimulates carbon sequestration, removing carbon dioxide from the atmosphere by increasing photosynthesis. Thus, increasing carbon accumulation in soil, a fact that reduces greenhouse gas emissions. In general, as stated by Berndt *et al.* (p. 98) more intensified livestock production systems produce more meat with the same methane emission intensity.

Sustainable intensification of production has been the main Brazilian strategy for promoting production technologies that lead to the adoption of more efficient production systems. Thus, the production of food, fibers and energy reaches the tripod of sustainability. Economically, it reduces the marginal cost of production, improving the profitability of the producer and encourages him to continue adopting good practices. Socially, in addition to employing more people, it also tends to qualify them, generating several positive impacts for the region. This, not to mention the greater price stability throughout the year. And, environmentally speaking, it increases production in already anthropized areas, further contributing to reducing the intensity of emissions.

Accounting for emissions from cattle farming

GHG emissions represent only part of the characteristics of livestock production systems, as it is also important to know the "outputs" or products (meat, milk, wool or labor) obtained in that production system. Emission intensity, or the carbon footprint, expressed in kilograms of equivalent CO_2 issued (kg CO_2eq) per kilogram of equivalent carcass (kg CARCeq) produced in a given production model can vary significantly depending on the calculation methodology employed and the level of technology adopted by the producer.

In relation to the gross ethane emission (kg/year), Brazilian production has been increasing over the years, due to the increase in the cattle herd in the country, which, in turn, has guaranteed food security in Brazil and in several countries of the world.

Between 1997 and 2014, the cattle herd increased by 32% (IBGE, 2018). Methane production increased by 29% (MCTIC, 2016). However in this same period the emission intensity levels (kgCO_2eq./kg CARCeq) decreased due to higher animal productivity. This demonstrates that the use of technologies aimed at increasing production rates results in actions that mitigate GHG in livestock.

References

ABIEC – Associação Brasileira das Indústrias Exportadoras de Carne. Perfil da Pecuária no Brasil 2020. Available at: http://abiec.com.br/publicacoes/beef-report-2020/

CEPEA – Centro de Estudos Avançados em Economia Aplicada – ESALQ/USP – PIB do Agronegócio- Available at:https://www.cepea.esalq.usp.br/br/pib-do-agronegocio-brasileiro.aspx

IBGE – Instituto Brasileiro de Geografia e Estatística. Produção da pecuária municipal. Rio de Janeiro: IBGE, 2020.

IPCC – Intergovernmental Panel on Climate Change, 2006. IPCC Guidelines for National Greenhouse Gas Inventories. Agriculture, Forestry and Other Land Use (vol. 4). Available at: http: //www.ipcc -nggip.iges.or.jp/public/2006gl/vol4.html.

IPCC - Intergovernmental Panel on Climate Change, 2007. Changes in Atmospheric Constituents and in Radiative Forcing. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC - Intergovernmental Panel on Climate Change, 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, GE, CHE.

LAPIG/UFG – Laboratório de Processamento de Imagens e Geoprocessamento – Universidade Federal de Goiás – Atlas de Pastagem, 2020. Available at: https://www.lapig.iesa.ufg.br/lapig/index.php/produtos/atlas-digital-das-pastagens-brasileiras.

MCTIC – Ministério da Ciência, Tecnologia e Inovação. Terceira Comunicação Nacional do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança do Clima. Brasília: MCTI, 2016. v. 3.

Sirene/MCTIC – Sistema de Registro Nacional de Emissões – Ministério da Ciência, Tecnologia e Inovações, 2020 – Available at: https://sirene.mctic.gov.br/portal/opencms/paineis/2018/08/24/Participacao_de_gases_por_setor.html

OLIVEIRA, P. P. A., BERNDT, A., PEDROSO, A. F., ALVES, T. C., PEZZOPANE, J. R. M., SAKAMOTO, L. S., HENRIQUE, F. L.; RODRIGUES, P. H. M. (2020). Greenhouse gas balance and carbon footprint of pasture-based beef cattle production systems in the tropical region (Atlantic Forest biome). Animal, 1-11 doi:10.1017/S1751731120001822

QUANTIFICATION ON ENTERIC METHANE EMISSION FACTORS IN GRAZING CATTLE

Ricardo Andrade Reis[1]; Ana Cláudia Ruggieri[1]; Abmael da Silva Cardoso[1].
1 Universidade Estadual Paulista Júlio de Mesquita Filho

Methane (CH_4) is the second most important greenhouse gas (GHG) in terms of quantity. Global CH_4 emissions represent 15% of the total GHG issued to the atmosphere. Of this 15%, a quarter comes from the enteric emission of ruminants. CH4 is produced in wetlands, irrigated rice production, by ruminants and termites. Ruminants produce emissions during the fermentation of fibers.

Archeas group microorganisms use H+ ions derived from the digestion of the fibrous fraction of bulky food, producing glucose and CO_2 and thus producing CH_4. This is an essential reaction, since without the drainage of ions, rumen's pH would decrease leading to ruminal acidosis and paralysis of the digestive process (IPCC, 2006).

Brazil has the largest commercial cattle herd in the world with more than 220 million head. Thus, it is of fundamental importance to know the of enteric CH_4 emission factors for these animals. More than 90% of beef cattle production occurs in Brachiaria grass pastures. According to the (2006) IPCC guide for national GHG inventories, the emission factor for beef cattle is 56 kg $animal^{-1}$ $year^{-1}$. As a reference, an animal of 430 kg of body weight is considered.

Among the evaluations of animal breeding experiments on pastures carried out in the Forage and Pasture sector at Unesp in Jaboticabal, is the quantification of the enteric CH_4 emissions using the tracer gas methodology (BERNDT et al., 2014). Evaluations of animals supplemented with mineral salt, conventional supplements and different supplementation strategies with co-products or additives. Since to compose inventories we must use data from experiments that simulate the real characteristics of the production systems, in this document we will present the results of systems with mineral supplementation and conventional supplementation.

RESULTS

- Assessments of enteric CH4 production have been taking place since 2012. In the work by Barbero et al. (2015) who evaluated different management heights of Marandu grass (15, 25 and 35 cm) daily CH_4 emissions were equal to 128 g animal -1 day $^{-1}$ in animals with 335 kg of body weight. The emission factor obtained by correcting for a 430 animal was 60 kg $animal^{-1}year^{-1}$. Therefore, very close to the emission factor recommended by the IPCC;
- Oliveira et al. (2018) also evaluated the emissions of enteric CH_4 in beef cattle as a function of low or high residual feed intake. In this experiment, the daily production of CH_4 was equal to 98 $ganimal^{-1}$ day^{-1} in animals weighing 297 kg. The emission factor obtained, correcting for a 430 kg animal, was 52 kg $animal^{-1}year^{-1}$. Therefore, also close to the emission factor recommended by the IPCC;
- These amounts are for grazing animals receiving mineral supplementation. Currently, evaluations are underway considering nitrogen pasture and supplementation strategies that will be made available in scientific publications soon.

CHALLENGES

- The methodology for the evaluation of enteric CH4 using the tracer gas methodology requires animals to use yokes and halters, in addition to requiring numerous stages. The main challenge is to train a team to calibrate halters, yokes and capsules for use in the field and later assessed in the laboratory;
- In terms of costs, each yoke costs 300 reais; the permeation tube, costs 50 reais; and each CH_4+SF_6(sulfur hexafluoride) assessment, costs 60 reais. Assessments are done using gas chromatography. Thus, because it requires the chromatograph and the high cost of the assessments, few teams carry out this type of study;
- Another challenge is to carry out evaluations on production systems since the methodology does not allow the transport of samples over long distances.

SOLUTIONS

- The enteric CH_4 emission factor for beef cattle in pastures was quantified.

DATA PUBLISHED IN:

BARBERO, R. P.; MALHEIROS, E. B.; ARAÚJO, T. L. R.; NAVE, R. L. G.; MULLINIKS, J. T.; BERCHIELLI, T. T.; RUGGIERI, A. C.; REIS, R. A. Combining Marandu grass grazing height and supplementation level to optimize growth and productivity of yearling bulls. Animal Feed Science and Technology, n. 209, p. 110-118, 2015.

OLIVEIRA, L. F.; RUGGIERI, A. C.; BRANCO, R. H.; COTA, O. L.; CANESIN, R. C.; COSTA, H. J. U.; MERCADANTE, M. E. Z. Feed efficiency and enteric methane production of Nellore cattle in the feedlot and on pasture. Animal Production Science, v. 58, n. 5, p. 886-893, 2018.

REFERENCES

IPCC – Intergovernmental Panel on Climate Change. Guidelines for National Greenhouse Gas Inventories. Japan: IGES, 2006. Disponível em: http://www.ipcc-nggip.iges.or.jp./public/2006gl/index.html.2006.

BERNDT, A.; PEDROSO, A. F.; PEREIRA, L. G. R.; RODRIGUES, P. H. M.; DE ALMEIDA, R. G.; GUIMARÃES JÚNIOR, R.; FRIGHETTO, R. T. S.; OLIVEIRA, P. R. A. Diretrizes para avaliação da emissão de metano entérico com a técnica do gás traçador SF_6. São Carlos, SP: Embrapa Pecuária Sudeste, 2014.

Figure: Animal using a yoke

Crédit: Abmael da Silva Cardoso.

PROJECT COORDINATORS

Dr. Ricardo Andrade Reis

Universidade Estadual Paulista

e-mail: ricardo.reis@unesp.br

Dra. Ana Cláudia Ruggieri

Universidade Estadual Paulista

e-mail: ana.ruggieri@unesp.br

Dr. Abmael da Silva Cardoso

Universidade Estadual Paulista

e-mail: abmael.cardoso@unesp.br

TANNINS AS A FOOD ADDITIVE TO MITIGATE METHANE EMISSIONS IN TAURINE AND ZEBU CATTLE

Flavio Perna Junior[1]; Ricardo Galbiatti Sandoval Nogueira[1]; Roberta Ferreira Carvalho[1]; Eduardo Cuelar Orlandi Cassiano[1]; Paulo Henrique Mazza Rodrigues[1]
1 Universidade de São Paulo

Although some feeding strategies have been proposed to decrease the emission of methane (CH_4) from ruminants, few have demonstrated a persistent decrease, mainly in vivo. The aim of the present study was to evaluate the use of different levels of tannins as food additives for ruminants in mitigating ruminal CH_4 emissions and waste. A replicated Latin square 4x4 experimental design (4 periods of 28 days each) was used, in 2x4 factorial arrangement, testing two distinct groups of bovines (Holstein [taurine] and Nellore [zebu]) and four levels of tannins (commercial extract of Acacia mearnsii, containing 82.3% of total tannins- tannic acid equivalent and 32.3% condensed tannins - leukocyanidin equivalent) in their diet (0; 0.5; 1.0 and 1.5% of the DM of the diet). To assess production of CH_4 in the manure, experimental anaerobic batch digesters were used, in a completely randomized design.

The levels of the additive used promoted changes in the animal's rumination behavior and, despite causing a linear reduction in the digestibility of nutrients, they maintained the balance between synthesis and ruminal consumption of N-NH3, linearly reduced microbial protein synthesis and ruminal CH_4 production without, however, reducing microbial efficiency and the production of short-chain fatty acids (AGCC) for both evaluated breeds. Through the Broken-line model, a 0.72% tannin threshold was detected in the diet as an inflection point to initiate the decrease in production of ruminal CH_4 . The process of biodigesting the waste was not modified by the use of tannins, however, the speeds of CH_4 and CO 2 production were influenced by the composition of the waste from the different groups of bovines evaluated, being more accentuated for the bulls, and able to be a positive factor for reduction of the biodigestion time. In addition, considering environmental issues is suggested, since assessing only the potential for biogas production and because there is no increase in GHG production, this would be a positive factor, on the other hand, would be irrelevant from the point of view of energy generation. In general, Acacia mearnsii extract levels between 0.5 and 1.0% of the DM of the diet proved to be indicative of the beginning of changes in the ruminal metabolic process, considering 1.5% levels a safe option for use as a food additive for Taureans and Zebu cattle, However, with a strong indirect effect on methanogenesis due to reduced digestibility of food, a more careful assessment of its effects on animal productivity is needed. Therefore, tannins can be used as additives for handling rumen fermentation, without presenting the undesirable compensatory effects of feces gas emissions.

Figure: Effect of adding four levels of A. mearnsii tannins on the production of ruminal CH_4 in different groups of cattle, using the Broken-line model to demonstrate the plateau.

Crédit: Perna Junior (2018).

RESULTS

- The assessment of the ruminal metabolism was performed using the ex-situ ruminal fermentation technique (RODRIGUES et al., 2012; PERNA JUNIOR et al., 2017), demonstrating a linear reduction in ruminal CH4 production(Figure), reaching a 26% reduction for the highest dose. This was also compared with other products of ruminal fermentation (Figure);
- The degradability of NDF, BP and the diet digestibility have been greatly reduced with increasing levels of tannins in the diet, which represents an indirect effect on methanogenesis, that is,reduced CH_4 production due to reduced use of food in the rumen;
- The ingestive behavior of the animals was evaluated, and for both breeds there was a linear increase in the number of rumination events (number of times the animal kept up the ruminating activity uninterrupted), probably due to the tannins astringent effect when ingested;

- The use of tannins to feed taurines and zebu cattle does not interfere in the potential for GHG generation when evaluated by means of anaerobic digesters.

CHALLENGES

- Find a natural food additive that promotes improved animal performance;
- Find an additive that doesn't affect food consumption, due to the astringent effect of tannins;
- Promotes improvement of ruminal fermentation without generating waste with greater polluting potential.

SOLUTION

- The use of Acacia mearnsii extract in low dosages (0.72% of the DM of the diet) can be an option to reduce the production of ruminal CH_4 for taureans and zebu, however, the reduction of the digestibility of the diet with the increase of the levels of tannins contributes negatively to feed efficiency.

REFERENCES:

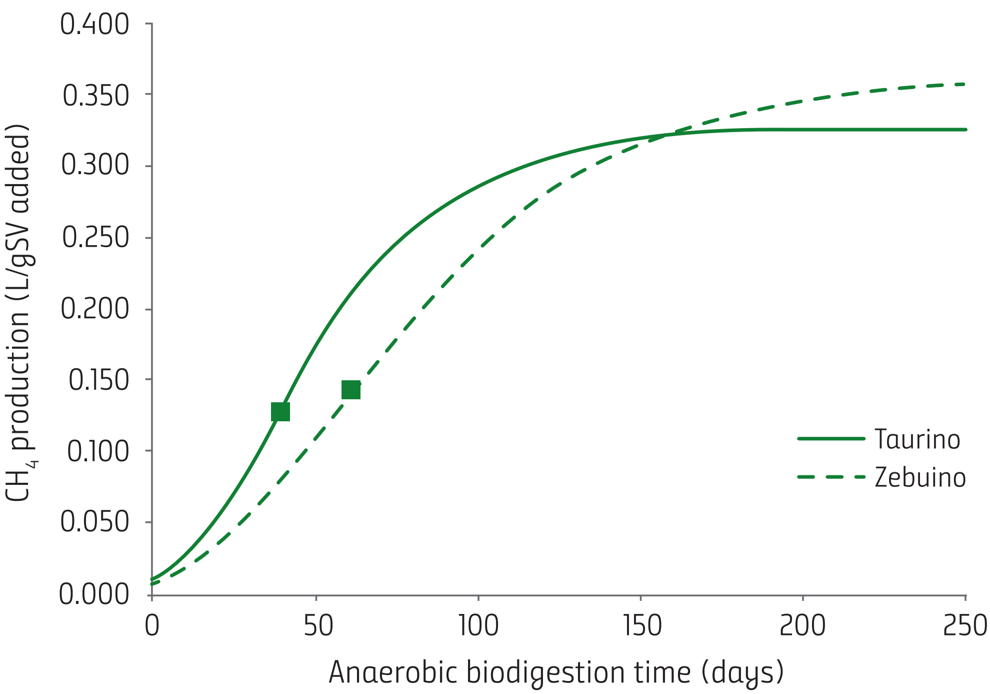
IMEHREZ, A. Z.; ØRSKOV, E. R. A study of the artificial bag technique for determining the digestibility of feeds in the rumen. Journal of Agricultural Science, v. 88, n. 3, p. 645-650, 1977.

PERNA JUNIOR, F.; CASSIANO, E. C. O.; MARTINS, M. F.; ROMERO, L. A.; ZAPATA, D. C. V.; PINEDO, L. A.; MARINO, C. T.; RODRIGUES, P. H. M. Effect of tannins-rich extract from Acacia mearnsii or monensin as feed additives on ruminal fermentation efficiency in cattle. Livestock Science, n. 203, p. 21-29, 2017.

RODRIGUES, P. H. M.; PINEDO, L. A.; SOLORZANO, L. A. R.; PERNA JUNIOR, F.; MARTINS, M. F.; CASTRO, A. L.; GODOY, G. L. A.; MARINO, C. T. Descrição da metodologia ex-situ de estudo da fermentação ruminal (micro-rúmen) com vistas à mensuração da produção de metano. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 49., 2012, Brasília. Anais [...]. Brasília: [S. n.], 2012.

DATA PUBLISHED IN:

PERNA JUNIOR, F. Taninos como aditivo alimentar para mitigação das emissões de metano em ruminantes. 2018. Tese (Doutorado) – Faculdade de Medicina Veterinária e Zootecnia, Universidade de São Paulo, Pirassununga, 2018.



PROJECT COORDINATOR

Dr. Paulo Henrique Mazza Rodrigues

Faculdade de Medicina Veterinária e Zootecnia, Universidade de São Paulo

e-mail: pmazza@usp.br

METHANE EMISSIONS FROM CATTLE IN INTEGRATED LIVESTOCK CROP SYSTEMS (ILCS)

Alda Lúcia Gomes Monteiro[1]; Thales Baggio Portugal[1] Anibal de Moraes[1]; Alexandre Berndt[2]; Cimélio Bayer[3]; Paulo César de Faccio Carvalho[3]

1 Universidade Federal do Paraná; 2 Empresa Brasileira de Pesquisa Agropecuária – Embrapa; Pecuária Sudeste; 3 Universidade Federal do Rio Grande do Sul.

The growing Greenhouse Gases (GHG) emissions caused mainly by human actions has influenced climate change, directly affecting ecosystems through global warming. One of humanity's greatest challenges is to produce food in a more sustainable way, from an economic and environmental point of view. Relating the high production of food to the reduction of environmental impacts is a challenge for the current generation. Livestock production is characterized by being a high gas emission activity, but with the potential to mitigate the effect of GHGs, removing them from the atmosphere or reducing emissions through soil and pasture management. In this context, the Integrated Livestock Crop Systems (ILCS) were considered by the United Nations Food and Agriculture Organization (FAO) as sustainable production models, thus contributing to the reduction of GHG emissions per unit of agricultural product, increasing the carbon stocks in the soil, efficiency in nutrient cycling and soil quality, while preserving natural resources and the environment.

In order to contribute to understanding ruminal methane emissions from cattle grazing in different SIPA arrangements in an area of environmental preservation, an experiment was conducted at the Center for Technological Innovations in Agriculture (NITA), between July 2017 and February 2018 (year 1) and from September 2018 to March 2019 (year 2). NITA is located at Fazenda Experimental do Canguiri, Pinhais PR, belonging to the Federal University of Paraná (UFPR), with geographical coordinates: 25º24'4.31''S latitude and 49º 7'15.02''O longitude, 918 m altitude. The experimental design was randomized blocks, with three replications and four treatments, namely: Livestock (L), Livestock-Forest (LF), Crop-Livestock (CL) and Crop-Livsetock-Forest (CLF). In all cases, the predominant forage plant in winter was oats (Avena sativa) and in summer, Megathyrsus maximus cv. Aries. The PEC treatment was the only one in monoculture, with only the livestock component. In the CL and CLF treatments, the "ley farming" system was used, with one year of farming (Zea mays) preceding two years of pasture (2017 and 2018). The LF and CLF tree component was planted in 2013, with a spacing of 14 m between rows and 4 m between plants, using Eucalyptus benthamii. Castrated Angus steers were used, with an initial live weight of 154.78 kg ± 35.22 kg and 10 months of age in year 1 and 241.19 kg ± 50.31 kg and 16 months of age in year 2. In each treatment, three test animals (sample unit) were used. Methane emissions (CH_4) were evaluated for cattle grazing using SF6 methodology, the forage intake on pasture, the digestibility of the forage consumed and animal productivity. The results of CH_4 emissions will be expressed in g of animal CH_4 day^{-1}, g of CH_4.kg of GPV^{-1},g of CH_4.Ingested MS^{-1}, g of CH_4.PV^{-1}and g of CH_4 hectare Day^{-1}. Assessment is being carried out at the Soil Department of the Federal University of Rio Grande do Sul (UFRGS).

RESULTS

Gross daily methane emissions from beef cattle produced in ILCS ranged from 130 to 220 g, with higher emissions in summer pastures compared to winter. Bovine production systems that followed the corn crop (CL and CLF) showed lower methane emissions by live weight gain and by area, in summer pastures. Crop rotation for grain production and pastures for cattle production can be considered a strategy, aiming at the possibility of lower emissions of methane gas by animals.

CHALLENGES

- Limited resources available for executing the experimental protocols;
- Variability of results, due to the use of methane emission measurement methodology for animals in pastures, with the use of SF6 (sulfur hexafluoride);
- Limited resources for publishing in high impact international journals;

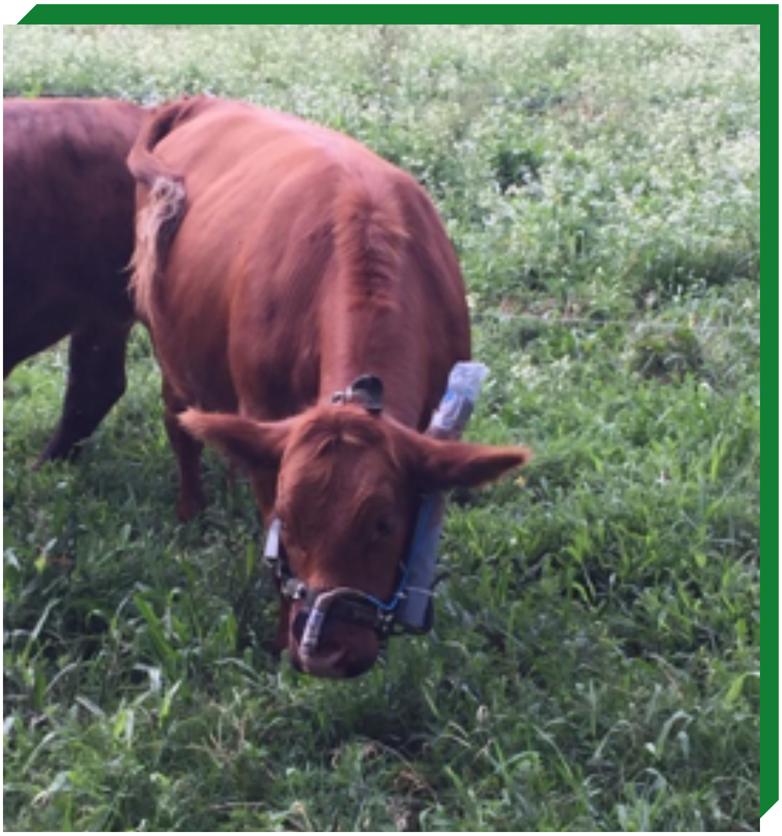
- Recent limitation in number of doctoral and postdoctoral fellowships for Federal Universities, which limits the work of the team that develops the projects, which are highly demanding in terms of high quality human resources.

SOLUTIONS

- Joint work with other institutions and teams from Brazil and other countries, seeking to optimize the use of human and material resources;

- Performance of multidisciplinary teams seeking better results in the application of highly complex methodologies.

Figure: Castrated Angus steers using methane measurement tubes.



Crédit: Thales Baggio Portugal.

PROJECT COORDINATORS

Dra. Alda Lúcia Gomes Monteiro

Universidade Federal do Paraná

e-mail: aldaufpr@gmail.com

Dr. Anibal de Moraes

Universidade Federal do Paraná

e-mail: aldaufpr@gmail.com

ENTERIC METHANE EMISSION FROM CROSSBRED CANCHIM, ANGUS, AND CHAROLAIS CATTLE, FINISHED IN CONFINEMENT FEEDLOTS

Leandro Sannomiya Sakamoto[1,2]; Paulo de Méo Filho[1,2]; Egleu Diomedes Marinho Mendes[1]; Maurício Melo de Alencar[1]; Rymer Ramiz Tullio[1]; Fábio Borba Ferrari[3]; Paulo Roberto Leme[2]; Alexandre Berndt[1]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pecuária Sudeste; 2 Universidade de São Paulo; 3 Universidade Estadual Paulista.

The objective of this work was to evaluate CH 4 emission intensities of crossbred cattle in feedlot finishing phase. 63 crossbred animals from different genetic groups were evaluated, grouped in proportion of Adapted of 25.00% and 37.50% (1A), 43.75% and 50.00% (2A) and 56.25%, 62.50%, 68.75% and 75% (3A), in proportion of Bos taurus: 31.25%, 50.00%, 56.25% and 75.00%, and according to the Heterozygosis percentage: 50.00% and 62.50% (1H), 81.25% (2H), and 100% (3H). Methane was measured using automated troughs (Greenfeed). All evaluated animals were neutered. Consumption was measured using the GrowSafe equipment. Animal performance data (live weight, weight gain, feed conversion), carcass (ribeye area of the Longissimus muscle, fat thickness, hot carcass weight (PCQ) and carcass yields (RendC) and gain (RendG)) and variables related to methane. The data was analyzed using the MIXED procedure of the SAS 9.3 program.

RESULTS

The groups of confined animals showed differences in the performance variables, but only the classification by heterozygosity showed differences in the methane variables. 3H animals showed better performance results compared to 1H animals. For the carcass-related variables, there was no difference in the PCQ ($p = 0.5842$), but 2H animals showed higher meat yield than 1H animals ($p = 0.0177$), and leaner carcass than the others ($p = 0$, 0007). In relation to methane, 2H animals showed better results compared to 3H animals, however the two groups presented an EI calculated by RendC lower than 1H animals ($p = 0.0173$). Despite the differences found between the genetic groups studied, it is important to evaluate the system as a whole, such as waste production, among others and not just the animal methane emissions.

CHALLENGES

Considering the diversity of production systems, bovine breeds, genetic groups and animal diets, it is difficult to establish average technical coefficients that represent all of Brazil. However, as there is still little research to evaluate the emission of enteric methane and its emission intensity in the country, this ends up becoming a reference value for other countries around the world. Therefore, more research and studies are needed in order to obtain reliable data from each region or production system. The country's great potential in producing food is sometimes seen in a negative way by society due to the lack of communication and lack of publications, which shed light on improvements achieved over the last decades. The application of technologies such as genetic improvement and pasture management aiming to increase productivity results in less impact on the environment since the production of Brazilian meat is mainly carried out on pasture. In light of the above, what motivated the execution of this work was the demystification of the unproductive or unsustainable vision of Brazilian livestock production through results obtained with rigorous science, and the specific objective of evaluating and understanding the balance between increasing productivity and minimizing costs, environmental impacts, mainly through ruminant GHG emissions.

SOLUTIONS

- In order to define which bovine genetic group to use, it is important to check those that best fit in its structure, aiming at sustainable production;
- It is important to assess methane emissions from more cattle in different genetic groups.

DATA PUBLISHED IN:

BERNDT, A.; MÉO FILHO, P.; SAKAMOTO, L. S.; MORELLI, M. Técnicas para mensurar emissão de metano em bovinos. In: SIMPÓSIO BRASILEIRO DE PRODUÇÃO DE RUMINANTES NO CERRADO, 4., 2018, Uberlândia. Anais [...]. Uberlândia: FAMEV-UFU, 2018. p. 85-96.

SAKAMOTO, L. S. Intensidades de emissão de gás metano de bovinos Nelore terminados a pasto e cruzados em confinamento. 2018. Tese (Doutorado) – Faculdade de Zootecnia e Engenharia de Alimentos, Universidade de São Paulo, Pirassununga, 2018.

SAKAMOTO, L. S.; BERNDT, A.; VILAS BOAS, D. F.; MÉO FILHO, P.; MENDES, E. D. M.; TULLIO, R. R.; GUILARDI, J. H.; ANDRADE, L. L.; CARDOSO, R. D.; LEME, P. R. Crossbred performance of genetic groups and sex different. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 53., 2016, Gramado. Anais [...]. Gramado: [S. n.], 2016.

Continued in Annex

Figure: Bovines crossed in confinement in collective pens to collect individual data on consumption and emission of enteric methane using the GrowSafe and GreenFeed equipment, respectively.

Crédit: Embrapa Pecuária Sudeste, São Carlos-SP

PROJECT COORDINATOR

Dr. Alexandre Berndt

Embrapa Pecuária Sudeste

e-mail: alexandre.berndt@embrapa.br

GREENHOUSE GAS EMISSION IN CATTLE PRODUCTION SYSTEMS IN SOUTHERN BRAZIL

Henrique Mendonça Nunes Ribeiro Filho[1]
1 Universidade do Estado de Santa Catarina

In 2012, the Research Group on Ruminant Nutrition on Pastures, from UDESC/Lages, started a partnership with the Federal University of Rio Grande do Sul (UFRGS) and Embrapa Pecuária Sudeste with the objective of evaluating enteric methane (CH_4) emissions in beef and dairy cattle. Sulfur hexafluoride (SF_6) was used in all experiments . Initially, CH_4 emissions were assessed in growing Charolais steers grazing in dwarf elephant grass with or without access to to a legume of tropical climate (peanut forage) pastures, in the city of Ituporanga (SC). Subsequently, trials were conducted using lactating dairy cows, of the Holstein or Holstein × Jersey breed, in the city of Lages (SC), focused on evaluating the effects of including grazed forage (millet grass or annual ryegrass) in the diet of cows being fed total mixed ration (TMR) as well as the use of different types of supplements (silage or corn grain) or food additives (tannin extract from Acácia mearnsii), for grazing dairy cows. Currently, a long-term experiment (expected duration: 15 years) to measure greenhouse gases (GHG: CO_2, CH_4 e N_2O) emissions and carbon sequestration according to the type of diet and land use in milk production systems using crossbred cows (Dutch ×Jersey) is underway. Experimental treatments are the absence of grazing (corn for silage followed by annual winter forage for hay making or pre-dried), corn for silage followed by annual winter forage for grazing, annual winter forage followed by annual summer forage (both under grazing) and perennial winter pasture. GHG emissions from soil and animal excreta are assessed throughout each year and the carbon stocks in the soil are assessed every three years. The global estimate of greenhouse gas emissions expressed in CO_2 equivalents per unit of product in the different production systems, as well as the fossil origin energy requirement, expressed in GJ/kg of product, will be quantified using the Life Cycle Analysis methodology.

RESULTS

- Growing Charolais breed cattle, grazing in dwarf elephant grass with access to Legume pastures, in the Alto Val do Itajaí Region (SC), increased emissions of (CH_4 g/day) due to the increase in daily DM consumption. However, CH_4(g/kg DM consumed) production and emission intensities (g/kg of product), remained unchanged (ANDRADE *et al.*, 2016);
- Supplementation with *Acacia mearnsii* tannin extract for Holstein × Jersey dairy cows crosses, in millet grass pasture + 6 kg concentrate/ animal day, in the Planalto Serrano Region (SC), reduced the emission intensity by approximately 40% (ALVES; DALL-ORSOLETTA; RIBEIRO-FILHO, 2017);
- Supplementation with corn grain or corn silage for dairy cows in annual winter pastures, typically used in the South of Brazil, reduced the production of CH_4 (g / kg DM consumed) by 26 and 10%, respectively, but did not change the emission intensity (DALL-ORSOLETTA *et al.*, 2019);
- The inclusion of annual winter pastures in diets for Holstein × Jersey dairy cow crosses, ingesting total mixed rations (TMR), based on corn silage, in the Planalto Serrano Region (SC), reduced CH_4 emissions by more than 25% due to the quality of the forage produced (DALL-ORSOLETTA *et al.*, 2016; CIVIERO *et al.*, in preparation);
- The inclusion of annual summer pastures in diets of Holstein × Jersey dairy cows crosses, ingesting RTM, in the Planalto Serrano Region (SC), increased the intensity of CH_4 emission by less than 5% (CIVIERO et al., in preparation).

CHALLENGES

- Using the SF6 technique instead of equipment such as the "Green Feed" to estimate enteric methane emissions;
- Obtaining financing for the acquisition of materials and equipment for sampling and laboratory analysis;
- Obtaining local emission factors for the elaboration of life cycle inventories and complete domain on the Life Cycle Analysis (LCA) methodology (MATTHEWS; HENDRICKSON; MATTHEWS, 2015), according to ISO standards (ISO 14040, 2006; ISO 14044, 2006), including the acquisition of computer programs that provide international databases.

SOLUTIONS

- The inclusion of forage legumes in cattle production systems can contribute to mitigating GHG emissions due to the reduction in the use of nitrogen fertilizers;
- The optimization of the use of grazed forage in cattle production systems can contribute to mitigate the global GHG emission in cattle production systems, but the real impacts of this practice in the country still need to be quantified through LCA;
- Using LCA methodology, including the evaluation of different scenarios through sensitivity analyses, with the objective of proposing lower carbon footprint systems and use of fossil fuel per kg of final product.

DATA PUBLISHED IN:

ALVES, T. P.; DALL-ORSOLETTA, A. C.; RIBEIRO-FILHO, H. M. N. The effects of supplementing Acacia mearnsii tannin extract on dairy cow dry matter intake, milk production, and methane emission in a tropical pasture. Tropical Animal Health and Production, n. 49, p. 1663-1668, 2017.

ANDRADE, E. A.; ALMEIDA, E. X.; RAUPP, G. T.; MIGUEL, M. F.; DE LIZ, D. M.; CARVALHO, P. C. F.; BAYER, C.; RIBEIRO-FILHO, H. M. N. Herbage intake, methane emissions and animal performance of steers grazing dwarf elephant grass v. dwarf elephant grass and peanut pastures. Animal, v. 10, n. 10, p. 1684-1688, 2016.

DALL-ORSOLETTA, A. C.; ALMEIDA, J. G. R.; CARVALHO, P. C. F.; SAVIAN, J. V.; RIBEIRO-FILHO, H.M.N Ryegrass pasture combined with partial total mixed ration reduces enteric methane emissions and maintains the performance of dairy cows during mid to late lactation. Journal of Dairy Science, v. 99, n. 6, 2016.

DALL-ORSOLETTA, A. C.; OZIEMBLOWSKI, M. M.; BERNDT, A.; RIBEIRO-FILHO, H. M. N. Enteric methane emission from grazing dairy cows receiving corn silage or ground corn supplementation. Animal Feed Science and Technology, v. 253, p. 65-73, May 2019. Available at: https://doi.org/10.1016/j.anifeedsci.2019.05.009.

REFERENCES:

ISO – The International Standards Organisation. ISO 14040: Environmental management: Life cycle assessment: Principles and framework. v. 2006, p. 1-28, 2006.

ISO – The International Standards Organisation.– ISO 14044: Environmental management: Life cycle assessment: Requirements and guidelines. v. 2006, p. 46, 2006.

MATTHEWS, H. S.; HENDRICKSON, C. T.; MATTHEWS, D. H. Life cycle assessment: quantitative approaches for decisions that matter. [S. l.]: MATLAB, 2015.

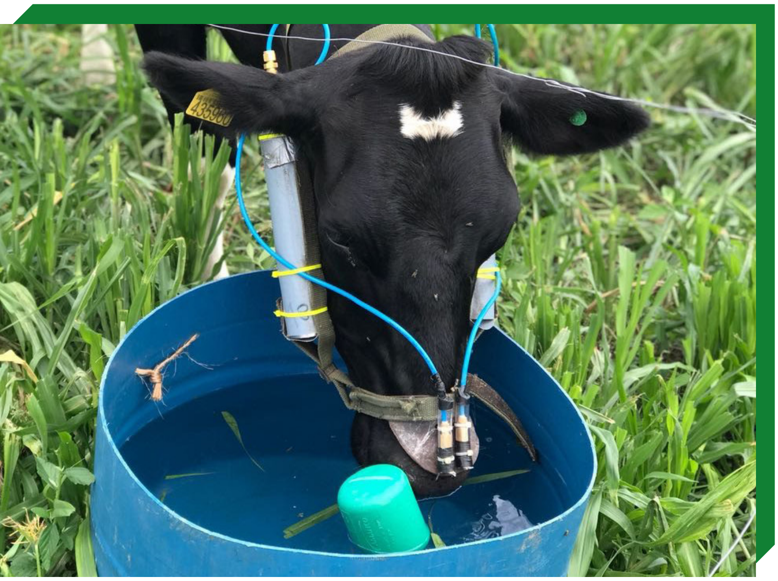


Figure: Measurement of CH_4 emissions from enteric origin using the sulfur hexafluoride (SF6)technique in dairy cows grazing millet grass

Crédit: Maurício Civiero.

PROJECT COORDINATOR

Dr. Henrique M. N. Ribeiro Filho

Universidade do Estado de Santa Catarina

e-mail: henrique.ribeiro@udesc.br

METHANE MITIGATION OPPORTUNITIES IN MEAT PRODUCTION THROUGH ANIMAL BREEDING

Maria Eugênia Zerlotti Mercadante[1]; Renata Helena Branco[1]; Joslaine Noely dos Santos Gonçalves Cyrillo[1]; Roberta Carrilho Canesin[1]; Sarah Figueiredo Martins Bonilha[1]; Leandro Sannomiya Sakamoto[1]; Sarah Bernades[1]; Luana Lelis Souza[1]; Alexandre Berndt[2]; Lucia Galvão de Albuquerque[3]

1 Instituto de Zootecnia, Centro Avançado de Pesquisa de Bovinos de Corte; 2 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Pecuária Sudeste; 3 Universidade Estadual Paulista Júlio de Mesquita Filho, Faculdade de Ciências Agrárias e Veterinárias.

The objective of the line of research is to set up a database of individual records of emission of enteric methane (CH_4, g/day), average daily gain (ADG, kg / day), dry matter consumption (DMI, kg/day) and live weight (LW, kg), of Nellore cattle after weaning, for phenotypic, genetic-quantitative and genomic studies of characteristics related to the emission of enteric methane and its associations with performance and feed efficiency characteristics. The experiments were carried out in 2011, 2012, and 2018, and will be reported below. Obtaining records of individual CH_4 and other characteristics in Nellore cattle after weaning is expected by 2023.

In all experiments, the emission of enteric methane was determined individually for each animal, for 5 to 7 consecutive days, using the sulfur hexafluoride tracer gas (SF6) technique, as described by Johnson and Johnson (1995), and adapted by Primavesi et al. (2004) and Deighton et al. (2014). The methane emission (g/day) of each animal is the average taken during the 5 to 7 days of CH_4 collection. The animals evaluated were in the same age pool (age difference of up to 90 days) and came from the same pure flock, born and raised in Sertãozinho, SP (21°10 'south latitude, 48°5' west longitude). The production systems evaluated were cattle growing in confinement and pasture.

RESULTS

- Cota *et al*. (2014) Consumption of individual dry matter (CMS) and live weight were determined in 47 animals (22 males and 25 females), with an average age of 396 days and live weight of 356 kg. Diet composed of corn silage (54% of dry matter), brachiaria hay (10% of DM), ground corn (22% of DM), soybean meal (12%), urea and mineral salt, with 14% of crude protein and 70% NDT. The same 47 animals went to brachiaria pasture (supplemented with 0.5 kg/animal/day. Pasture: 9% crude protein, 68% NDT), with an average age of 468 days and live weight of 371 kg. Average of individual feedlot records: live weight = 356 kg; DMI= 8.98 kg / day; CH_4= 104 g/day; CH_4/DMI= 12 g CH_4/kg DM;CH4/live weight = 0.29 g CH_4/kg live weight. Average of individual pasture records: live weight = 371 kg; CMS= 6.67 kg/day; CH_4 =98.4 g/day; CH_4/DMI= 15.7 g CH_4/kg MS;CH_4/ live weight = 0.26 g CH_4/kg live weight;

- Mercadante et al. (2015). Individual dry matter consumption (CMS) and average daily gain (ADG) were determined in 46 animals (23 males and 23 females), with an average age of 365 days, live weight of 285 kg and ADG of 0.750 kg/day. Diet composed of brachiaria hay (44.5% of dry matter), ground corn (32.2% of DM), cotton seed cake (21.4% of DM), urea and mineral salt, with 13% crude protein and 70% of total digestible nutrients (TDN). Average of individual feedlot records:DAG 0.750 kg/day; DMI= 6.00 kg/day; CH4= 143 g/day; CH_4/ DMI= 24 g CH_4/kg MS;CH_4/ADG = 197 g CH_4/ kg ADG;

- Sakamoto *et al*. (2019) and Souza *et al.* (2019). Individual dry matter intake (DMI) and average daily gain (ADG) were determined for 70 males, with an average age of 434 days, live weight of 342 kg, and ADG of 0.825 kg/day. Diet composed of corn silage (54% of dry matter), brachiaria hay (10% of DM), ground corn (22% of DM), soybean meal (12%), urea and mineral salt, with 14% of crude protein and 70% NDT. Average of individual feedlot records: ADG= 0.825 kg/day; DMI = 8.00 kg/day; CH_4= 199 g/day; CH_4/DMI= 25 g CH_4/ kg MS; CH_4/ADG = 241 g CH_4/kg ADG.

CHALLENGES

- Individually measure enteric methane emission at some stage of the bovine's productive life, in a large number of cattle, taking into account the high complexity of the technique and high cost of execution;

- Genetic studies always require a large number of animals to be evaluated for the emission of individual enteric methane during the same productive phase of the animal;

- Obtaining funding for continuing research until consistent results are obtained, both from state and federal research bodies, as well as from the private sector represented in this chain by owners of selection herds and by the companies commercializing bovine genetics.

SOLUTIONS

- A better quality diet promotes less energy loss in the form of methane;
- The sulfur hexafluoride (SF6) tracer gas technique to measure the emission of enteric methane

DATA PUBLISHED IN:

COTA, O.; FIGUEIREDO, D. M.; BRANCO, R. H.; MAGNANI, E.; NASCIMENTO,

C. F.; OLIVEIRA, L. F.; MERCADANTE, M. E. Z. Methane emission by Nellore cattle subjected to different nutritional plans. Tropical Animal Health and Production, v. 46, n. 7, p. 1100-1106, 2014.

MERCADANTE, M. E. Z.; CALIMAN, A. P. M.; CANESIN, R. C.; BONILHA, S. F. M.; BERNDT, A.; FRIGHETTO, R. T. S.; MAGNANI, E.; BRANCO, R. H. Relationship between residual feed intake and enteric methane emission in Nellore cattle. Revista Brasileira de Zootecnia, v. 44, p. 255-262, 2015.

SAKAMOTO, L. S.; SOUZA, L. L.; BENFICA, L. F.; CYRILLO, J. S. G.; BERNDT, A.; ALBUQUERQUE, L. G.; MERCADANTE, M. E. Z. Feed efficiency and enteric methane emission of Nellore cattle. In: GREENHOUSE GAS AND ANIMAL AGRICULTURE CONFERENCE, 7., 2019, Foz do Iguaçu.

SOUZA, L. L.; SAKAMOTO, L. S.; BENFICA, L. F.; BIS, F. C.; MERCADANTE, M. E. Z.; SILVA, J. A. I. V; ALBUQUERQUE, L. G. Efeito da técnica do gás traçador SF6 para mensuração de metano entérico sobre consumo e comportamento ingestivo de bovinos de corte em crescimento. In: SIMPÓSIO BRASILEIRO DE MELHORAMENTO ANIMAL, 13., 2019, Salvador.

REFERENCES:

DEIGHTON, M. H.; WILLIAMS, S. R. O.; HANNAH, M. C.; ECKARD, R. J.;

BOLAND, T. M.; WALES, W. J.; MOATE, P. J. A modified sulphur hexafluoride tracer technique enables accurate determination of enteric methane emissions from ruminants. Animal Feed Science and Technology, v. 197, p. 47-63, 2014.

JOHNSON, K. A.; JOHNSON, D. E. Methane emissions from cattle. Journal of Animal Science, v. 73, p. 2483-2492, 1995.

PRIMAVESI, O.; FRIGHETO, R. T. S.; PEDREIRA, M. S.; LIMA, M. A.; BERCHIELLI,

T. T.; DEMARCHi, J. J. A. A.; MANELLA, M. Q.; BARBOSA, P. F.; JOHNSON, K. A.;

WESTBERG, H. H. SF6-tracer technique for bovine ruminal methane field measurements: adaptations to Brazilian conditions. São Carlos: Embrapa Pecuária Sudeste, 2004. (Document 39).

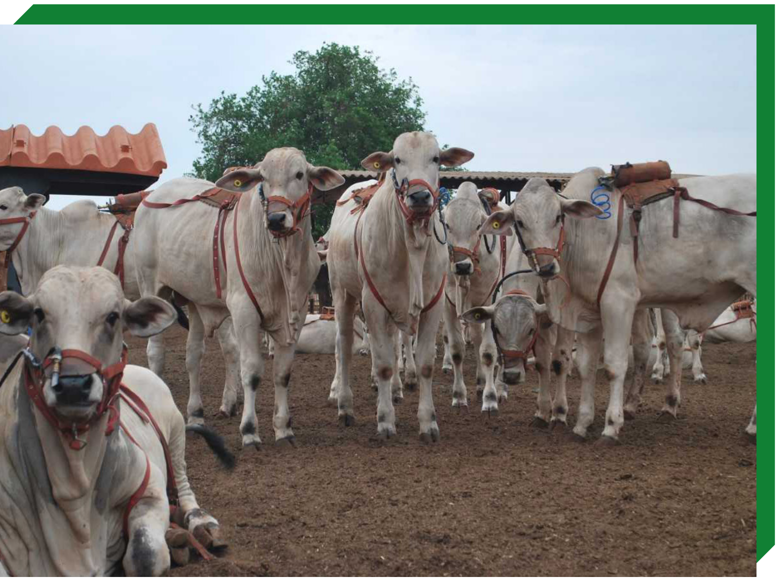


Figure: Collection of individual methane emissions from cattle confined in a collective stall. Sulfur hexafluoride tracer gas technique.

Crédit: Instituto de Zootecnia, SAA-SP.

PROJECT COORDINATORS

Dra. Maria Eugênia Zerlotti Mercadante

Instituto de Zootecnia, Centro Avançado de Pesquisa de Bovinos de Corte

e-mail: mezmercadante@gmail.com e maria.mercadante@sp.gov.br

Dra. Lucia Galvão de Albuquerque

Universidade Estadual Paulista Júlio de Mesquita Filho. Faculdade de Ciências Agrárias e Veterinárias

e-mail: galvao.albuquerque@unesp.br

ROTATIONAL GRAZING WITH ELEPHANT-GRASS FOR DAIRY COWS: GRAZING STRATEGIES, ANIMAL PRODUCTIVITY AND ENTERIC METHANE AND NITROUS OXIDE EMISSIONS

Guilhermo Francklin de Souza Congio[1]; Marina Miquilini[3]; Marília Barbosa Chiavegato[2]; Sila Carneiro da Silva[3]
1 Corporação Colombiana de Investigação Agropecuária; 2 The Ohio State University; 3 Universidade de São Paulo.

Pasture-based systems play an important role in milk production in temperate (CHAPMAN, 2016) and tropical (SANTOS *et al.*, 2014) climates and are thus essential to meet the growing demand for food (GODFRAY *et al.*,2010; ALEXANDRATOS AND BRUINSMA, 2012). Increasing production must be linked to the sustainable intensification of agricultural systems through practices that minimize environmental impacts (ROYAL SOCIETY, 2009; GARNETT AND GODFRAY, 2012). Currently, the milk production system is considered the second largest GHG emitter when comparing production systems. Enteric methane (CH_4), the main greenhouse gas in these systems (AGUIRRE-VILLEGAS $_{et\ al.}$, 2017), is the product of rumen fermentation and its production is influenced by food consumption and the chemical composition of forage (JANSSEN, 2010). The second main GHG is nitrous oxide (N_2O) from the soil, formed by incomplete denitrification or nitrification in soils under pasture (WRAGE *et al.*, 2001; SAGGAR *et al.*, 2013). Grazing management strategies that optimize the use of forage and the consumption of digestible dry matter in order to improve land use and mitigate environmental impacts are an alternative that can intensify production systems, without increasing the use of inputs. (MUÑOZ *et al.*, 2016; GREGORINI *et al.*, 2017).

In this context, two experiments were carried out in a non-irrigated area of elephant grass (*Pennisetum purpureum Schum. Cv. Cameroon*) managed under intermittent stocking by dairy cattle (HPB × Jersey cows) at the "Luiz de Queiroz" (ESALQ-USP) School of Agriculture, in Piracicaba, SP, Brazil. The first experiment (December 2015 to April 2016) compared two pre-grazing targets (95% and maximum light interception of the canopy during regrowth; IL 95% and ILMáx, represented by the heights of 100 and 135 cm of the forage canopy, respectively) , both with 50% defoliation severity. The influence of pre-grazing goals on pasture structure, forage nutrient value, dry matter intake (DMI), milk production, stocking rate, enteric methane emissions from HPB × Jersey cows and the flow of nitrous oxide from soil were identified. Enteric
CH4 emissions were estimated daily during the experimental period using sulfur hexafluoride (JOHNSON AND JOHNSON, 1995) and soil gases were sampled during two periods throughout the experimental period (P1 = 08/01/2016 to 01/22/2016 and P2 = 02/25/2016 to 10/03/2016), and measured using the closed non-ventilated static chamber methodology, updated by the Global Research Alliance on Agricultural Greenhouse Gases (KLEIN; HARVEY, 2015).

Once the ideal pre-grazing goal was established in the first experiment (IL95%), the second experiment (January to March 2017) was carried out in the same area with
the management criterion of 95% canopy light interception and 50% defoliation severity, and the influence of two schedules of allocation of new paddocks to the animals (morning and afternoon) on the chemical composition of the forage, consumption of dry matter, milk production and composition, and enteric CH_4 emissions from HPB × Jersey cows was evaluated.

RESULTS

- In comparison with the ILMáx target, the IL95% target provided more grazing cycles, with a shorter period of animal paddock occupation and a shorter rest period;
- ILMáx and IL95% showed similar forage production, but the target IL95% produced more leaves and less stems compared to the target ILMáx, which may explain the higher nutritional value (higher crude protein content and lower levels of acidic detergent fiber and lignin) accounted for in this management strategy;
- The IL95% target had lower forage losses due to grazing, that is, it showed greater grazing efficiency, and this determined a stocking rate 33% higher than the ILMáx target. The forage supply was higher for ILMáx, but consumption was higher for IL95%, which also presented 15% higher milk production per cow;
- Enteric methane emission was similar for ILMáx and IL95%, but the intensity of emission (ratio between methane emission and milk production) and methane production (ratio between methane issued and methane consumption) was lower for cows consuming forage produced using the IL95% management target;
- Milk productivity (milk production per hectare) was 52% higher for cows in pastures managed with the target IL95% (170 and 112 kg/ha.day for IL95% and ILMáx, respectively) and, as they presented a higher rate of capacity, they showed a higher

emission of enteric methane per hectare. However, considering the quantity of milk produced and the emission of enteric methane, when compared to the ILMáx target, the IL95% target showed 16% higher milk production per kg of enteric methane issued per hectare;

- The IL95% target provided a lower intensity of N_2O emission (ratio between average emission of N_2O per hectare and milk production per hectare) in relation to the ILMáx target (0.34 and 0.57 gN-N_2O kg milk.ha.dia, for IL95% and ILMáx respectively), issuing 40% less N_2O per kg of milk;

- Soil methane emission, originating mainly from the decomposition of animal feces, represented less than 1% of the total emission and, in some cases, was negative, suggesting the action of the methanotrophic bacteria in the soil;

- The IL95% target showed a higher total gas emission, however, when considering milk productivity, it presented a 20% lower gas emission intensity than that of the ILMáx target;

- Adopting the target IL95% and comparing the time for changing paddocks for the animals (morning and afternoon), the forage in the afternoon showed higher levels of dry matter (DM), soluble carbohydrates and starch, and lower levels of soluble fiber in neutral detergent (AD) and acid detergent soluble fiber (NSC). Despite the similar crude protein (CP) content, the forage in the morning showed a greater relationship between non-fibrous carbohydrates (NFC) and digestible proteins. There was no difference between forage consumption and milk production, however there was a higher production of protein and casein and less excretion of urea nitrogen in the milk for the animals that consumed forage from the paddocks exchanged in the afternoon. There was no difference for enteric methane emissions comparing the two animal allocation periods.

CHALLENGES

- In milk production systems in temperate pastures, it is usually recommended to add inputs such as nitrogen fertilizers and concentrated feed to increase productivity. Since this practice results in an environmental cost, the results of this work indicate the possibility of intensifying milk production systems in tropical pastures through the adoption of adequate management strategies (good grazing management practices), as long as minimum soil fertility levels are ensured for grazing. However, there is a scarcity of results generated in studies carried out in milk production systems in tropical environments to associate, in addition to GHG sources, the sequestration and storage of carbon by pastures in order to obtain more accurate estimates of the carbon energy balance;

- Tropical pastures have enormous potential to increase soil organic carbon and thus offset GHG emissions (BRAZ *et al.*, 2013; ABDALLA *et al.*, 2018). In addition, tropical forage species, when subjected to high grazing intensity in humid and warm regions, are more likely to increase the soil's organic carbon when compared to low-intensity management (ABDALLA *et al.*, 2018). In this context, the challenge of obtaining research that includes analysis of the sequestration and carbon stock in the soil is crucial to obtain more accurate estimates of the carbon balance, in order to determine and encourage mitigation strategies to be adopted by producers.

SOLUTIONS

- Optimization of ecological processes to intensify the milk production system in tropical pastures, that is, without the increase of external resources (fertilizers and external supplements), but with the efficient use of existing resources (solar radiation, rainwater, pasture, fertilizer, supplement);

- Strategic pasture management, represented by the IL95% pre-grazing target associated with the allocation of animals to a new paddock in the afternoon, determines the best food value of tropical pastures and, consequently, higher milk productivity, which configures a better use of soil and greater supply of animal protein to a growing consumer market. Additionally, it mitigates the main environmental impacts typical of milk production systems such enteric CH_4 and nitrous oxide emissions from the soil, as well as improving the efficiency of nitrogen use by cows;

- Height monitoring is a practical and reliable solution for the adoption of management strategies by the producer, allowing sustainable intensification in milk production systems in tropical climate pastures. Additionally, strategic management is a practice that is easy to adopt and free of charge, which increases the profitability of production systems.

DATA PUBLISHED IN:

CONGIO, G. F. S. Rotational stocking management on elephant grass for dairy cows: grazing strategies, animal productivity, enteric methane and nitrous oxide emissions. 2018. Tese (Doutorado) – Universidade de São Paulo, Piracicaba, 2018.

CONGIO, G. F. S et al. Strategic grazing management and nitrous oxide fluxes from pasture soils in tropical dairy systems. Science of The Total Environment, v. 676, p. 493-500, 2019.

CONGIO, GF S et al. Strategic grazing management towards sustainable intensification at tropical pasture-based dairy systems. Science of the Total Environment, v. 636, p. 872-880, 2018.

REFERENCES:

ABDALLA, M.; HASTINGS, A.; CHADWICK, D. R.; JONES, D. L.; EVANS, C. D.; JABDALLA, M.; HASTINGS, A.; CHADWICK, D. R.; JONES, D. L.; EVANS, C. D.; JONES, M. B.; REES, R. M.; SMITH, P. Critical review of the impacts of grazing intensity on soil organic carbon storage and other soil quality indicators in extensively managed grasslands. Agric. Ecosyst. Environ., N. 253, p. 62-81, 2018. DOI: https://doi.org/10.1016/j.2017.10.023.

AGUIRRE-VILLEGAS, H. A.; PASSOS-FONSECA, T. H.; REINEMANN, D. J.;

LARSON, R. A. Grazing intensity affects the environmental impact of dairy systems. J. Dairy Sci., n. 100, p. 6804-6821, 2017. DOI: https://doi.org/10.3168/jds.201612325.

ALEXANDRATOS, N.; BRUINSMA, J. World Agriculture Towards 2030/2050. Rome: FAO, 2012. Available at: http://www.fao.org/fileadmin/ templates/esa/Global_persepctives/world_ag_2030_50_2012_rev.pdf.

Continued in Annex

Figure 1: HPB × Jersey cows grazing elephant grass managed in the treatment of IL95%.

Crédit: Guilhermo F. S. Congio.

Figure 2: HPB × Jersey cows grazing elephant grass managed in the treatment of IL95%.

Crédit: Guilhermo F. S. Congio.

PROJECT COORDINATOR

Dr. Sila Carneiro da Silva

Universidade de São Paulo Escola Superior de Agricultura Luiz de Queiroz

e-mail: siladasilva@usp.br

CARBON NEUTRAL BEEF: TESTING THE GUIDELINES IN A CASE STUDY

Roberto Giolo de Almeida[1]; Rodrigo da Costa Gomes[1]; Vanderley Porfírio-da-Silva[2]; Fabiana Villa Alves[1]; Gélson Luís Dias Feijó[1]; André Dominghetti Ferreira[1]; Edilson Batista de Oliveira[2]; Davi José Bungenstab[1]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Gado de Corte; 2 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Florestas.

Carbon Neutral Beef (CNBB) is a new concept developed by Embrapa for sustainable beef production in the tropics. The CNBB concept, launched in 2015, is based on silvopastoral or agrosilvipastoral systems that are able to neutralize methane emissions through the production of wood from planted trees, in addition to providing better thermal comfort to grazing animals. The objective of this work is to present the first case study of the application of the CNBB guidelines in a commercial farm, with results affecting animal production, pasture characteristics, microclimate parameters, wood productivity, meat quality and neutralization of methane emissions from animals grazing. The study was carried out on a farm located in the Cerrado biome, in Mato Grosso do Sul, with Aw type climate and in a Quartzene Neossoil. An area with a silvopastoral system, implanted in 2010, was selected, with Brachiaria brizantha cv. BRS Piatã (89%) and B. dictyoneura (11%), and with eucalyptus trees, clone I-144 of Eucalyptus urophylla x E. grandis and E. urophylla x E. camaldulensis VM-01 clone, with 10 m spacing between double-row rows, 3 m between rows within the row and 2 m between row trees [(arrangement 3 m × 2 m) x 10 m], totaling 769 trees/ha. Twenty-two Nellore steers, weighing 437 kg of initial live weight and 27 months old, were evaluated during the period from December 2015 to May 2016, totaling 154 days, according to CCN guidelines.

RESULTS

The stocking rate was adjusted to maintain adequate pasture conditions, maintained under conditions of high shading, and varied from 0.4 to 0.5 animal unit/ha. The pasture was managed at a height between 31 and 48 cm, providing forage availability ranging from 2,395 to 3,603 kg/ha (dry matter). The nutritional protocol (pasture plus supplementation) allowed the animals to gain an average daily weight gain of 490 g with a live weight gain of 75.5 kg during the period, presenting adequate carcass characteristics such as: carcass weight of 274.6 kg, grade maturity ≤ 4 permanent teeth and a dorsal fat score of 3.2; Besides appropriate characteristics regarding meat quality such as pH, color and tenderness. Regarding microclimate variables that make up the temperature and humidity index (THI) - an indicator of thermal comfort -, the silvopastoral system showed more favorable thermal conditions for grazing animals (indexes ranging from 77 to 83), compared to adjacent areas with pasture under full sun (rates ranging from 80 to 84).

In the tree management plan, a thinning of 50% was considered in the 6th year and final cutting of the remaining trees in the 12th year. The estimated mean annual increment (MAI), for six-year-old trees, reached 30 m^3/ha/year. This MAI value was used in the SIS Eucalyptus software to estimate the amount of carbon fixed by the remaining trees (wood logs) in the year 12. Enteric methane emission from grazing animals was estimated at 0.63 t CO_2eq/ha/year, while the amount of carbon fixed in the sawed wood was estimated at 5.35 tCO_2eq/ha/year, after 11 years of grazing - considering that the animals begin grazing one year after the trees were established. Therefore, it is possible to neutralize GHG emissions from cattle kept in the system with an carbon excess of 4.72 t of CO_2eq/ha/year. CNBB guidelines can easily be implemented by commercial farms and allow the production of high quality meat as well as neutralization of methane in silvopastoral systems.

DATA PUBLISHED IN:

ALMEIDA, R. G.; GOMES, R. C.; SILVA, V. P.; ALVES, F. V.; FEIJÓ, G. L. D.; FERREIRA, A. D.; OLIVEIRA, E.; BUNGENSTAB, D. J. Carbon neutral brazilian beef: testing its guidelines through a case study. In: INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN AGRICULTURE, 2., 2016, Campo Grande, MS. Proceedings [...]. Campo Grande, MS: Embrapa Gado de Corte, 2016. p. 277-281.

PROJECT COORDINATOR

Dr. Roberto Giolo de Almeida

Embrapa Gado de Corte

e-mail: roberto.giolo@embrapa.br

GREENHOUSE GAS BALANCE AND CARBON FOOTPRINT OF BEEF CATTLE IN THREE DIFFERENT PASTURE MANAGEMENT SYSTEMS IN BRAZIL

Eduardo Barretto de Figueiredo[1]; Susantha Jayasundara[2]; Ricardo de Oliveira Bordonal[3]; Telma Teresinha Berchielli[3]; Ricardo Andrade Reis[3]; Claudia Wagner-Riddle[2]; Newton La Scala Jr[3].

1 Universidade Federal de São Carlos; 2 University of Guelph; 3 Universidade Estadual Paulista Júlio de Mesquita Filho.

Integrated Systems (IS) have been identified as an efficient land management strategy to restore degraded areas worldwide, thereby increasing grain and beef production and providing technical potential for carbon sequestration (C) in the soil and trees as an option to offset CH_4 emissions from livestock production.

The purpose of our study is to estimate the greenhouse gas (GHG) balance and the C footprint for beef cattle (fattening cycle) in three contrasting production scenarios in Brachiaria pasture in Brazil: I) Degraded pasture (DP); II) Managed pasture (MP); and III) Crop-Livestock-Forest Integration System (ICLF), presenting new land use alternatives as a GHG mitigation strategy. Total GHG emissions according to area scale were higher in MP (84,541 kg CO_2 eq ha^{-1}), followed by ICLF (64,519 kg CO_2eq ha^{-1}) and PD (8004 kg CO_2 eq ha^{-1}) over a period of 10 years. The largest C footprint for beef cattle was detected in the PD system, 18.5 kg CO_2eq per kg LW (live weight), followed by 12.6 kg CO_2eq per kg PV in ICLF and 9.4 kg CO_2 eq per kg PV in PM, without taking into account the potential for C sequestration in the soil in PM (C soil) and ICLF (C soil and *eucalyptus*). Considering the potential for soil C sequestration in PM and ICLF, the carbon footprint in beef cattle can be reduced to 7.6 and -28.1 kg CO_2eq per kg PV in PM and ICLF, respectively. Converting degraded pastures to well-managed pastures and the introduction of the ICLF can reduce GHG emissions in terms of kg CO_2eq issued per kg of cattle produced, increasing the production of meat, wood and grains. This reduction is mainly due to pasture improvement and increases in livestock production, as well as the technical potential for C sinks in the soil and biomass to offset livestock emissions.

RESULTS

- The need for agricultural land for the production of one kg of live weight (LWG) of beef (land occupation factor for a period of 10 years) was 230 m^2 kg^{-1} LWG in the PD system, 22,9 m^2 kg^{-1} LWG in ICLF and 11 m^2 kg^{-1} LWG in PM, indicating considerable potential for land savings in the PM and CLFS compared to the production of beef cattle in the DP scenario. Although the amount of land occupation was higher in ICLPF than in MP, it is important to highlight that the ICLF has the potential to produce, in addition to beef cattle, three types of grains (corn, sorghum and soy, totaling approximately 24.2Mg ha^{-1}) and eucalyptus wood (26 m^3), during the 10-year production cycle within the same land area unit;
- Although the DP scenario had the lowest total emissions per unit of land area, it is not possible to reduce the C footprint of livestock in this system, which occupies large areas with low yield and high GHG emissions per kg of product, in comparison with more intensive production systems, such as PM and ICLF;
- The intensification of livestock production systems can contribute to avoid further deforestation, as a result of a lower land occupation factor in these systems.

CHALLENGES

- Additional efforts should be made to gain a better understanding of more intensive pasture management in different productive systems, such as PM and ICLF, their interactions with associated GHG emissions and their potential for sequestering C in biomass and soil.

SOLUTIONS

- Converting degraded pastures to well-managed pastures and the introduction of ICLF can reduce GHG emissions associated with the production of beef cattle on pastures, in terms of kg of CO_2eq issued per kg live weight produced, increasing the production of meat, grains and wood. This reduction is mainly due to pasture improvement and increases in livestock production and the favoring of the technical potential for sequestering C in soil and in biomass.

DATA PUBLISHED IN:

FIGUEIREDO, E. B. de. et al. Greenhouse gas balance and carbon footprint of beef cattle in three contrasting pasture-management systems in Brazil. Journal of Cleaner Production, v. 142, p. 420-431, 2017.

REFERENCES:

CERRI, C. E. P.; BERNOUX, M.; CHAPLOT, V.; VOLKOFF, B.; VICTORIA, R. L.; MELILLO, J. M.; PAUSTIAN, K.; CERRI, C. C. Assessment of soil property spatial variation in an Amazon pasture: basis for selecting an agronomic experimental area. Geoderma, v. 123, p. 51-68, 2004. DOI: http://dx.doi.org/10.1016/j.geoderma.2004.01.027.

CERRI, C. E. P.; COLEMAN, K.; JENKINSON, D. S.; BERNOUX, M.; VICTORIA, R. L.; CERRI, C. C. Modeling soil carbon from forest and pasture ecosystems of Amazon. Brazil. Soil Sci. Soc. Am. J., n. 67, 1879-1887, 2003. DOI: http://dx.doi.org/10.2136/sssaj2003.1879.

IPCC – Intergovernmental Panel on Climate Change. Climate Change 2007: the physical science basis. In: SOLOMON, S. et al. (ed.). Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK; New York, US: Cambridge University Press, 2007. p. 996.

IPCC – Intergovernmental Panel on Climate Change. IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by Eggleston, S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (eds.). Japan: IGES, 2006. p. 664.

Figure: CLFS located at Embrapa São Carlos

Crédit: Eduardo Barretto de Figueiredo.

PROJECT COORDINATOR

Dr. Eduardo Barretto de Figueiredo

Universidade Federal de São Carlos (UFSCar)

e-mail: eduardofigueiredo@ufscar.br

EMISSION FACTORS FOR NITROUS OXIDE FROM CATTLE URINE AND DUNG IN PASTURES OF THE BRAZILIAN SUBTROPIC

Jeferson Dieckow[1]; Priscila Simon[1]; André Sordi[2]; Josiléia Acordi Zanatta[3]; Cecile Klein[4]; Cimélio Bayer[5]; Jonatas Thiago Piva[6]; Aníbal de Moraes[1]

1 Universidade Federal do Paraná; 2 Universidade do Oeste de Santa Catarina; 3 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Florestas; 4 AgResearch Invermay; 5 Universidade Federal do Rio Grande do Sul; 6 Universidade Tecnológica Federal do Paraná.

This work aimed to quantify the nitrogen emission factor in the form of nitrous oxide (EF) from cattle urine and manure (Holstein and Jersey dairy cows) applied in pastures of kikuyu (*Pennisetum clandestinum*), brachiaria (*Brachiaria humidicola*) and aries ries grass (*Panicum maximum*) in a Haplic Cambisol in Southern Brazil (Pinhais-PR). The central hypothesis is that the waste emission factors in the Brazilian sub-tropics are lower than the default value of 2% (EF3) proposed by the IPCC (2006 Guidelines). Three studies were conducted from 2011 to 2017. In study 1, the EF was evaluated in three urine volumes (0.5; 1.0 and 1.5 times the average volume of 1.97 L/urination) and three fresh dung masses (0.5; 1, 0 and 1.5 times the average mass of 3.37 kg/defecation) in the summer, winter and spring of 2011, in the kikuyu pasture. In study 2, only one dose of urine (1.70 L) and dung (2.30 kg fresh) was tested, in the four seasons of 2014, and on the same pasture. In summer 2016/17, in study 3, the urine dose of 2.00 L/urination was applied in brachiaria pasture and aries pasture, under the additional hypothesis that the emission in the brachiaria is lower due to a possible nitrification inhibitory effect (brachylactones exuded by roots). Dung was applied in circular microplots of 33 cm in diameter (0.083 m^2), while in study 3 in rectangular microplots of 34 × 52 cm (0.18m^2) were used. Each microplot was delimited by a metallic structure (metallic base) anchored 5 cm in the soil before the beginning of each study. The emission of nitrous oxide (N_2O) from the excreta was monitored using the closed static chamber method (height 30 cm and covered with an aluminum blanket for thermal insulation), in several sessions during 60-90 days after application, ending when the N_2O flux returned and remained at the baseline level. In each air sample collection session, a sample was taken at 0, 15, 30 and 45 minutes after coupling (closing) of the chamber on the metallic base. Samples were taken with polypropylene syringes and transferred to 12 mL flasks (Exetainer, Labco). The N_2O concentration in the samples was determined by gas chromatography (electron capture).

RESULTS

- In study 1, the mean EF for urine (across the three seasons) decreased with an increase in urine volume, from 0.33% in 0.5 times the volume of urination to 0.19% in 1.5 times the volume of urination, possibly due to the greater percolation of urine in the soil with the highest dose. On the other hand, the average EF for dung was 0.19%, 0.12% and 0.14% for 0.5, 1.0 and 1.5 times the fresh mass per defecation. On average, the EF for urine was 0.26% and for manure 0.15%, the highest EF in urine being attributed to the greater availability of urine N-urea than the non-soluble organic forms of manure;
- In study 2, the average EF across the four seasons was 0.34% for urine and 0.11% for dung;
- In study 3, the EF for urine was 1.06% in the brachiaria pasture and 1.33% in the aries pasture, suggesting a possible effect of the brachiaria in reducing N_2O emission;
- The three studies showed that the urine EF (0.26 - 1.33%) and the EF of manure (0.11 - 0.15%) in the Brazilian subtropics were lower than the default value of 2% (EF3) proposed by the IPCC 2006 Guidelines;
- In addition, the EF of manure was lower than that of urine.

CHALLENGES

- Revising of the default EF value 2% (EF3) for urine and manure for the subtropics; and, because the EF of manure is lower than the urine EF, this review should also consider the breakdown of the EF into urine and manure.

SOLUTIONS

- Next actions: Conduct new studies in order to reduce the FEs of urine and manure through the use of nitrification inhibitors (natural or synthetic) and the improvement of the structural conditions of the soil under pasture.

DATA PUBLISHED IN:

SIMON, P. L. Plant use as alternative to curb nitrous oxide emissions from cattle urine patches in subtropical and temperate systems. 2019. Tese (Doutorado em Ciência do Solo) -- Universidade Federal do Paraná, Curitiba, 2019.

SIMON, P. L.; DIECKOW, J.; KLEIN, C. A. M. de; ZANATTA, J. A.; WEERDEN, T. J. van der; RAMALHO, B.; BAYER, C. Nitrous oxide emission factors from cattle urine and dung, and dicyandiamide (DCD) as a mitigation strategy in subtropical pastures. Agriculture, Ecosystems & Environment, v. 267, p. 74-82, 2018.

SORDI, A.; DIECKOW, J.; BAYER, C.; ALBURQUERQUE, M. A.; PIVA, J. T.; ZANATTA,

J. A.; TOMAZI, M.; ROSA, C. M. da; MORAES, A. de. Nitrous oxide emission factors for urine and dung patches in a subtropical Brazilian pastureland. Agriculture, Ecosystems & Environment, v. 190, p. 94-103, 2014.

PROJECT COORDINATOR

Dr. Jeferson Dieckow

Universidade Federal do Paraná

e-mail: jefersondieckow@ufpr.br

QUANTIFICATION OF DIRECT AND INDIRECT NITROUS OXIDE EMISSION FACTORS

Ana Cláudia Ruggieri[1]; Ricardo Andrade Reis[1]; Abmael da Silva Cardoso[1]
1 Universidade Estadual Paulista Júlio de Mesquita Filho

Nitrous oxide (N2O)is a potent greenhouse gas (GHG). Its emission power is 265 times greater than carbon dioxide (CO2). The production of N2O in cattle production systems occurs derived from animal feces and urine as well as the fertilization of pastures with nitrogen fertilizers. N2O emission is considered direct when it originates from the N from excreta or fertilizer and indirect when it occurs after N has been volatilized or leached (IPCC, 2006).

For the correct estimation of N2O emissions in emission inventories we need to know how much N is excreted by the animals, the direct and indirect emissions of the gas, consequently the amount of N that has been volatilized or leached in the system in question. According to the 2006 Intergovernmental Panel on Climate Change (IPCC) guide, the emission factor rates for N2O are: the EF1 of 1% of the N applied in the form of fertilizers lost as N2O, the EF3 of 2% of the N excreted via urine and feces in the form of N2O and indirectly the EF4 of 1% of the volatilized N lost as N2O and EF5 of 0.75% of the N leachate issued as N2O, the latter two being factors of indirect N2O emissions. In addition to these emission factors we have the emission factors referring to the volatilization of N where 10% of the N applied in the form of fertilizer would be volatilized (FracGASF) and 20% of the animal feces and urine (FracGASM), while 30% of the It would not be leached (FracLEACH).

The percentages above refer to default values that were established by experts based on surveys carried out up to 2006. Each country must quantify it's local emission factors by climate region and specific production systems in order to correctly estimate GHG emissions. Our line of research aims to quantify the emission factors of the application of nitrogen fertilizers in pastures and animal excreta. Assessment begun in July 2012 and continue to the present. Initially, emissions from cattle pasture production systems were evaluated considering the effect of seasons, type of excreta, pasture management and fertilization strategies. These assessments will be extended to other species in future studies.

N2O evaluations are carried out continuously using the static chamber methodology. N2O emission considering the type of excreta and season was carried out between 2012 and 2014 and measurements were based on the application of urea fertilizer between 2015 and 2016. N losses in the form of ammonia (NH3) are carried out using the semi-open static chamber methodology. Each assessment is carried out during a 21 day minimum period.

RESULTS

- Emission factors differ according to the type of bovine excreta (feces versus urine) and according to the season;
- The urine emission factor was 0.67%; and feces, 0.41% of the applied N, well below the 2% recommended by the IPCC;
- During the rainy season the urine emission factor is equal to 1.02% of the N excreted and in the dry season equal to 0.32%;
- Emissions in the feces are similar in the two seasons, being equal to 0.41% of the N excreted via feces;
- Regarding nitrogen fertilization (EF1), the emission factor obtained in the period from 2012 to 2014 was equal to 1.00%, confirming the IPCC default emission factor;
- Emissions assessments aiming to assess the urea emission factor in the period from 2015 to 2016 resulted in an emission factor of 0.92% in the first year and 1.08% in the second year, thus confirming the assessments of the previous two years and the IPCC emission factor;
- Regarding the excreta ammonia volatilization (EF4), there were seasonal differences in the urine. During wet seasons N losses were 6.3% and in droughts 14.2%. The average annual loss in the feces was 6.6%;
- The ammonia volatilization of the urea fertilizer was 17% (EF5).

CHALLENGES

- The cost of carrying out experiments aiming at obtaining emission factors is very high;
- Training the team to collect, analyze and interpret data takes about four months;
- An experiment to obtain N2O emission factors requires two years of evaluation; and, in each evaluation, at least four samples must be collected. An experiment with four treatments results in more than 4,000 annual samples analyzed in gas chromatography;
- Calculations for obtaining the correct flows and emission factors are complex;
- Future challenges are obtaining emission factors for the excreta of other species (goats, horses and sheep) and different sources of nitrogen fertilizers.

SOLUTIONS

- The five years of research reached specific emission factors for cattle urine feces and nitrogen fertilization of pastures with urea.

DATA PUBLISHED IN:

CARDOSO, A. S.; OLIVEIRA, S. C.; JANUSCKIEWICZ, E. R.; BRITO, L. F.; MORGADO, E. S.; REIS, R. A.; RUGGIERI, A. C. Seasonal effects on ammonia, nitrous oxide, and methane emissions for beef cattle excreta and urea fertilizer applied to a tropical pasture. Soil Tillage Research, n. 192, p. A-H, 2019.

RUGGIERI, A. C.; RAPOSO, E.; BRITO, L. F. de; ARAUJO, T. L. R.; OLIVEIRA, L. F.; VERSUTI, J.; CARDOSO, A. S.; REIS, R. A. N2O emissions factor from urea application in an intensive tropical grassland. In: CONFERENCIA DE GASES DE EFECTO INVERNADERO EN SISTEMAS AGROPECUARIOS DE LATINAOAMÉRICA, 3., 2017, Colonia de La Estanzuela. Libro de Resúmenes [...]. Montevideo: INIA, 2017. v. 1. p. 97.

REFERENCES:

IPCC – Intergovernmental Panel on Climate Change. Guidelines for National Greenhouse Gas Inventories. Japan: IGES, 2006. Available at: http://www.ipcc-nggip.iges.or.jp./public/2006gl/index.html.

Figure: Static chambers used to collect N2O used in the study.

Crédit: Abmael da Silva Cardoso.

PROJECT COORDINATORS

Dra. Ana Cláudia Ruggieri

Universidade Estadual Paulista

e-mail: ana.ruggieri@unesp.br

Dr. Ricardo Andrade Reis

Universidade Estadual Paulista

e-mail: ricardo.reis@unesp.br

Dr. Abmael da Silva Cardoso

Universidade Estadual Paulista

e-mail: abmael.cardoso@unesp.br

+ PRECOCE - EFFICIENCY AND INNOVATION IN THE FIRST-CALF CHAIN INTEGRATING THE PANTANAL AND CERRADO BIOMES

Ivan Bergier[1]; Urbano Gomes Pinto de Abreu[1]; Luiz Orcírio Fialho de Oliveira[1]; Michely Tomazi[2]; Fernando Rodrigues Teixeira Dias[1]; Eriklis Nogueira[1]; Juliana Corrêa Borges-Silva[1]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pantanal; 2 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Agropecuária Oeste.

Livestock production of calves in the Pantanal Biome is an important source for supplying calves for the breeding and fattening systems in the Cerrado Biome, making it necessary to study the methane emissions in each phase and in each biome in order to correctly assess greenhouse gas emissions in the beef cattle production chain. Nellore cattle enteric emissions produced on pastures on farms located in floodplains (like the Pantanal) can be considered null in view of the landscapes emission balance, since, in the absence of cattle, these pastures would be largely converted into methane native herbivore ruminants, via fermentation in anaerobic soils or via the emission of pyrogenic methane (fires). Enteric emissions should be considered null for extensive stocking rates (up to 0.5 AU*/ ha in the annual average) or incremental in proportion to the increased stocking rate within the limits of sustainable intensification (increased forage supply).

*1 AU (Animal Unit) is equivalent to 450 kg or 37.5 arrobas.

RESULTS

- In summary, for flooded cattle ranches in the Pantanal or in similar areas:
- Enteric emissions are zero for stocking rates of 0.2 to 0.5 AU/ha;
- The net enteric emissions (extra cattle) are computed with the daily emission factors from 141 g (autumn/winter) to 323 g (spring/summer) of CH_4 (Oliveira *et al*., 2016) for stocking rates> 0.5 AU/ha.

CHALLENGES

- Reduce and mitigate emissions of ammonia and other greenhouse gases in livestock production systems. (Meat Portfolio)

Table 1: Emissões de metano difusivo de paisagens inundáveis e não inundáveis na Fazenda São Bento

Landscape	Area (hectares)	Area (%)	Emission factor range (mg CH_4.m^{-2} h^{-1})		Integrated flows by area (Mg CH_4.y^{-1})		References
Forests	885.5	10	-0.013	-0.002	-1.0	-0.2	Bergier *et al.* (2019)
Pastures with little flooding	2.010.4	22	-0.013	-0.002	-2.2	-0.4	Bergier *et al.* (2019)
Aquatic macrophytes	607.5	7	6.327	10.423	336.7	554.5	Bergier *et al.* (2019)
River plains	1.501.3	16	6.327	10.423	832.1	1.370,4	Bergier *et al.* (2019)
Flooded fields	3.185,.9	35	6.327	10.423	1.765,7	2.908,0	Bergier *et al.* (2019)
Wetlands	584.5	6	6.327	10.423	324.0	533.7	Bergier *et al.* (2019)
Open Water	138.1	2	0.292	9.917	3.5	119.9	Alvalá and Kirchhoff (2000)
Roads	291.8	3	-	-	-	-	Bergier *et al.* (2019)
Total	9.205	100	-	-	3.258,9	5.487,4	Bergier *et al.* (2019)

Crédits: the authors.

SOLUTIONS

- Enteric emission mitigation methodology (zero up to 0.5 AU/ha or sustainable> 0.5 AU / ha) for flooded farms in the Pantanal.

DATA PUBLISHED IN:

Bergier et al. Could bovine livestock intensification in Pantanal be neutral regarding enteric methane emissions? Science of the Total Environment, v. 655, p. 463-472, 2019.

REFERENCES:

ALVALÁ P.C., KIRCHHOFF V.W.J.H. (2000) Methane Fluxes from the Pantanal Floodplain in Brazil: Seasonal Variation. In: van Ham J., Baede A.P.M., Meyer L.A., Ybema R. (eds) Non-CO2 Greenhouse Gases: Scientific

Understanding, Control and Implementation. Springer, Dordrecht. https://doi.org/10.1007/978-94-015-9343-4_6

OLIVEIRA, L. O. F. et al. Comparison of methane emissions by cattle pastures in the Pantanal, between two seasons of the year. In: INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN AGRICULTURE, 2., 2016, Campo

Grande, MS. Proceedings [...]. Brasília: Embrapa, 2016. p. 73-74.

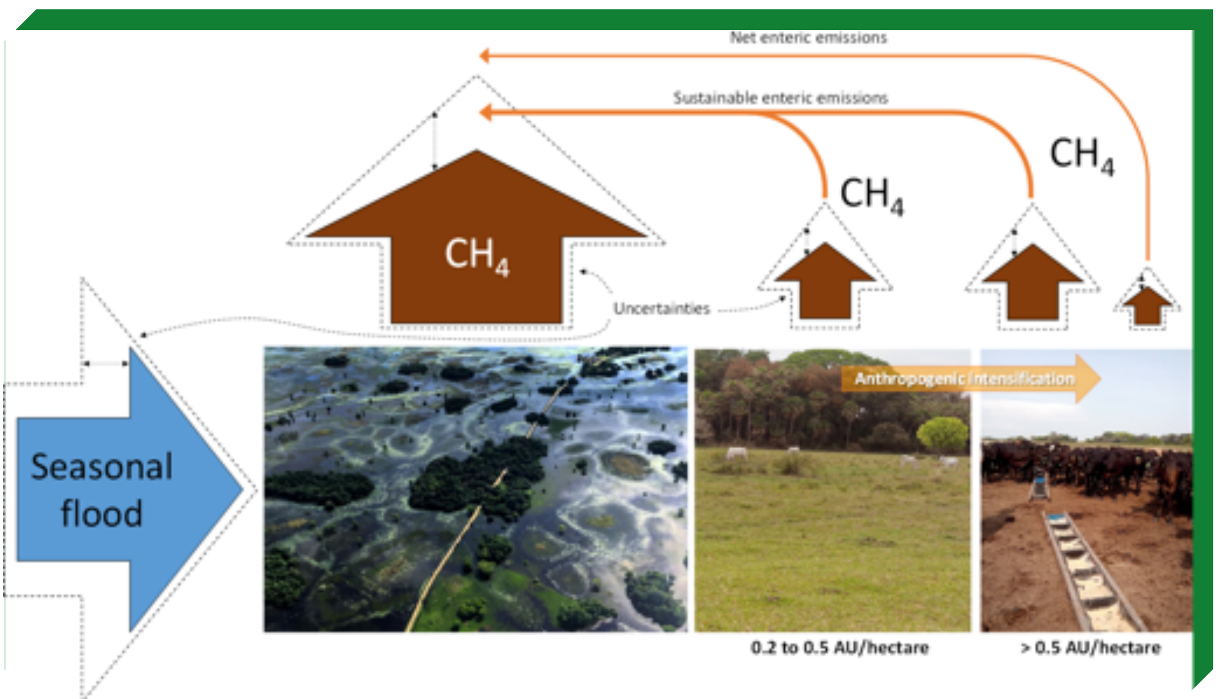
PROJECT COORDINATORS

Dra. Juliana Correa Borges Silva

Embrapa Pantanal

e-mail: juliana.correa@embrapa.br

Figure 1: Dynamics of CH_4 fluxes through flooded landscapes and beef cattle (Nellore) in the Pantanal



Crédit: Ivan Bergier.

METHANE LEVELS AND ENERGY LOSSES IN BEEF CATTLE, SUPPLEMENTED OR NOT, IN MOMBAS A GRASS PASTURES (*PANICUM MAXIMUM CV. MOMBASA*)

Carlos Augusto de Alencar Fontes[1] (in memoriam), Alexandre Berndt[2], Rosa Toyoko Shiraishi Frighetto[3], Viviane Aparecida Carli Costa[4], João Gomes de Siqueira[5], Karina Zorzi[6](in memoriam), Elizabeth Fonsêca Processi[1], Tiago Neves Pereira Valente[5]

1 Universidade Estadual do Norte Fluminense; 2 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Pecuária Sudeste; 3 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Meio Ambiente; 6 Scholarship holder fromPNPD/CAPES; 5 PHd student from Universidade Estadual do Norte Fluminense.

The impact of protein-energy supplementation on the methane (CH_4) emission of steers during breeding on mombas a grass pasture was evaluated. The evaluated treatments were: T0 - Only mineral supplementation; T1 - Protein-energy supplementation. The hexafluoride (SF6) internal tracer gas technique was used to estimate the daily CH4 emission. Twenty animals were used, ten for each treatment, in two trials, measuring CH_4 during five consecutive days. The statistical analysis of of the CH_4 emission data employed the mixed model methodology for repeated measures of the SAS. Animals were also evaluated regarding the food use efficiency, using residual food consumption (CAR) as a criterion. Supplemented and non-supplemented animals did not differ (P> 0.05) regarding daily methane production and total daily energy loss in the form of CH_4. However, when the energy loss was expressed in g/kg of dry matter consumed (21.51 vs. 29.76 g/kg) and as a percentage of the gross energy (EB) ingested (6.36 versus 8.59%), supplemented animals had lower losses (P <0.05) than non-supplemented animals. High, medium and low CAR animals did not differ (P> 0.05) in terms of methane emission levels (total or per kg dry matter - DM ingested). Thus, researchers concluded that: supplementation with concentrate is an effective way of mitigating methane emission; and that differences in the CAR cannot be attributed to differences in methane emission levels.

RESULTS

- There was no substitute effect of the forage by the concentrate;There was no difference in forage consumption;
- There was a higher consumption of dry matter in supplemented animals;
- There was no difference in daily methane emissions (g/day)
- There were less energy losses in the supplemented animals.

CHALLENGES

- The impact of protein-energy supplementation on steer's methane (CH_4) emissions during breeding on mombaça grass pasture was evaluated.
- Structuring and training the UENF team to perform methane collections using the SF6 technique.

SOLUTIONS

- Supplementation with concentrate in grazing animals has a mitigating effect on methane emissions.

DATA PUBLISHED IN:

FONTES, C.A.A.; BERNDT, A.; FRIGHETTO, R.T.S.; COSTA, V.A.C.; SIQUEIRA, J.G; ZORZI, K.; PROCESSI, E.F.; VALENTE, T.N.P. Níveis de metano e perdas energéticas em bovinos de corte, suplementados ou não, em pastagem de capim mombaça (Panicum maximum cv. Mombaça). 49ª. Reunião Anual da Sociedade Brasileira de Zootecnia, Anais..., Brasília. 2012.

Figure 1: Grazing Steers.

Crédits: Alexandre Berndt

Figure 2: Steers in confinement.

Crédits: Alexandre Berndt

Table 1: Concentrate consumption, fodder consumption, total DM consumption, daily EB consumption, daily CH4 production, CH 4 production per Kg of DM ingested, energy loss in CH4 and percentage of loss of gross energy ingested in the form of CH4, of supplemented or not supplemented beef cattle.

Treatment variable	Treatment		
	Supplemented	Not supplemented	Pr>F
Forage Consumption (kg/day)	3.84 ± 0.15	3.95 ± 0.16	0.6368
Concentrate consumption (kg/day)	1.63 ± 0.05	0.07 ± 0.05	<0.0001
Total DM consumption (kg/day)	5.47 ± 0.16	4.02 ± 0.17	<0.0001
Gross energy consumption (EB) (Mcal/Kg)	24.57 ± 0.82	17.46 ± 0.82	<0.0001
Daily production of CH_4(g/day)	116.8 ± 4.70	112.74 ± 4.59	0.5437
CH_4 production per kg of DM ingested (g/kg)	21.51 ± 1.51	29.76 ± 1.48	0.001
Energy loss in the form of CH_4 (Mcal/day)	1,55 ± 0,08	1.45 ± 0.08	0.377
Energy loss by CH_4(% of EB ingested)	6.36 ± 0.61	8.59 ± 0.61	0.0184

PROJECT COORDINATORS

Prof. Dr. Carlos Augusto de Alencar Fontes

Universidade Estadual do Norte Fluminense - UENF

e-mail: cafontes@uenf.br (in memoriam)

DATA OF METHANE EMISSION FACTORS FROM THE ENTERIC FERMENTATION OF BEEF AND MILK CATTLE IN BRAZIL

Magda Aparecida de Lima[1]; Odo Primavesi[2]; Márcio dos Santos Pedreira[6]; João José Assumpção de Abreu Demarchi[3]; Telma Terezinha Berchielli[4]; Simone de Oliveira; Rosana A. Possenti[3]; Rosa Toyoko Shiraishi Frighetto[1], Alexandre Berndt[2]; Marcelo Manella[3]; Raul Franzolin[5]

1 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Meio Ambiente; 2 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Pecuária Sudeste; 3 Instituto de Zootecnia; 4 Universidade Estadual Paulista; 5 Universidade de São Paulo; 6 Universidade Estadual do Sudoeste da Bahia.

Methane is produced as a result of ruminant herbivore's natural digestive process, occurring in the rumen as a result of a symbiotic relationship between ruminants and the ruminal microbiota composed of bacteria, protozoa and fungi. Large ruminants are therefore primarily responsible for methane emissions. In Brazil, cattle account for about 84% of livestock production (89% beef cattle and 11% dairy). Extensive production systems are predominant and most of the national herd is composed of Zebu cattle (B. indicus), of which Nellore is the most numerous breed (80%), raised in predominantly extensive systems (Lima *et al.*, 2010).

Given the importance of these animals to Brazilian livestock production, a series of partnerships formed to measure and determine the methane emission of cattle, consequently, generating the first emission factors obtained under field conditions in the country. The project team was responsible for introducing the SF6 tracer technique in early 2001, through a partnership established with US.EPA, and the developers of this technique (Dr.Kristen Johnson and Hal Westberg, from Washington State University) who came to train the teams. This technique was later adapted and widely adopted by other projects from several national institutions, generating more data on methane emission factors for cattle and other ruminants.

Within the scope of the AGROGASES project, Demarchi et al. (2016) reported the first results on the methane emission potential for beef cattle (Nellore breed) under Brazilian conditions. These authors indicated a seasonal effect on methane emissions, reflecting the qualitative conditions of pastures in the dry and wet seasons in southeastern Brazil. Through these studies, the conversion rate of methane or losses of raw energy ingested was estimated on average at 6.8% (5.0% to 9.1%), close to the global average of 6.5% (Dong *et al.*, 2006).

Pedreira *et al.* (2009) and Primavesi *et al*. (2014) reported, in turn, the first national results on the potential of methane emissions by dairy cattle in Brazilian tropical conditions. Various experiments were conducted, among which, involving the comparison between intensive and extensive production systems of dairy cattle (Holstein and crossbred Zebu animals), indicating little difference in methane emissions in the summer and autumn seasons. In the summer, lactating Holstein cows and dry cows emitted 147 kg of methane each year -, respectively 1 and 101 kg methane year^{-1}, while crossbred lactating and dry cows, respectively issued, 121 kg methane year^{-1} and 107 kg methane year-1. In the autumn, lactating Holstein cows and dry cows issued 139 kg methane year^{-1} and 94 kg methane year^{-1}, respectively, while lactating crossbred and dry cows issued 108 kg methane year-1and 86 kg methane, respectively. year-1 (Primavesi *et al*., 2004). To estimate the amount of dry matter ingested, confinement studies with intake control were also carried out. In addition to the need for greater precision in obtaining consumption data in order to finally obtain the emission factors, studies were carried out with supplementary bulks (sugarcane) for the dry season.

The data of methane emission factors by ruminants presented in this collection were generated by the projects "Influence of the management of animal production on the emission of methane in beef cattle" (MCT/ Embrapa/FAT/APTA), "Improvements of national inventories on methane emission from ruminants (US. EPA - Environmental Protection Agency / Embrapa) and "Carbon dynamics and greenhouse gas emissions from Brazilian agricultural, forestry and agroforestry production systems - AGROGASES". The emission factors are published in the Greenhouse Gas Emission Factor Database (EFDB) of the Intergovernmental Panel on Climate Change (IPCC), starting in 2020 (https://www.ipcc-nggip.iges.or.jp/EFDB/find_ef_id.php).

RESULTS

- A study using sorghum silage, corrected with urea and 60% of dry matter in concentrate, found that the inclusion of concentrate in the diet, regardless of the sorghum hybrid used, provided an increase in the efficiency of energy use, reflected by the lower loss of methane in relation to the raw energy intake. The lower production of methane per unit of dry matter ingested, associated with the negative correlation between rumen digestibility coefficient and methane emission, showed that the use of food by animals should be maximized with the supply of diets that have better nutritional quality (Oliveira et al., 2007; Primavesi et al., 2004).

- Testing increasing levels of concentrate in the dry matter of diets based on sorghum silage, found that silage without concentrate provided a lower emission of methane in relation to the live weight of the animals, and that the addition of 30% of concentrate to the diet led to a maximum increase in emissions, suggesting that other variables should influence the methane emission process, especially animal consumption and performance. However, there was a reduction in methane emissions per unit of dry matter and digestible energy ingested.

- According to Pedreira et al. (2009), the maximum emission of methane (150.9 g day-1) occurred with a proportion of 36.6% of concentrate in the diet. With 60% concentrate, the emission of methane showed a downward trend, due to the lower fiber content in the diet, in addition to the possible change in the composition of the rumen's microbial population.

- In turn, the improvement in the quality of the diet can occur without the use of grains, using early stages of maturation of grass forages or forages with C3 metabolism, with less fiber and a greater digestible fraction, such as legumes, promoting a better enteric fermentation pattern and the reduction of methane emissions (Possenti et al., 2008). The highest level of leucaena in the presence of yeast (Sacharomyces cerevisae) promoted a better fermentation pattern, with an increase in the production of propionic acid and a reduction in methane emission.

- These other experiences were conducted within the scope of the projects referred to above, and further details can be obtained in published articles. In the Tables, data on emission factors for different categories of beef and dairy cattle are presented, respectively, under different dietary treatments and seasons, accompanied by the corresponding bibliographic references.

SOLUTIONS

- Maximizing the use of food by providing diets that have better nutritional quality is recommended .

- The improvement in the quality of the diet can occur without the use of grains, using early stages of maturation of grass forages or forages with C3 metabolism, with less fiber and a greater digestible fraction, such as legumes, promoting a better enteric fermentation pattern and the reduction of methane emissions.

DATA PUBLISHED IN:

Possenti, R.A.; Franzolin, R.; Schammas, E.A.; Demarchi, J.J.A.A.; Frighetto, R.T.S.; Lima, M.A. 2008. Efeitos de dietas contendo Leucaena leucocephala e Saccharomyces cerevisae sobre a fermentação ruminal e a emissão de gás metano em bovinos. Revista Brasileira de Zootecnia, v. 37, n. 8, p. 1509-1516.

Demarchi, J. J. A. de A.; Manella, M. Q.; Primavesi, O. M. A. S. P. R.; Frighetto, R. T. S.; Romero, L. A.; Berndt, A.; Lima, M. A. de. 2016. Effect of seasons on enteric methane emissions from cattle grazing Urochloa brizantha. Journal of Agricultural Science, Toronto, v. 8, n. 4, p. 106-115.

Primavesi, O. M. A. S. P. R.; Berndt, A.; Lima, M. A. de; Frighetto, R. T. S.; Demarchi, J. J. A. de A.; Pedreira, M. dos S.; Berchielli, T. T.; Oliveira, S. G. de. 2014. Greenhouse gas production in agricultural systems: Groundwork for an inventory of methane emissions by ruminants. In: Boddey, R. M. et al. (Ed.). Carbon stocks and greenhouse gas emissions in Brazilian agriculture. Brasília, DF: Embrapa. Chapter 8 (epub).

Oliveira, S. G.; Berchielli, T. T.; Pedreira, M. S.; Primavesi, O.; Frighetto, R.; Lima, M. A. 2007. Effect of tannin levels in sorghum silage and concentrate supplementation on apparent digestibility and methane emission in beef cattle. Animal Feed Science and Technology, Amsterdam, NL, v. 135, n. 3-4, p. 236-248.

Pedreira, M. dos S.; Oliveira, S. G. de; Primavesi, O. M. A. S. P. R.; Lima, M. A. de; Frighetto, R. T. S.; Berchielli, T. T. Methane emissions and estimates of ruminal fermentation parameters in beef cattle fed different dietary concentrate levels. Revista Brasileira de Zootecnia, Brasília, v. 42, n. 1, p. 592-598, 2013.

Pedreira, M.S.; Primavesi, O.; Lima, M.A.; Frighetto, R.; de Oliveira, S.G.; Berchielli, T.T. Ruminal methane emission by dairy cattle in southeast Brazil. Sci. Agric. (Piracicaba, Braz.), v.66, n.6, p.742-750, November/December 2009.

REFERENCES:

Demarchi, J. J. A. de A.; Manella, M. Q.; Primavesi, O. M. A. S. P. R.; Frighetto, R. T. S.; Romero, L. A.; Berndt, A.; Lima, M. A. de. Effect of seasons on enteric methane emissions from cattle grazing Urochloa brizantha. Journal of Agricultural Science, Toronto, v. 8, n. 4, p. 106-115. 2016.

Dong, H.; Mangino, J.; Mcallister, T. A.; Hatfield, J. L.; Jonhnson, D. E.; Lassey, K. R.; Lima, M. A. de; Romanosuskaya, A. Emissions from Livestock and Manure Management-Agriculture, Forestry and Other Land Use, v.4, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Japan: IGES, 2006.

Lima, M. A. de, Pessoa, M. C. P. Y., Neves, M. C., & Carvalho, E. C. de. Emissões de metano por fermentação entérica e manejo de dejetos de animais. Segundo inventário brasileiro de emissões antrópicas de gases de efeito estufa relatórios de referência (p. 120). Ministério da Ciência e Tecnologia: Brasília, DF. 2010.

Oliveira, S. G.; Berchielli, T. T.; Pedreira, M. S.; Primavesi, O.; Frighetto, R.; Lima, M. A. Effect of tannin levels in sorghum silage and concentrate supplementation on apparent digestibility and methane emission in beef cattle. Animal Feed Science and Technology, Amsterdam, NL, Vol. 135, n. 3-4, p. 236-248. 2007.

Pedreira, M.S.; Primavesi, O.; Lima, M.A.; Frighetto, R.; de Oliveira, S.G.; Berchielli, T.T. Ruminal methane emission by dairy cattle in southeast Brazil. Sci. Agric. (Piracicaba, Braz.), v.66, n.6, p.742-750, November/December 2009.

Pedreira, M. dos S.; Oliveira, S. G. de; Primavesi, O. M. A. S. P. R.; Lima, M. A. de; Frighetto, R. T. S.; Berchielli, T. T. Methane emissions and estimates of ruminal fermentation parameters in beef cattle fed different dietary concentrate levels. Revista Brasileira de Zootecnia, Brasília, v. 42, n. 1, p. 592-598, 2013.

Possenti, R.A.; Franzolin, R.; Schammas, E.A.; Demarchi, J.J.A.A.; Frighetto, R.T.S.; Lima, M.A. 2008. Efeitos de dietas contendo Leucaena leucocephala e Saccharomyces cerevisae sobre a fermentação ruminal e a emissão de gás metano em bovinos. Revista Brasileira de Zootecnia, v. 37, n. 8, p. 1509-1516.

Primavesi, O.; Frighetto, R.T.S.; Pedreira, M. S.; Lima, M.A.; Berchielli, T.T.; Barbosa, P.F. Metano entérico de bovinos leiteiros em condições tropicais brasileiras. Pesq. agropec. bras., Brasília, v.39, n.3, p.277-283, mar. 2004.

Primavesi, O. M. A. S. P. R.; Berndt, A.; Lima, M. A. de; Frighetto, R. T. S.; Demarchi, J. J. A. de A.; Pedreira, M. dos S.; Berchielli, T. T.; Oliveira, S. G. de. Greenhouse gas production in agricultural systems: Groundwork for an inventory of methane emissions by ruminants. In: Boddey, R. M. et al. (Ed.). Carbon stocks and greenhouse gas emissions in Brazilian agriculture. Brasília, DF: Embrapa. Chapter 8 (epub), 2014.

PROJECT COORDINATORS

Dra. Magda Aparecida de Lima

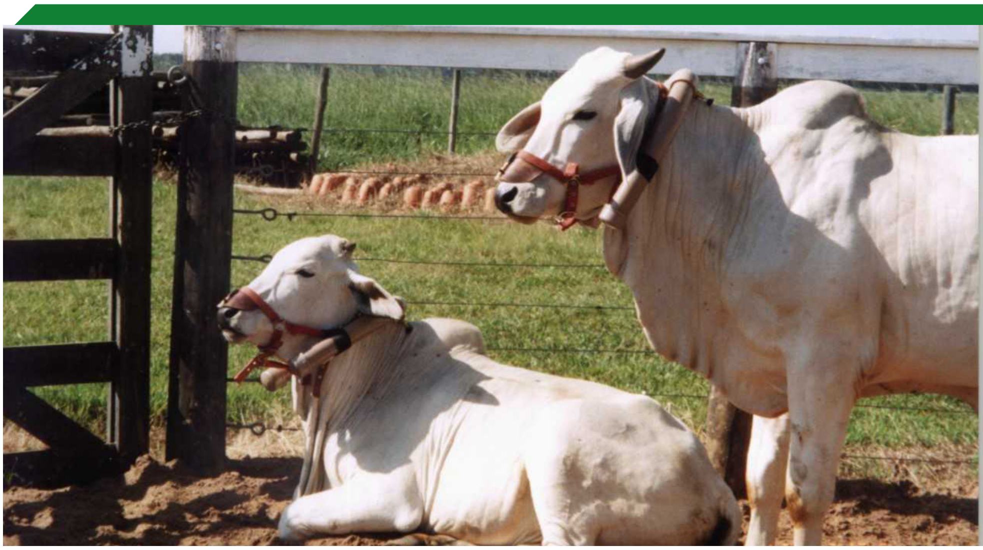
Embrapa Meio Ambiente

e-mail: magda.lima@embrapa.br

Dr. Odo Primavesi

Embrapa Pecuária Sudeste

Figure 1: Pioneer experiment to measure methane by enteric fermentation in Nelore beef cattle in Nova Odessa, SP.



Crédits: Magda Lima

Figure 2: Methane measurement experiment by enteric fermentation in crossbred dairy cattle (Holstein × Gir) in Sao Carlos, SP.

Crédits: Odo Primavesi

System description	Emission factor (kg animal^{-1} year^{-1})	Reference
Adult crossbred bovines with 80% Cynodon dactylongrass hay, coast-cross cultivar, with 20% Leucaine, without yeast.	53.86	Possenti *et al.*, 2008.
Crossbred cattle on 50% grass hay from the coast-cross cultivar of Cynodon dactylon, with 50% Leucaena, without yeast.	47.04	Possenti *et al.*, 2008.
Adult crossbred cattle on 80% grass hay, 20% Leucaena and 10% yeast.	49.17	Possenti *et al.*, 2008.
Adult crossbred cattle with 50% grass hay, 50% Leucaena and 10% yeast.	51.72	Possenti *et al.*, 2008.
18-month Nellore steers in winter (dry season).	37.41	Demarchi *et al.*, 2016.
18-month old Nellore steers in the spring (rainy season).	48.18	Demarchi *et al.*, 2016.
18-month old Nellore steers in the summer (rainy season).	80.63	Demarchi *et al.*, 2016.
18-month old Nellore steers in winter (dry season).	58.39	Demarchi *et al.*, 2016.
Male Nellore cattle, confined, on a Brachiaria brizantha diet in three stages of development (15 days).	48.55	Primavesi *et al.*, 2014.
Male Nellore cattle, castrated, in confinement, with a Brachiaria brizantha diet in three stages of development (45 days).	48.91	Primavesi *et al.*, 2014.
Male Nellore cattle, confined, on a Brachiaria brizantha diet in three stages of development (90 days).	50.37	Primavesi *et al.*, 2014.
Sorghum lower tannin silage + urea (LTSU)	18.08	Oliveira *et al.*, 2007.
Sorghum tannin silage + concentrate (LTSC)	24.32	Oliveira *et al.*, 2007.
High sorghum tannin silage + urea (HTSU)	17.98	Oliveira *et al.*, 2007.
Higher tannin sorghum silage + concentrate (HTSC)	25.71	Oliveira *et al.*, 2007.
Beef cattle fed with sorghum silage and 0% concentrate (dry matter consumption: 5.5 kg day, $^{-1}$), in confinement.	45.70	Pedreira *et al.*, 2013.
Bovinos de corte alimentados com silagem de sorgo e 30% de concentrado (Consumo de matéria seca: 7,9 kg.dia^{-1}), sob confinamento.	54.71	Pedreira et al., 2013.
Beef cattle fed with sorghum silage and 30% concentrate (Dry matter consumption: 7.9 kg.day^{-1}), in confinement.	51.25	Pedreira *et al.*, 2013.

Note The studies used the sulfur hexafluoride (SF6) tracer gas measurement technique, as described by Johnson *et al.* (1994, 2007) and adapted by Primavesi *et al.* (2004).

PECUS RESEARCH NETWORK - DYNAMICS OF GREENHOUSE GASES IN BRAZILIAN AGRICULTURE AND LIVESTOCK PRODUCTION SYSTEMS

PECUS NETWORK

In light of the questions on Brazilian livestock and its share in Greenhouse Gas (GHG) emissions and global warming and the knowledge gaps regarding the sector's real contribution, Embrapa (Brazilian Agricultural Research Corporation), a branch of MAPA (Ministry of Agriculture, Livestock and Supply), surveyed the real role of Brazilian livestock in the dynamics of national GHGs.

To meet this demand, Embrapa made efforts to articulate, coordinate and partially finance a national network project across several research institutions to address the dynamics of greenhouse gases in Brazilian agricultural production systems, involving production systems and alternative species with different species of animals used for livestock in six Brazilian biomes. Several research institutes joined the initiative and approved research grants and scholarships for students to develop their projects on the theme. The private initiative, especially through associations of technicians, producers and farmers and cooperatives, also made efforts both to support research and dissemination results, especially through support for events addressing this theme.

The PECUS research network was designed to impartially produce this information through using internationally standardized methods, aiming to support the Brazilian government in the elaboration of international policies and negotiations.

The general objective of the PECUS project is to contribute to the competitiveness and sustainability of Brazilian livestock through the planning, development and organization of research to estimate the participation of agricultural production systems in the GHG dynamics, aiming to subsidize public policies and mitigation alternatives. The project also generated information which can be used to improve standards and mechanisms for ensuring the quality, safety and traceability of livestock products.

The diverse Brazilian landscape and production systems, the complex aspects to be evaluated and the need for measurements carried out over long periods of time, generated the demand for a research network that could function inter-institutionally, with multidisciplinary teams and long-term repeated projects in the main Brazilian biomes (Amazon, Caatinga, Cerrado, Atlantic Forest, Pantanal, Pampa).

The PECUS network was made up of twelve component projects, six of which assessed the balance between anthropogenic GHG emissions and the carbon sinks of the various livestock production systems in the main Brazilian biomes. In these component projects, the GHG dynamics in small and large ruminant farming systems using pastures and feedlots were evaluated, as well as swine and poultry farming.

The Rumen gases component project "Conceptual progress in diagnosis and mitigation strategies for enteric methane in ruminants in Brazil" analyzed solutions for enteric methane emissions. The objective was to conceptually advance in evaluation methodologies and strategies for mitigating enteric methane in ruminants in Brazil, in addition to setting up a structure for multi-user laboratories that supported the network's research.

Four specific component projects were responsible for storing primary data in an organized, integrated and systematized way for biophysical modeling studies, to evaluate the economic and social aspects and produce geostatistical studies, which enabled the joint analysis of results and the prospection of future scenarios.

The main results already obtained by the Research Network were the publication of national and international documents, containing an estimate of the contribution of several Brazilian production systems to GHG dynamics, suggesting more competitive and sustainable production systems, taking into account the potential for mitigating grazing pastures and the tree component of improved systems, as well as to point out nutritional practices, ingredients or additives that reduce enteric methane emissions.

The Network also contributed by producing organized results and assessments that meet the needs of the national inventory of anthropogenic GHG emission and removal factors, providing parameters with improved approximation (Tiers), avoiding the use of international GHG emission factor standards (default), often unsuitable for Brazilian conditions.

The following are results related to research carried out with large ruminants, within the scope of the PECUS project.

RESULTS

- Obtaining GHG emission removal factors for Brazilian conditions:
  - » Animal waste emission factors (cattle, goat, sheep, pig and bird feces and urine) in confined conditions and pasture farms;
  - » Ruminal methane emission factors for cattle, buffaloes, goats and sheep;
  - » GHG and ammonia emission factors in swine and poultry farms;
  - » Survey of carbon soil stocks and annual carbon sequestration rates in pastures and crops of exclusive or integrated livestock production systems;
  - » Survey of carbon stocks in trunks and annual rates of carbon sequestration by trees in integrated production systems involving livestock.
  - » Management practices to improve carbon sequestration:
  - » Recovering degraded pastures;
  - » Adequate pasture management;
  - » Adequate soil management (soil conservation and fertility);
  - » Use and improvement of nitrogen fertilization efficiency.
  - » Use of integrated production systems.
- Animal nutrition practices to reduce enteric methane:
  - » Protein/energy supplementation;
  - » Use of grains and concentrated foods;
  - » Use of legumes in animal feed;
  - » Use of additives with the potential to reduce the emission of enteric methane.

CHALLENGES

- Combine the mitigation strategies assessed for the separate components (plant, animal, soil) in production systems that mitigate greenhouse gas emissions and increase carbon sequestration;
- Constantly seek technological innovation in order to reduce the emission factors of Brazilian livestock, increase the rates of carbon sequestration to mitigate the emission of GHGs, ensuring the sustainability of livestock, while maintaining the economic competitiveness of Brazilian livestock;
- The next steps are the strengthening decision making tools that are being built and/or adapted to Brazilian conditions, which will allow the environmental and economic aspects to be integrated in studies that can support decision-making in the livestock sector.

SOLUTIONS

- Continue to invest in the innovation of research and development to generate national scientific information on agricultural production practices that reduce GHG emissions and allow the adoption of sustainable production systems.

PROJECT COORDINATORS

Dra. Patrícia Perondi Anchão Oliveira
Embrapa Pecuária Sudeste
e-mail: patricia.anchao-oliveira@embrapa.br

Dra. Ana H. B. M. Fernandes
e-mail: ana.marozzi-fernandes@embrapa.br

Dr. André de Faria Pedroso
Embrapa Pecuária Sudeste
e-mail: andre.pedroso@embrapa.br

Dr. Luís Gustavo Barioni
Informática Agropecuária
e-mail: luis.barioni@embrapa.br

Dr. Luiz Gustavo R. Pereira
e-mail: luiz.gustavo@embrapa.br

Dr. Marcos Cezar Visoli
e-mail: marcos.visoli@embrapa.br

Dra. Maria do Carmo R. Fasiaben
e-mail: maria.fasiaben@embrapa.br

Dr. Roberto Giolo de Almeida
e-mail: roberto.giolo@embrapa.br

Dra. Salete Alves de Moraes
e-mail: salete.moraes@embrapa.br

Dra. Sandra Furlan Nogueira
e-mail: sandra.nogueira@embrapa.br

Dra. Teresa Cristina Genro
e-mail: cristina.genro@embrapa.br

ENTERIC METHANE EMISSIONS BY CANCHIM STEERS IN INTEGRATED SYSTEMS OF PRODUCTION COMPARED TO EXCLUSIVE PRODUCTION SYSTEMS FOR REARING AND FATTENING

Leandro Sannomiya Sakamoto[1,2]; Alexandre Berndt[2]; Amanda P. Lemes[2,3]; Kauê Mahlmeister[2]; Daniella F. Vilas Boas[2]; Paulo de Méo Filho[1,2]; José Ricardo M. Pezzopane[2]; Sérgio N. Esteves[2]; Alberto Carlos de Campos Bernardi[2]; André De F. Pedroso[2]; Teresa Cristina Alves[2]; Patrícia Perondi Anchão Oliveira[2]

1 Universidade de São Paulo; 2 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pecuária Sudeste; 3 Universidade Estadual Paulista Júlio de Mesquita Filho.

Using integrated systems has recently increased and has been providing economic and environmental benefits due to the improved use of natural resources and the recovery of degraded areas. In addition, systems that include trees provide animal welfare and better-quality food, which can improve feed efficiency and interfere with the emission of enteric methane. The objective of this study was to measure enteric methane emission from Canchim garrotes (synthetic breed 5/8 Charolais) allocated in integrated production systems. The experiment was carried out at Embrapa Pecuária Sudeste in São Carlos-SP, where 30 castrated males (18 months old and average weight of 335 kg) were distributed in five rearing-fattening production systems: management-intensive grazing (MIG), forestry or silvopastoral (IMF) livestock integration, crop-livestock or agropastoral (ICL), crop-livestock-forestry or agrosilvopastoral (ICLF) crop integration (ILPF) and the extensive system (EXT). Each production system was replicated in two areas, containing approximately 3 ha each, divided into six paddocks, with an occupation period of six days and thirty days rest period, except the extensive pasture that was not divided into paddocks because it was managed with continuous stocking. Enteric methane emissions were carried out in February 2015, using the SF6 tracer technique, during five consecutive days, changing the devices every 24 hours. CH4 and SF6 concentrations were determined by gas chromatography to estimate the enteric methane emission fluxes. Data was analyzed using SAS PROC MIXED (Statistical Analysis System, version 9.3) and the means were compared using the ded

Table: Enteric methane emissions in different production systems

Variable	Treatments					Mean	P
	Intensive (IS)	Silvopastoril (IPF)	Agropastoril (ILP)	Agrosilvopastoral (ILPF)	Extensive (EXT)		
Live Weight (kg)	333.2	333.0	342.7	343.7	327.2	336.0	0.93
CH_4(g / day)	198.1	202,1	198.4	180. 3	190.1	198.8	0.88
CH_4(kg/year)	72.3	73.8	72.4	65.8	69.4	72.58	0.88
CH_4(g/Kg live weight)	0.596	0.610	0.579	0.527	0.586	0.593	0.74

Crédit: the authors.

PRELIMINARY RESULTS

- There were no statistical differences between treatments for the mean live weight (LW - kg), with a weight variation between 330 and 347.2 kg;
- For the enteric CH_4 emissions in the different production systems evaluated, we observedsimilarities between the means for CH_4(g/d) CH_4 (kg/year) and CH_4LW (g CH_4/kg LW) with respective emission averages between all treatments of 198.83 g/day, 72.58 kg/year and 0.593 g CH_4/kg LW.

CHALLENGES

- Perform data integration during the two year experimentation period.

SOLUTIONS

- Understanding enteric methane from Canchim steers in integrated production systems.

DATA PUBLISHED IN:

SAKAMOTO, L. S.; BERNDT, A.; LEMES, A. P.; MAHLMEISTER, K.; VILAS BOAS, D. F.; MÉO FILHO, P.; PEZZOPANE, J. R. M.; ESTEVES, S. N.; BERNARDI, A. C. C.; PEDROSO, A. F.; ALVES, T. C.; OLIVEIRA, P. P. A. Enteric methane emissions of Canchim steers in five crop-livestock-forest integrated system. In: INTERNATIONAL SYMPOSIUM ON INTEGRATED CROP-LIVESTOCK SYSTEMS – TOWARDS SUSTAINABLE INTENSIFICATION, 3., 2015, Brasília.

Figure: Canchim steers in integrated systems

Crédit: Alexandre Berndt.

PROJECT COORDINATORS

Dra. Patrícia Perondi Anchão Oliveira

Embrapa Pecuária Sudeste

e-mail: patricia.anchao-oliveira@embrapa.br

Dr. André de Pedroso Faria

Embrapa Pecuária Sudeste

e-mail: andre.pedroso@embrapa.br

ENTERIC METHANE EMISSIONS FROM BEEF CATTLE ON NATURAL PASTURE WITH DIFFERENT LEVELS OF INTENSIFICATION

Teresa Cristina Moraes Genro[1]; Leandro Bochi da Silva Volk[1]; Alexandre Berndt[2]; Paulo Cézar de Faccio Carvalho[3]; Cimélio Bayer[3]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pecuária Sul; 2 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pecuária Sudeste; 3 Universidade Federal do Rio Grande do Sul.

Natural pastures are the main food base for beef cattle production systems in southern Brazil, northern Argentina and Uruguay. Data on methane emissions by ruminants grazing in this environment are rare.

This project aimed to evaluate the methane (CH_4) emissions of beef steers during rearing and finishing, maintained in natural pastures with. different levels of intensification. The study was carried out at Embrapa Pecuária Sul, Bagé-RS, Brazil. Methane emissions were measured at three levels of intensification: natural pasture (NP), natural fertilized pasture (NFP) and natural pasture fertilized and strewn with ryegrass (Lolium multiflorum) and red clover (Trifolium pratense; NFPS). Treatments were implemented in the area in 2005. Since then, 50 kg of N per hectare have been applied in fertilization treatments in the fall and the same amount in the spring. Clover (8 kg/ha) and ryegrass (25 kg/ha) sowing in the NFPS treatment was carried out in April 2005. Reseeding occurs whenever the rate of these species in the area is lower than 15%. The continuous grazing method was used with variable stocking, in order to keep forage supply of 12 kg of dry matter for each 100 kg of live weight. In August 2012, 27 Hereford steers averaging 10 months of age and 180 kg were introduced into the area. Methane collection was performed using the SF6 tracer gas technique in collecting tubes connected to the animals' nostrils, during a five-day evaluation period (Figure 1). Evaluations were made during summer, autumn, winter and spring, in 2013 and 2014. CH_4 concentration was measured using gas chromatography. Animals were weighed at the beginning of the experiment and every 28 days to determine the average daily gain (ADG).

RESULTS

- Steers grazing fertilized natural pasture issued, on average, 47.8 kg of methane per year and the steers grazing natural fertilized pasture strewn with ryegrass and red clover issued 48.0 kg of methane per year. Animals that fed on natural pasture issued 54.0 kg of methane a year;
- It is important to highlight that the average amounts of methane emissions per animal are lower than those proposed by the IPCC for this category of animals, which is 70 kg/year;
- The steers finished in fertilized natural pasture and natural fertilized and sown with exotic species showed an average daily weight gain of 163% and 189% higher than the steers kept in natural pasture;
- Proper pasture management and the use of tools, which intensify the production of quality forage, are essential to sustainably increasing the productivity of livestock in the Pampa biome.

CHALLENGES

- Teach farmers how to properly manage and intensify natural pastures to contribute to the mitigation of methane emissions;
- Recommend using an animal stocking rate adjustment in relation to the availability of adequate food for each type of pasture;
- Test new production strategies for beef cattle with low carbon emissions in production systems based on natural pasture in the Pampa biome.

SOLUTIONS

- This project showed that the use of adequate pasture management can contribute to mitigate the methane emissions of beef steers;
- Using fertilization and overseeded tools for sowing exotic forages in natural pasture allows the reduction of the period between birth and slaughter, as they accelerate the average daily

weight gain per animal, which contributes to the reduction in the emission of GHGs, since the animals spend less time in the field;

- Natural pastures, when well-managed, have the potential to produce quality meat with lower methane emission values, reducing environmental impacts;

DATA PUBLISHED IN:

GENRO, T. C. M.; FARIA, B.; SILVA, M. da; AMARAL, G.; CEZIMBRA, I.; SAVIAN, J.; BERNDT, A.; BAYER, C.; CARVALHO, P. Methane emission by beef steers on natural grassland in Southern Brazil. In: LIVESTOCK, CLIMATE CHANGE AND FOOD SECURITY CONFERENCE, 2014, Madrid. Conference abstract book [...]. [Paris]: INRA, 2014. p. 48.

Table: Average methane emissions per animal per day (CH_4, g/ day) and per year (kg/year), average daily gain (ADG, kg/d) of Hereford steers on natural pasture (NP), fertilized natural pasture (FNP) and fertilized and overgrown natural pasture (FNPs). Two year average evaluations.

Treatments	CH_4 (g/day)	CH_4 (kg/animal/year)	GMD (kg/day)
NP	147.25 a	54.0 a	0.38 b
NFP	130.96 b	47.8 b	0.62 a
NFPS	131.56 b	48.0 b	0.72 a

Note: Means followed by different letters differ from each other by Tukey's test ($P < 0.05$).

Figure: Experimental animals with enteric methane collection equipment

Crédit: Teresa Cristina Moraes Genro.

PROJECT COORDINATOR

Dra. Teresa Cristina Moraes Genro

Embrapa Pecuária Sul

e-mail: cristina.genro@embrapa.br

ENTERIC METHANE EMISSIONS FOR CATTLE IN INTEGRATED SYSTEMS IN THE BRAZILIAN MID-NORTH

Marcílio Nilton Lopes da Frota[1]; Raimundo Bezerra de Araújo Neto[2]; Marcos Lopes Teixeira Neto[2]; Geraldo Magela Cortês Carvalho[2]; Alexandre Berndt[3]; Rosa Toyoko Shiraishi Frighetto[4]; Leandro Sannomiya Sakamoto[3]; Maria Socorro de Souza Carneiro[5]

1 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Caprinos e Ovinos; 2 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Meio-Norte; 3 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Pecuária Sudeste; 4 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Meio Ambiente; 5 Universidade Federal do Ceará.

This project aimed to evaluate the emission of enteric methane from Curraleiro-Pé-duro (CPD) - Nellore (F1) cattle in a silvopastoral system of mombaça grass with Babaçu palms compared to a monoculture pasture in the Cocais Maranhenses region. The experimental design was entirely random. The treatments considered the type of pasture (silvopastoral and in monoculture) and the independent variables were: live weight, daily weight gain (DWG kg), dry matter intake (DMI kg), methane emission day, methane kilo year, methane emission in grams per kilogram of live weight, methane emissions in grams per kilogram of GPD, methane emission in grams per kilogram of DMI, loss of gross energy in the form of methane, including the fixed effects of animal, period of collection and treatment. The collection period was considered as a repeated measure over time. Six steers were used in each system weighing 185 (± 26) kg at the start and all from the similar age pool. Each area was divided into seven 4,200 m² paddocks. Animal entry and exit height in paddocks was around 80 and 40 cm, respectively. The diet consisted of pasture, mineral salt and water at will. The experimental period included the dry season of 2015 (May to August) and the rainy season of 2016 (January to April). The cattle were weighed every 28 days, after a 12-hour fast. The integrated forest system contained 67 trees per hectare with 25% shade area. DMI, the emission of enteric methane and animal performance were evaluated simultaneously. Forage dry matter intake was estimated with the indirect method using LIPE® as an external indicator. In vitro digestibility using the modified two-stage technique in an automated Ankom® DaisyII Incubator and methane emission

using the sulfur hexafluoride tracer gas (SF6). Methane collections were carried out during five consecutive days, where collection tubes were changed every 24 hours during dry and wet periods. Determining CH_4 and SF6 concentration carried with gas chromatography using a flame ionization detector and an electron capture detector. From gas chromatography results, it was possible to determine methane emission factor: g of CH_4/day (CH_4gd); kg of CH_4/year (CH_4ka). Emissions per animal in the systems were similar during the same period and ranged from 45 kg/year to 70 kg/year, depending on the season of the year During the dry season, the emission intensity (kg of CH_4per daily weight gain) was greater and there were differences in relation to the loss of gross energy CH_4. The silvopastoral system showed less loss, animals were more efficient in using the energy contained in the food. During the rainy season there was a higher consumption of dry matter in the systems, with no differences between treatments, the DWG was around 1 kg/day. The intensity of CH_4 emission during this period was around seven times lower in full sun and more than three times lower in the silvopastoral system. Thus, it is concluded that the methane emission varies throughout the year, the better the quality of the pasture and the consumption, the lower the emission intensity, the tree system resembles the monoculture pasture system that has gone through a stage of deforestation. The deforestation of the entire area did not offer an advantage in terms of production and animal methane emissions under the conditions studied. The silvopastoral system represents a sustainable management option and CPD-Nellore cattle are an option for meat production in forest areas.

RESULTS

- Methane emissions in general vary according to the time of year. This variation is influenced by the quality of the pasture and by animal consumption;
- The methane emission in the systems was similar during the same period and reached 45 kg/year during the dry period and 70 kg/year in the rainy season;
- The lower the food supply and the greater the amount of fiber, the greater the intensity of methane emissions. The average observed, considering the two systems was 1029 g of CH_4/kg of weight gain against 195 g of CH_4/kg of weight gain issued during the wet period;
- In relation to the systems in the rainy season, in the silvopastoral the emission intensity was more than three times lower and in the full sun more than seven times lower when compared to the same system in the dry period;

- During the dry period there were differences in relation to the loss of gross energy, which was lower in the silvopastoral system. In this system there was a better use of the energy contained in the food;
- Within the same period of the year, there were no differences in animal productivity in relation to the systems;
- ½ Curraleiro-Pé-Duro x ½ Nelore animals showed good development and daily weight gain of around 1 kg/day during the rainy season.

CHALLENGES

- Studies that account for soil emissions and tree sequestration, to provide an idea of the potential for GHG mitigation in systems (goats, horses and sheep) and different sources of nitrogen fertilizers.

SOLUTION

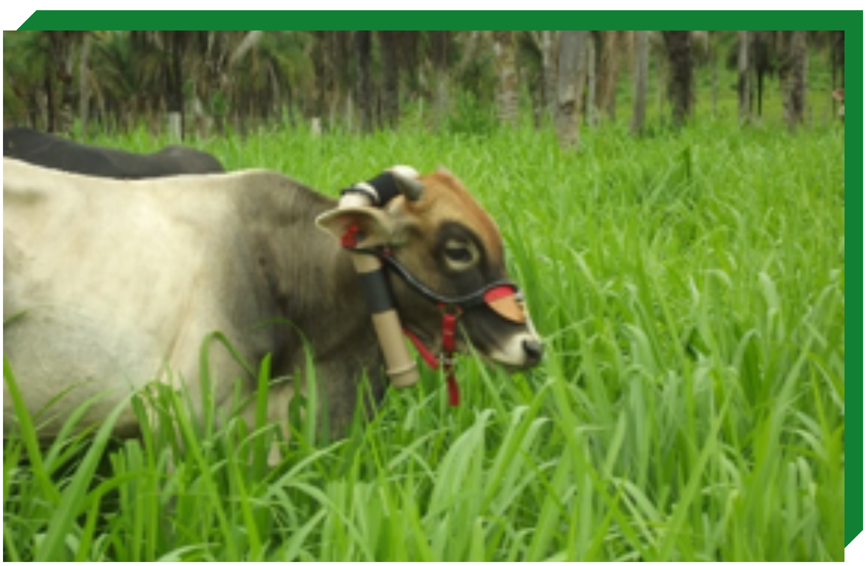
- Pastures with good nutritional value and good forage mass favor the consumption of dry matter and decrease methane emissions per kilo of product generated (kg of daily weight gain) and can be used as a strategy to mitigate emissions;
- The use of ½ mestizo Curraleiro-Pé-Duro- ½ Nellore animals is an option for meat production in tropical areas integrated with forests;
- Livestock-forest integration systems, such as the one studied in this work, may have productivity and enteric methane emissions similar to monoculture systems that have gone through a stage of total deforestation of the area.

DATA PUBLISHED IN:

FROTA, M. N. L da. Emissão de metano entérico e parâmetros comportamentais de bovinos tropicais em sistema silvipastoril. 2017. Tese (Doutorado em Zootecnia) – Universidade Federal do Ceará, Fortaleza, 2017.

FROTA, M. N. L da *et al.* Enteric methane in grazing beef cattle under full sun, and in a silvopastoral system in the Amazon. Pesquisa Agropecuária Brasileira, Brasilia, v. 52, n. 11, p. 1099-1108, nov. 2017.

Figure: Evaluation of the enteric methane emission of Curraleiro-Pé-Duro-Nelore steers in a forest livestock integration system



Crédit: Marcilio Nilton Lopes da Frota.

PROJECT COORDINATOR

Dr. Marcilio Nilton Lopes da Frota

Embrapa Caprinos e Ovinos

e-mail: marcilio.frota@embrapa.br

METHANE EMISSIONS FROM BEEF CATTLE ON TEMPERATE PASTURES AND INTEGRATED AGRICULTURAL SYSTEMS

Laíse da Silveira Pontes[1]; Raquel Santiago Barro[2]; Jean Victor Savian[3]; Alexandre Berndt[4]; José Luiz Moletta[1]; Vanderley Porfírio-da-Silva[5]; Cimélio Bayer[6]; Paulo César de Faccio Carvalho[6]

1 Instituto Agronômico do Paraná; 2 Universidade Federal de Viçosa; 3 Instituto Nacional de Investigación Agropecuaria; 4 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Pecuária Sudeste; 5 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Florestas; 6 Universidade Federal do Rio Grande do Sul.

The concept of sustainable intensification emerged in face of the current challenge of intensifying food production to guarantee food security and to protect environmental quality. In other words, to increase ecosystem services, such as C sequestration. Among the strategies of sustainable intensification of land use through diversification, the integrated agricultural production systems (IAPS) stand out. The objective of this research project was to assess the balance between greenhouse gas (GHG) emissions and C accumulation in two SIPA, that is, crop-livestock integration (CLI) vs. crop-livestock-forest integration (CLFI), with two doses of nitrogen fertilizer, 90 and 180 kg of N ha^{-1} (N90 and N180, respectively, applied during the pasture phase). The experiment was implemented in 2006, through the Technical Cooperation Term no. SAIC / AJU no 21500.10 / 0008-2, still in force, signed between Embrapa Florestas and the Agronomic Institute of Paraná (IAPAR), with the objective of developing research and technology transfers in SIPA. During the winter, Purunã beef cattle (¼ Aberdeen Angus, ¼ Canchim, ¼ Caracu, ¼ Charolais) were grazed black oat pasture (Avena strigosa) intercropped with ryegrass (Lolium multiflorum), while in the summer the area was used for soybean or corn crops in both systems. The four treatments, namely: ILP N90, ILP N180, ILPF N90 and ILPF N180, had three repetitions (plots between 0.77 and 1.22 ha). The ICLF system consisted of simple lined strips of eucalyptus trees (*Eucaliptus dunnii*), pink pepper (*Schinus terebinthifolius*) and grevillea (*Grevillea robusta*), planted in 2006, in a 3 x 14 m arrangement (initially with 238 $treesha^{-1}$), implanted in contour lines. The study was conducted at the Fazenda Modelo Experimental Station of the Agronomic Institute of Paraná (IAPAR), located in the Center-South Region of Paraná (25 ° 07´ 22 "S; 50 ° 03´ 01" W), altitude 953 m. According to the Köppen classification, the region's climate fits into the Cfb variety, subtropical without a dry season, with an annual average temperature of 17.6ºC, varying between 14ºC in July and 21ºC in January. Annual rainfall is 1.400 mm. The soil is classified as an association of typical Dystrophic Cambisol and Typical Red Dystrophic Latosol (EMBRAPA, 2006). GHG emission fluxes (CO_2 equivalent) were quantified and measured the accumulation of carbon in the soil in the ICLF. During the winter, in three consecutive years, between 2012 and 2014, daily methane emissions were measured using the SF_6 tracer gas technique, described by Johnson et al. (1994), with adaptations (GERE; GRATTON, 2010). Collections were carried out in two animals per plot, totaling 24 Purunã heifers, aged around 10 months and at an initial weight of 250 kg, on average, in five consecutive days, starting on August 9, 15 and 24 2012, 2013 and 2014, respectively. The emission results per kg of live weight, per kg of average daily gain (ADG) and per area, were determined using the daily CH_4 emissions per animal, DAG and animal load, respectively.

RESULTS

- CH_4 emissions per animal and per kg live weight (LW) did not differ between treatments (Table 1) and evaluated years (P> 0.05), with average values of 163 ± 9.12 g $animal^{-1}$ day^{-1} and 0.58 ± 0.030 g kg-1 PV;
- CH_4 emission per area unit varied significantly between the years, that is, between 0.53 ± 0.058 and 0.71 ± 0.080 kg of CH_4 ha^{-1} day^{-1}, in 2013 and 2012, respectively, depending on the variations in the animal load, aiming to keep the height of the pasture constant at around 20 cm;
- In N180 ICL treatment, there was a tendency for a higher CH_4 emission per unit area (P <0.10), due to the greater support capacity (+0.5 AU ha^{-1}, on average) in this treatment, in addition to lower methane emission by DAG (Table 1), since the emission of CH_4 is reduced in animals with higher DAG;
- In terms of CO_2equ, the amounts obtained in the present study were 4.2 and 6.0 kg CO_2equ DAG^{-1} for the ICL and ICLF systems, respectively, values that are lower than what is normally found in the literature, suggesting greater efficiency and production, in the present study, per unit of CO_2equ issued;
- In the wood system, an annual CH^4 emission of 326 kg C equ ha^{-1} $year^{-1}$ was estimated, considering a grazing period of 100 days, in areas with ICLF, and 2.1 AU ha^{-1}, on average in such a system. However, the study highlighted the potential for sequestering

C in trees. For example, the 79 8-year-old eucalyptus trees, in 2014, would have sequestered 26.5 Mg of C ha^{-1}, which would easily neutralize CH_4 emissions in such systems;

- In addition to the results on enteric methane emissions by cattle, Prof. Dr. Jeferson Dieckow from UFPR and team also assessed N_2O and CH_4 emissions from the soil, emissions from animal waste, as well as in relation to the organic C stock in the soil. These results will be published shortly.

CHALLENGES

- Multidisciplinary teams, field instrumentation, equipment and laboratory reagents for analysis;
- Project management required the integration of multidisciplinary skills as well as the involvement of several research institutions in the face of legal precepts;
- Due to the countless necessary assessments and factors to be considered (eg the agricultural practices carried out, inputs used, etc., which should be transformed into carbon equivalents), the balance between GHG emissions and the accumulation of C of ICLF is still being calculated.

DATA PUBLISHED IN:

PONTES, L. da S.; BARRO, R. S.; SAVIAN, J. V.; BERNDT, A.; MOLETTA, J. L.; PORFÍRIO-DA-SILVA, V.; BAYER, C.; CARVALHO, P. C. de F. Performance and methane emissions by beef heifer grazing in temperate pastures and in integrated crop-livestock systems: The effect of shade and nitrogen fertilization. Agriculture, Ecosystems and Environment, v. 253, p. 90-97, 2018.

SOLUTION

- The results generated demonstrate the potential of wooded ICLF as a CO_2 mitigation strategy;
- The results generated demonstrate the importance of the tree management component, in order to avoid shading levels above 40% and the consequent reduction in pasture productivity and support capacity.

REFERENCES:

EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária. Centro Nacional de Pesquisa de Solos. Sistema brasileiro de classificação de solos. 2. ed. Brasília: Embrapa Produção de Informação, 2006.

GERE, J. I.; GRATTON, R. Simple, low-cost flow controllers for time averaged atmospheric sampling and other applications. Latin Am. Appl. Res., N. 40, p. 377-381, 2010.

JOHNSON, K.; HUYLER, M.; WESTBERG, H.; LAMB, B.; ZIMMERMAN, P.

Measurement of methane emissions from ruminant livestock using a SF6 tracer technique. Environ. Sci. Technol., n. 28, p. 359-362, 1994.

Figure: Evaluation of enteric methane emissions for Purunã beef heifers in integrated agricultural production systemsCrédito: Laíse Pontes.

PROJECT COORDINATORS

Dra. Laíse da Silveira Pontes

Instituto Agronômico do Paraná

e-mail: laisepontes@iapar.br

Dr. Vanderley Porfírio-da-Silva

Embrapa Floresta

e-mail: vanderley.porfirio@embrapa.br

Dr. José Luiz Moletta

Instituto Agronômico do Paraná

e-mail: moletta@iapar.br

ENTERIC METHANE EMISSIONS IN BUFFALOES IN EASTERN AMAZON: TIER2 METHODOLOGY AND SULFUR HEXAFLUORIDE (SF6)

Vinícius Gomes de Castro[1]; João Maria do Amaral Júnior[2]; Lucieta Guerreiro Martorano[3]; Paulo Campos Christo Fernandes[4]; Samanta do Nascimento Monteiro[5]; José de Brito Lourenço Júnior[6]

1 Universidade Federal Rural da Amazônia; 2 Instituto Federal do Amapá; 3 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Amazônia Oriental; 4 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Cerrado; 5 Universidade Federal Rural da Amazônia; 6 Universidade Federal do Pará.

The increase in the concentration of greenhouse gases (GHG) in the atmosphere has become more intense and is attributed to human activities. In Brazil, the productive sector responsible for the most GHG emissions is related to soil use, agriculture and livestock. In 2014, Brazilian agriculture and livestock emissions represented about 20% of the total GHG emission (SEEG, 2016). In livestock, one of the main factors of GHG emissions are the methane (CH_4) from enteric fermentation in ruminants, responsible for 68% of emissions in the livestock sector (Berchielli *et al.*, 2012). Therefore, this work aims to compare the estimated enteric methane emissions by tier 2 are presented and determined using SF_6 gas in buffaloes consuming different levels of palm oil pie (Elaeis guineensis) in the Eastern Amazon. The tier 2 equations were used considering the same diet used in the field trial to quantify the enteric methane emissions with the SF6 tracer gas technique, according to the methodology described by Johnson *et al.* (1994). Data from the field trials was obtained by the PECUS Project and belongs to the doctoral thesis database of a member of the research team. It is worth mentioning that the data was obtained at the "Senador Álvaro Adolpho" Animal Research Unit belonging to Embrapa Amazônia Oriental, in the city of Belém, Pará, Brazil. Diets were supplied to 24 crossbred Murrah-Mediterranean females, weighing an average of 514 ± 69.88 kg, from to the experimental herd at Embrapa Amazônia Oriental. The study was approved by the Animal Ethics Committee - CEUA according to protocol 007/2015. The animals were handled in confinement, during which they spent 21 days adapting to the experimental diets, with free access to water and mineral mixture. The experiment followed a completely randomized design, with four treatments and six repetitions: in this study, only three treatments were considered, that is, inclusion of palm kernel pie in relation to body weight (BW) at the levels of 0% (T1), control; 0.5% (T2); and 1.0% (T3). 0.15% wheat bran (CP) was added to all treatments to increase palatability and corn silage was added as roughage. The animals were fed individually twice a day (8 am and 5 pm). The amounts of silage were weighed daily and adjusted to achieve daily leftovers of up to 10%. These diets were used to estimate the emission factor employing the IPCC (IPCC, 2006) methodology, called Tier 2. Animal characteristics and diets were considered: animal age, initial weight, average weight, final weight, weight gain, digestible energy and gross energy. Average enteric methane emissions, determined by the SF_6 tracer gas technique and those estimated in Tier 2, show that there were no significant differences ($p > 0.05$) in the control treatments and with the addition of 0.25 and 0.50% of palm oil pie> to the diet, indicating that Tier 2 can be used as an estimator of enteric emissions from ruminants, when the nutritional composition of the diet and characteristics of the animals are known, such as category, weight, sex and production system. However, measurements in the treatment with 1.0% of palm oil cake were lower ($p < 0.05$) than those estimated by Tier 2. This fact can be explained by the higher content of lipids in the diet, which reduces the emission of enteric methane, and which could be detected with greater precision using the (SF_6) tracer gas methodology., which is sensitive to evaluating enteric methane emissions in animals that received a diet with a higher level of inclusion of methane production reducing components.

RESULTS

- The enteric methane emission estimated by tier 2 presented amounts close to those measured with the SF_6 tracer gas technique until lipid supplementation in 0.5% of live weight;
- Amounts were overestimated for lipid supplementation at 1.0% live weight by Tier 2;
- Tier 2 can be used to calculate ruminant emissions in the Amazon biome, since most of the region's herd is raised on extensive farms;
- The sulfur hexafluoride tracer gas methodology requires trained labor, a structured laboratory and research team, like that of the PECUS Network.

CHALLANGES

- Improvement of management techniques that aim to contribute to lower GHG emissions, including enteric methane;
- Farmers adoption of by-products of agribusiness, for example, palm oil pie contribute to the mitigation of enteric methane without compromising animal performance.

SOLUTIONS

- Efficient pasture management can decrease enteric methane emissions from the buffalo herd, as well as contribute to improving land use and its nutritional constituents, which may prevent the continued deforestation of native forest areas in the Brazilian Amazon;
- Nutritional strategies to reduce enteric methane emissions, for example, lipid supplementation in ruminant's diets;
- Use of technologies can sustainably transform productive systems from an economic, social and environmental point of view.

DATA PUBLISHED IN:

CASTRO, V. C. G.; AMARAL JUNIOR, J. M.; MARTORANO, L. G.; FERNANDES, P. C. C.; MONTEIRO, S. N.; LOURENCO JUNIOR, J. B. Emissões de metano entérico em búfalas na Amazônia Oriental: TIER 2 e hexafluoreto de enxofre. Amazonian Journal of Agricultural and Environmental Sciences – Revista de Ciências Agrárias, v. 60, p. 286-290, 2017.

CASTRO, V. C. G.; AMARAL JUNIOR, J. M.; MARTORANO, L. G.; MONTEIRO, S. N.; BEZERRA, A. S.; FERNANDES, P. C. C.; LISBOA, L. S.; OLIVEIRA, P. P. A. Enteric methane estimation with Tier2 compared to results obtained in a field experiment with water buffaloes supplemented with palm kernel cake in the amazon biome. Documentos Embrapa Gado de Corte, v. 216, p. 107-111, 2016.

CASTRO, V. C. G.; LUCAS, R. C.; FERNANDES, P. C. C; BARROS, K. K. S.; MARTORANO, L. G. Técnicas de avaliação de metano entérico em bubalinos: conteúdo ruminal. In: ENCONTRO AMAZÔNICO DE AGRÁRIAS - SEGURANÇA ALIMENTAR: DIRETRIZES PARA AMAZÔNIA, 7., 2015, Belém: ENAAG, 2015.

Continued in Annex

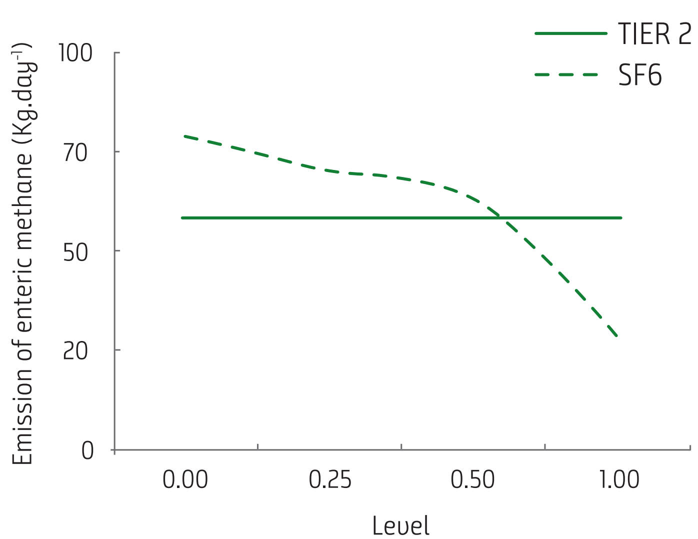
REFERENCES:

BERCHIELLI, T. T.; MESSANA, J. D.; CANESIN, R. C. Produção de metano entérico em pastagens tropicais. Revista Brasileira Saúde Produção Animal, v. 13, p. 954-968, 2012.

IPCC – Intergovernmental Panel on Climate Change. IPCC Guidelines for National Greenhouse Gas Inventories. Japan: IGES, 2006. Chapter 10 Volume 4.

JOHNSON, K .; HUYLER, M .; WESTBERG, H .; LAMB, B .; ZIMMERMAN, P. Measurement of methane emissions from ruminant livestock using a SF6tracer technique. Environ. Sci. Technol., N. 28, p. 359-362, 1994. SEEG – Sistema de Estimativa de Emissão de Gases de Efeito Estufa. 2016. Available at: http://seeg.eco.br

Figure: Emission of enteric methane from buffaloes receiving a diet with different levels of inclusion of palm kernel pie, using tier 2 and SF_6. techniques.



PROJECT COORDINATORS

Dra. Patrícia Perondi Anchão Oliveira

Embrapa Pecuária Sudeste

e-mail: patricia.anchao-oliveira@embrapa.br

Dra. Lucieta Guerreiro Martorano

Embrapa Amazônia Oriental

e-mail: lucieta.martorano@embrapa.br

ENTERIC METHANE EMISSION IN BUFFALOES SUPPLEMENTED WITH PALM KERNEL CAKE IN THE AMAZON BIOME

João Maria do Amaral Júnior[1]; Eziquiel De Morais[2]; Elder Santana Natividade do Carmo[3]; Marco Antônio Paula de Sousa[4]; André Guimarães Maciel e Silva[4]; Bruna Almeida da Silva[5]; Lucieta Guerreiro Martorano[6]; Alexandre Berndt[7]
1 Instituto Federal do Amapá; 2 Instituto Federal do Pará; 3 Universidade Federal Rural da Amazônia; 4 Universidade Federal do Pará; 5 Universidade do Estado do Pará; 6 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Amazônia Oriental; 7 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pecuária Sudeste;

With the increase of the biofuel production chain in Brazil, an increase in demand and supply of vegetable fibers resulting from these industrial processes is expected. The palm oil market has been growing at a fast pace in the Amazon region, the state of Pará produced more than 816,000t of palm oil, representing more than 90% of national production (IBGE, 2017). One of the co-products generated in large volumes by this activity is palm kernel cake (PKC), which can potentially be used in animal feed. The objective of this study was to evaluate the effect of PKC supplementation on buffalo feeding, observing the effect of this co-product on voluntary consumption and in vivo production of enteric methane in the buffalo species. 24 mixed race, dry females buffaloes with an initial age and average weight of 34 months ± 04 and 514kg ± 69.88kg, respectively, from Embrapa Amazônia Oriental's herd, under the climatic conditions of the city of Belém/PA (Martorano *et al.*, 2017). The experimental procedures were authorized through certification by the Animal Ethics Committee - CEUA No. 007/2015. Buffaloes received dietary supplementation during the months of September and October 2015. The experiment consisted of adding palm kernel cake at the following levels in relation to body weight (BW): 0% (T1), with (control), 0.25% (T2), 0.50% (T3) and 1.0% (T4) to the diet, in a completely randomized design, with 04 treatments and six repetitions, considering the animal an experimental unit. Associated with each diet level, 0.15% BW of wheat bran was included in all treatments, in order to provide better acceptability of PKC. The assessment of methane emissions (CH_4) was performed using the sulfur hexafluoride (SF_6) tracer gas technique, as per Johnson et al., 1994. In figure 1 we see the animals with yokes. CH_4 and SF_6 concentrations were determined using gas chromatography. The analyses in this experiment showed variation in the production of methane regarding the different levels of PKC included. Enteric methane emission was lower in the treatment with the 1.0% level of inclusion of the palm kernel pie (27.65 kg / year^{-1}) when compared to the control group (T1) which produced an average of (78.15 kg/$^{-1}$) and in relation to the IPCC (2006) estimates for buffaloes (55.00 kg /year^{-1}). Animal supplementation, based on the inclusion of increasing levels of palm kernel pie, did not influence the voluntary consumption of buffaloes with up to 1.0% of the PC. The provision of levels above 0.50% of the animals body weight supplemented with palm kernel pie, reduces the emission of enteric methane in buffaloes in the Eastern Amazon.

RESULTS

- There was a significant effect on animal consumption (kg day^{-1}) for the variables Dry matter, Organic matter, Crude protein, Fiber in neutral detergent, Fiber in acid detergent and Ethereal extract, depending on the levels offered in the palm kernel pie;
- A decreasing linear effect was detected for the estimation of methane production due to the inclusion of palm kernel pie in the buffaloes diet;
- The emission of enteric methane per day was lower in the treatment with an offer level of palm kernel pie of 1.0% in relation to body weight (27.65 kg year^{-1}), presenting lower amounts than those observed in the IPCC (2006) that estimated the emission in buffaloes of (55.00 kg year^{-1});
- The inclusion of palm kernel pie in the diet did not influence the buffaloes' voluntary consumption.

CHALLENGES

- Reducing bovine's methane production without altering animal productivity is desirable, both as a strategy to mitigate the total emission of greenhouse gases, as well as to improve the feed conversion efficiency of ruminants;
- It is necessary to have a larger number of field sample collections with farm animals to increase the accuracy of the methodology used, reducing experimental errors;
- Implementation of economically viable techniques, helping to mitigate GHG emissions, without influencing animal performance offering greater access to these results for the entire livestock production chain in the Amazon.

SOLUTIONS

- The results demonstrate the importance of developing research aimed at animal production, improving the sustainable management of the entire production chain;

- The estimation of enteric methane production in buffaloes optimized the use of the co-product (palm kernel pie), so it can be used in animal feed, respecting the adequate levels of supply to the animals;

- The methodology used demonstrates the reliability and the need for new techniques for measuring and monitoring farm animals, in view of the importance of this segment to the world economy.

DATA PUBLISHED IN:

AMARAL JÚNIOR, J. M. CONSUMO, CINÉTICA RUMINAL E PRODUÇÃO DE METANO EM BÚFALAS SUPLEMENTADAS COM NÍVEIS CRESCENTES DE TORTA DE PALMISTE NO BIOMA AMAZÔNIA. 2017. TESE (DOUTORADO EM PRODUÇÃO ANIMAL) – UNIVERSIDADE FEDERAL DO PARÁ, BELÉM, 2017.

AMARAL JÚNIOR, J. M.; MORAIS, E.; CARMO, E. S. N.; SOUSA, M. A. P.; SILVA, B. A.; MARTORANO, L. G.; BERNDT, A.; SILVA, A. G. M. ENTERIC METHANE EMISSION OF FEMALE BUFFALOES SUPPLEMENTED WITH PALM KERNEL CAKE IN THE AMAZON BIOME. IN: SIGEE - SECOND INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN AGRICULTURE, 2., 2016, CAMPO GRANDE, MS.

REFERENCES:

IBGE – Instituto Brasileiro de Geografia e Estatística, Censo Agropecuário 2017, Disponível em: https://censos.ibge.gov.br/agro/2017 Accessed on: 11 dez, 2017.

IPCC – Intergovernmental Panel on Climate Change. IPCC Guidelines for National Greenhouse Gas Inventories. Agriculture, forestry and other land use. Hayama, Japan. v.4, p: 10.1-10.84, 2006.

JOHNSON, K., HUYLER, M., WESTBERG, H., LAMB, B., ZIMMERMAN, P., 1994.

Measurement of methane emissions from ruminant livestock using the SF6 tracer technique. Environ. Sci. Technol. 28, 359–362.

MARTORANO, L. G. et al. Climate conditions in the eastern amazon: Rainfall variability in Belem and indicative of soil water defict. African Journal of Agricultural Research, 12 (21): 1801-1810, 2017.

Figure: Evaluation of enteric methane emissions by female buffaloes using the sulfur hexafluoride (SF6) tracer gas technique.

Crédit: João Maria do Amaral Júnior.

PROJECT COORDINATORS

Dra. Patrícia Perondi Anchão Oliveira

Embrapa Pecuária Sudeste

e-mail: patricia.anchao-oliveira@embrapa.br

Dra. Lucieta Guerreiro Martorano

Embrapa Amazônia Oriental

e-mail: lucieta.martorano@embrapa.br

NITROUS OXIDE EMISSION IN TROPICAL PASTURES OF BEEF CATTLE PRODUCTION SYSTEMS

Patrícia Perondi Anchão Oliveira[1]; Mariana Vieira Azenha[1]; Paulo Henrique Mazza Rodrigues[2]; Teresa Cristina Alves[1]; Amanda Prudêncio Lemes[1]; André de Faria Pedroso[1]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pecuária Sudeste; **2** Universidade de São Paulo.

Brazil has 851.58 million hectares, 158.75 million of which are occupied by pasture, making up 18.6% of its territory and 58.1% of the area of the production units (IBGE, 2010). Brazilian beef cattle production is based on tropical pastures. The recovery and intensification of pastures has the potential to mitigate Greenhouse Gases (GHG) due to the high production of forage mass, which can increase carbon sequestration, removing GHG from the atmosphere (OLIVEIRA, 2015). However, the need to use soil improvers and fertilizers and the adoption of irrigation can cause an increase in the emission of greenhouse gases. The main GHGs related to agriculture are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The concentration of N_2O in the atmosphere is much lower than the concentration of CO_2, but assessing its emission is important due to its high potential for global warming, which is 270 to 310 times greater than CO_2 (SNYDER *et al.*, 2008; MCTI, 2014). The objective of this study was to evaluate the effect of the recovery and intensification of pasture management and climatic seasons of the year on N_2O.

The experiment was developed at Embrapa Pecuária Sudeste - SP in the Brazilian Atlantic Forest biome, in 2014 to 2015. The treatments were four pastoral production systems for rearing and fattening Nellore steers: 1) IAL: irrigated pasture with high animal stocking (5.9 - animal units - AU/ha; Panicum maximum); 2) SAL: dryland pasture with high stocking (4.9 AU/ha; Panicum maximum), 3) SML: dryland pasture with medium stocking (3.4 AU / ha; *Brachiaria brizantha*); 4) PD: degraded pasture with low animal stocking (1.1 AU/ha; Brachiaria decumbens). The pastures of the IAL, SAL and SML systems were managed with rotational stocking and the PD system pasture with continuous stocking. Animal stocking was adjusted using the "put and take" technique. In the IAL, SAL and SML systems, soil correction with lime and basic fertilization with K, P and micronutrients were carried out. Five fertilizer applications were made on the IAL pasture with 80 kg of N during the wet season and five applications with 40 kg of N during the dry season (600 kg N / ha.year), with tropical pasture overwintered with oats and ryegrass during that season. In the pastures of the SAL and SML systems, five applications of nitrogen fertilizer with 80 and 40 kg of N occurred during the wet season, totaling 400 and 200 kg N/ha.year, respectively. Urea was the nitrogen fertilizer used for all treatments. In the PD system, soil correction and fertilization were not carried out. Emission fluxes of N_2O were assessed collecting air samples from static chambers (six per treatment) in pastoral systems and in the semideciduous seasonal forest of the Mata Atlântica biome (positive control) for two years and during all climatic seasons. The entire procedure for collecting gas samples and accessory variables was performed according to Zanatta, *et al*. 2014. The samples were analyzed using gas chromatography.

RESULTS

- Nitrous oxide emissions were low considering the high doses of fertilizers used in the most intensified systems and the use of irrigation that could have promoted denitrification with a consequent nitrous oxide emission. This was possibly due to the fact that the soils were well ventilated;

- The accumulated emissions of nitrous oxide differed between the production systems and the climatic seasons, and there were interactions between these factors;

- The total emission of nitrous oxide was higher in the irrigated system (IAL), intermediate in the rainfed with high stocking (SAL) and lower in the recovered (SML) and degraded (DP) systems, which were similar to each other;

- The emission in the irrigated system was higher in the summer and lower in the spring compared to other seasons of the year, in the high-capacity rainfed system (SAL) the difference between the seasons followed similar behavior, however with less pronounced differences. For the degraded (DP), rainfed systems with low capacity (SML) and in the forest, the emission was the same during the seasons, possibly due to the low nitrogen supply in these systems..

CHALLENGES

- Improve understanding of the physical, chemical and microbiological processes of the soil that allowed low losses of nitrous oxide.

SOLUTIONS

- Nitrous oxide emissions were below the expected, considering the amount of nitrogen fertilizer used and the use of irrigation;
- Possibility of using pasture recovery and intensification to increase C sequestration with low impact on nitrous oxide emission.

DATA PUBLISHED IN:

OLIVEIRA, P. P. A.; AZENHA, M. V.; RODRIGUES, P. H. M.; ALVES, T. C.; LEMES, A. P.; PEDROSO, A. de F. Nitrous oxide emission by pastures in tropical beef production systems. In: INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN AGRICULTURE, 2., 2016, Campo Grande, MS. Proceedings [...]. Brasília, DF: Embrapa, 2016. p. 93-96. (Embrapa Gado de Leite. Documentos, 216).

REFERENCES:

IBGE – Instituto Brasileiro de Geografia e Estatística. Confronto dos resultados dos dados estruturais dos Censos Agropecuários – Brasil – 1970/2006. Available at: http://www.ibge.gov.br/home/estatistica/Economia / agropecuaria/censoagro/2006/defaulttab_censoagro.shtm.

MCTI – Ministério da Ciência, Tecnologia e Inovação. Estimativas anuais de emissões de gases de efeito estufa no Brasil. Brasília: MCTI, 2014.

OLIVEIRA, P. P. A. Gases de efeito estufa em sistemas de produção animal brasileiros e a importância do balanço de carbono para a preservação ambiental. Revista Brasileira de Geografia Física, v. 8, p. 623-634, 2015.

Continued in Annex

Figure: General view of pastures and Nellore breed animals using yokes

Crédit: Alexandre Berndt.

PROJECT COORDINATORS

Dra. Patrícia Perondi Anchão Oliveira

Embrapa Pecuária Sudeste

e-mail: patricia.anchao-oliveira@embrapa.br

Dr. André de Faria Pedroso

Embrapa Pecuária Sudeste

e-mail: andre.pedroso@embrapa.br

MODELING NITROUS OXIDE EMISSIONS FROM PURE GRASS PASTURES AND INTERCROPPED GRASS AND LEGUMES IN THE WESTERN BRAZILIAN AMAZON

Falberni de Souza Costa[1]; Maykel Franklim Lima Sales[1]; Antônio Carlos Reis de Freitas[2]; Cleberson Pereira de Souza[3]
1 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Acre; 2 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Cocais; 3 Universidade Federal do Acre.

Brazilian agriculture is associated with greenhouse gas (GHG) emissions, and the exact contribution of emissions from pastures is not yet known due to the varying degree of their quality/degradation. These emissions can cause extreme events that, in a closed cycle of cause and effect, can affect production systems in the Amazon. Knowing the magnitude of the contribution of livestock systems to GHG emissions in the Amazon Biome identifies variables associated with the generating processes and emission factors, potentially enhancing technological solutions for a positive balance between carbon inputs and outputs in the production system. The dynamics of mineral nitrogen (N) in the soil and the exchange of its gaseous forms at the soil-atmosphere interface are closely associated with the deposition of animal waste (urine and feces) in the pasture. According to the content of inorganic N in the soil and the studied site, forest or pasture, pasture age, the contents of N-ammonium and N-nitrate may be similar in the forest or dominated by N-ammonium in the pasture as it gets older. In addition, the average annual net nitrification rates on the soil surface in the forest may be higher than on pasture suggesting potential greater losses of N-nitrate or by leaching or gaseous emissions in preserved forest soils compared to soil under consolidated pasture (NEILL *et al.*, 1995). To Melillo et al. (2001) emissions of nitrous oxide (N_2O) from young pastures (5.0 kg N-N_2O ha-1year-1) were two to one and a half times lower than in the forest (9.0 kg N-N_2O ha-1year^{-1}) during the first two years of pasture, increasing to one third of these amounts when the pasture was more than three years old (1.4 kg N-N_2O ha^{-1} year^{-1}). The magnitude of the nitrate content on the soil surface is one of the best indicators for predicting N_2O emissions (VERCHOT *et al.*, 1999, MELILLO *et al.*, 2001). N_2O emissions can be measured through field samples by gas chromatography or estimated by process-based models. The DNDC (Decomposition Denitrification) model simulates biogeochemical cycles of carbon and nitrogen in agricultural systems (GILTRAP *et al.*, 2010). The N_2O emissions estimated by the DNDC model of pure grass pastures (> 30 years of> age) and intercropped with leguminous grass (> from four years after> 30 years of age) and from the soil of a native forest in the west of the Brazilian Amazon.> > To enable knowledge regarding the magnitude of the livestock systems in the Amazon Biome's contribution to GHG emissions, these were monitored in livestock in pasture systems in Acre, in the western Amazon, Brazil.

Emissions of nitrous oxide (N_2O) were estimated using the Denitrification-Decomposition (DNDC) model.

The evaluated systems were pure pastures of *Brachiaria humidicola* (Rendle) Scheick (G) and B. humidicola grass intercropped with forage peanut Arachis pintoi Krapov. & WC Greg cv. BRS Mandobi (GL), both without fertilization. A native forest (NF) classified as open/dense bamboo was the benchmark for assessing land use change from native forest to pasture. Pure pasture was the benchmark for changing pasture management. The evaluated systems have the same type of soil, a plinthic Red-Yellow Argisol (EMBRAPA, 2013). The experiment was installed in 2011 at the Guaxupé farm (68 ° 05 'W, 9 ° 57' S, 200 m above sea level) in Rio Branco, State of Acre, Brazil. The native forest was removed from the soil used in the experiment occurred in 1981.

The soil collections were carried out in G, GL and FN from February to December 2014 and from January to July 2015 in the layers of 0-10 cm and 10-20 cm, the soil sampling followed the Pecus Network protocol.

The results of soil sample analysis and meteorological information were the inputs from the DNDC model for predicting N_2O emissions (LI *et al.*, 1994).

PRELIMINARY RESULTS

- The average N_2O emission in 166 days followed the following order: pure pasture (35.8 μg Nm^{-2}h^{-1})> native forest (28.2 μg N m^{-2} h^{-1})> intercropped pasture (27.2 μg Nm^{-2} h^{-1}).>> N2O emissions were lower during the transition from the wet-dry and dry-wet seasons and higher in the characteristic wet and dry seasons of the Brazilian Amazon;

- N_2O emissions were correlated with the porous space filled with soil water (0-10 cm) and with the soil temperature (0-10 cm) in the FN, G and GL systems (P <0.05) and showed no correlation with soil N-nitrate content;

- The annual N_2O emission was 3.13 kg N\ha^{-1} year^{-1} in G, 2.47 kg N ha^{-1}year^{-1} in FN and 2.38 kg N ha^{-1}year^{-1} in GL. The annual emission predicted in the G, GL and FN systems is in the range of the annual emission tabulated by Verchot et al. (1999) for humid tropical forests (0.3 to 6.7 kg N ha[-1]year[-1]) and according to Meurer *et al*. (2016) for pastures;

- The total N_2O emission for the evaluated period was 4.6 kg N ha^{-1} in G, 3.0 kg N ha^{-1} in FN and 2.7 kg N ha^{-1} in GL (Figure), higher than those cited by Melillo *et al.* (2001) for older pastures, however they are in the range mentioned by Meurer *et al.* (2016);

- Although in the range of N_2O emissions measured in the Brazilian Amazon, the emissions predicted by the DNDC in this study should be treated with caution, since results of emissions measured in the field are not yet available for the soil, regional meteorological conditions and pasture management on the farm evaluated in this study.

CHALLENGE

- Measure N_2O emissions in field conditions for soil, regional meteorological conditions and pasture management evaluated in this study..

SOLUTIONS

- Integrated groups of well-established researchers in the Brazilian Amazon and national and international groups on the topic of climate change;

- A laboratory in the southwest of the Brazilian Amazon with continuous operational capacity.

DATA PUBLISHED IN:

ALMEIDA et al. (coord.). Anais do 2° Simpósio Internacional sobre gases de efeito estufa na agropecuária. Campo Grande, MS: Embrapa gado de corte, 2016.

REFERENCES:

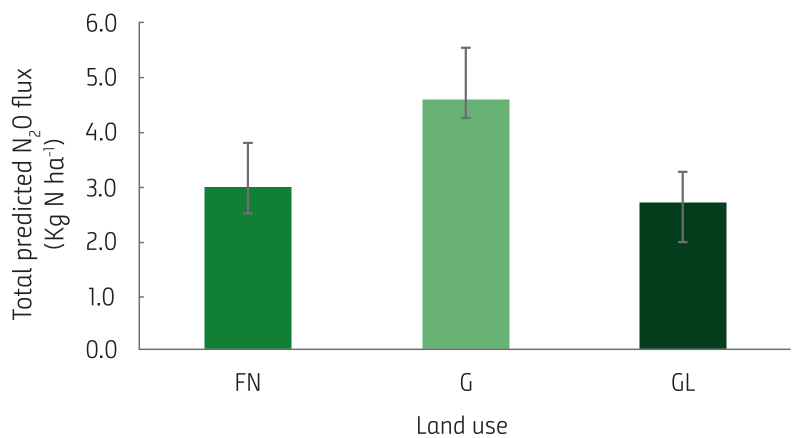
Embrapa - Empresa Brasileira de Pesquisa agropecuária. Sistema brasileiro de classificação de solos. 3. ED. Brasília: Embrapa, 2013.

GILTRAP, D. L. et al. DNDC: A process-based model of greenhouse gas fluxes from agricultural soils. Agriculture, ecosystems and environment, V. 136, P. 292-300,2010.

LI, C. et al. Modeling carbon biogeochemistry in agricultural soils. Global biogeochem. Cycles, N. 8, P. 237-254, 1994.

Continued in Annex

Figure: Total N_2O flux predicted at Guaxupé farm, State of Acre, Brazil. FN = native forest. G = pure *Brachiaria humidicola pasture* and GL = intercropped B. *humidicola with Arachis pintoi* cv BRS Mandobi pasture. Values are averages of 38 simulations of soil parameters in the DNDC. Bars are the standard deviation of the mean.



PROJECT COORDINATORS

Dra. Patrícia Perondi Anchão Oliveira

Embrapa Pecuária Sudeste

e-mail: patricia.anchao-oliveira@embrapa.br

Dra. Lucieta Guerreiro Martorano

Embrapa Amazônia Oriental

e-mail: lucieta.martorano@embrapa.br

Dr. Falberni de Souza Costa

Embrapa Acre

e-mail: falberni.costa@embrapa.br

GREENHOUSE GAS DYNAMICS AND THEIR INTERFACE WITH EFFICIENCY, FOOD QUALITY AND SUSTAINABILITY IN AGRICULTURAL PRODUCTION SYSTEMS OF THE ATLANTIC RAINFOREST BIOMA

Alexandre Berndt[1]; Leandro Sannomiya Sakamoto[1,2]; André de Faria Pedroso[1]; Amanda Prudêncio Lemes[1]; Mariana Vieira Azenha[1]; Teresa Cristina Alves[1]; Paulo Henrique Mazza Rodrigues[2]; Rosana Ruegger Corte[2]; Paulo Roberto Leme[2]; Patrícia Perondi Anchão Oliveira[1]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pecuária Sudeste; 2 Universidade de São Paulo.

The objective of this work was to evaluate the CH_4 emission intensities of Nellore cattle in pasture systems during the finishing phase. 48 castrated Nelore animals during two harvests were evaluated, 24 per harvest, distributed in the four pasture production systems: under intensive irrigated management with high stocking (IAL), under intensive dryland management with high stocking (SAL), in recovery under rainfed management with moderate animal stocking (SML) and degraded with low animal stocking (DEG).

Methane was measured using the sulfur hexafluoride (SF_6) tracer gas technique. Pasture samples were analyzed and Nelore animal consumption was estimated. Animal performance data (live weight, weight gain, feed conversion), carcass (ribeye area of the Longissimus muscle, fat thickness, hot carcass weight (PCQ) and carcass yields (RendC) and gain (RendG)) as well as methane related variables. Data per hectare was also presented. The data was analyzed using the MIXED procedure of the SAS 9.3 program.

RESULTS

- More intensified systems showed better results of forage quality compared to DEG, this reflected in the animal's consumption and performance which demonstrated worse results. DEG was the least productive of all. Some variables related to CH_4 varied between treatments: I) the emission in relation to daily weight gain (CH_4 DWG) was lower for the IAL system (371 g CH_4/ kg DWG) compared to the DEG (478.4) and SAL (484.5) systems, the SML system (404.0) did not differ from IAL and DEG; II) the gross energy lost in the form of CH_4(YM) showed higher values for the SAL and DEG systems compared to the IAL and SML. The systems with higher intensification had a higher stocking rate ($p < 0.0001$) and higher weight and carcass gain ($p < 0.0001$) per hectare. SAL demonstrated lower emission intensity (EI) calculated by RendG than DEG ($p = 0.0269$). However, the systems did not show differences in EI due to weight gain ($p = 0.3602$) and per kg of carcass calculated by RendC ($p = 0.1567$), despite finding partial differences in emissions per year and

Tabela 1: Variáveis de metano obtidas de machos Nelore em sistemas com diferentes níveis de intensificação a pasto

Variables 4	Treatments 1				Mean ± SD2	EPM3	P
	IAL.	SAL	SML	DEG			
CH_4GD (g/d)	185.1	199.2	192.7	177.7	188.4 ± 52.6	3.858	0.2484
CH_4PVm(g/kg)	0.429	0.468	0.453	0.466	0.451 ± 0.11	0.008	0.3544
CH_4PMet(g/kg)	1.945	2.128	2.047	2.050	2.037 ± 0.49	0.036	0.3865
CH_4GPD(g/kg)	371.0c	484.5a	404.0bc	478.4ab	422.3 ± 203	15.28	0.0078
CH_4CMS(g/kg)	23.98	26.67	25.24	27.57	25.76 ± 5.92	0.434	0.0602
CH_4DDM(g/%)	62.54	64.73	65.80	61.90	63.62 ± 17.9	1.307	0.6985
CH_4EB(Mcal/d)	2.457	2.646	2.562	2.353	2.50 ± 0.70	0.051	0.1848
YM% ($EBCH_4$/EBI)	7.714b	8.760a	7.792b	8.610a	8.193 ± 1.86	0.136	0.0170

Caption: a, b, c Different letters on the same line differ from each other (p <0.05) by the T test.

1IAL: irrigated pasture with high stocking rate, SAL: dryland pasture with high stocking rate, SML: dryland pasture with moderate stocking rate, DEG: degraded pasture; 2DP: standard deviation; 3EPM: average standard error; 4CH_4GD: methane emission in g / day, CH4PVm: methane emission in g CH_4/ kg of average live weight,CH_4PMet: methane emission in g CH_4/ kg of metabolic weight, CH_4GPD: methane emission in g CH_4/ kg of average daily weight gain,CH_4CMS: methane emission in gCH_4/ kg of average daily dry matter consumption, CH_4DDM: methane emission in CH4 g/% digestible dry matter, CH_4EB: methane emission in Mcal CH_4/ animal/day, YM: percentage of gross energy lost in the form of methane.

per stocking rate ($p < 0.0001$) with higher values for intensified systems, which demonstrates the possibility of greater meat production with the same EI, when considering only enteric methane emission. Despite the differences found between the levels of pasture intensification, it is important to evaluate the system as a whole, such as carbon sequestration from soils, nitrous oxide emission, among others and not just the animals' methane emission.

CHALLENGES

- Considering the diversity of production systems, bovine breeds, genetic groups and animal diets, it is difficult to establish average technical coefficients to represent all of Brazil. However, as there is still little research to evaluate the emission of enteric methane and its emission intensity in the country, this ends up becoming a reference value for other countries around the world. Thus, there is a latent need for more research and studies to obtain reliable data according to each region or production system. The country's great potential in producing food is sometimes seen in a negative way by society due to the lack of communication and lack of publications, reporting evidence of the improvements achieved over decades. The application of technologies such as genetic improvement and pasture management aiming to increase productivity reflects less impact on the environment since the production of Brazilian meat is mainly carried out on pasture. Considering the above described reality, this project came together with the motivation to demystify the supposed unproductive or unsustainable vision of Brazilian livestock production through results obtained with scientific rigor, with the specific objective of evaluating and understanding the balance between increasing productivity and minimizing environmental impacts, mainly through GHG emissions by ruminants.

SOLUTIONS

- Research has shown that more intensified systems produce more meat with the same methane emission intensity;
- In order to define which production system, bovine genetic group, type of diet, level of intensification to use, it is important to check those that best fit into its structure, aiming at sustainable production. The environmental impacts caused by the activity can even be neutralized with sufficient planning and execution.

DATA PUBLISHED IN:

BERNDT, A.; MÉO FILHO, P.; SAKAMOTO, L. S.; MORELLI, M. Técnicas para mensurar emissão de metano em bovinos. In: SIMPÓSIO BRASILEIRO DE PRODUÇÃO DE RUMINANTES NO CERRADO, 4., 2018, Uberlândia. Anais [...]. Uberlândia: FAMEV-UFU, 2018. p. 85-96.

OLIVEIRA, P. P. A.; CORTE, R. R. S.; SILVA, S. L.; RODRIGUEZ, P. H. M.; SAKAMOTO, L. S.; PEDROSO, A. F.; TULLIO, R. R.; BERNDT, A. The effect of grazing system intensification on the growth and meat quality of beef cattle in the Brazilian Atlantic Forest biome. Meat Science, v. 139, p. 157-161, 2018.

SAKAMOTO, L. S. Intensidades de emissão de gás metano de bovinos Nelore terminados a pasto e cruzados em confinamento. 2018. Tese (Doutorado) – Faculdade de Zootecnia e Engenharia de Alimentos, Universidade de São Paulo, Pirassununga, 2018.

Continued in Annex

Figure: Nellore cattle in pasture grazing systems with different levels of intensification in individual data collection of enteric methane emission using the sulfur hexafluoride (SF_6) tracer gas technique.

Crédit: Alexandre Berndt

PROJECT COORDINATORS

Dra. Patrícia Perondi Anchão Oliveira

Embrapa Pecuária Sudeste

e-mail: patricia.anchao-oliveira@embrapa.br

Dr. André de Pedroso Faria

Embrapa Pecuária Sudeste

e-mail: andre.pedroso@embrapa.br

ORGANIC CARBON STOCK AND SOIL GREENHOUSE GAS EMISSIONS IN A NATURAL GRASSLAND AREA OF THE PAMPA BIOME

Leandro Bochi da Silva Volk[1]; José Pedro Pereira Trindade[1]; Teresa Cristina Moraes Genro[1]
1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pecuária Sul

Over 50% of the bovine herd in Rio Grande do Sul, and almost all of the herd of sheep, is still raised in natural grassland of the Pampa biome. This biome represents about 63% of the territory of Rio Grande do Sul state, and is responsible for the maintenance and production of bovine and sheep herds. However, the natural grassland vegetation also occurs in significant areas of the Pantanal, Atlantic Forest and Cerrado biomes. This natural ecosystem, even when managed with livestock, is environmentally multifunctional and provides numerous ecological functions. This characteristic is responsible for its potential to contribute to the conservation of natural resources (soil, water and biodiversity), differentiation of products, provision of ecosystem services and adaptation to climate change. Another important point is the fact that State Decree nº 52.431 of 2015, which regulates the use of Legal Reserves in the Rural Environmental Registry for the Pampa biome, allows the use of rural areas and properties belonging to the Legal Reserve for livestock production. Thus, the Embrapa Pecuária Sul research group has been making an effort to define management systems that maintain the protection of this vegetation in accordance with environmental legislation, while delivering society a number of ecosystem services (such as carbon and nitrogen sequestration in soil and the decrease of greenhouse gas emissions) and ensuring livestock production and income for farmers. To this end, this research group conducted activities not only to characterize the carbon and organic nitrogen stock and the emission of greenhouse gases (GHG) from the soil, but also to understand how they relate to vegetation and animal management. Assessments of soil gas emissions were carried out between 2014 and 2015, in a native field area with Hereford steers at three intensification levels: natural grassland (NP), fertilized natural grassland (FNP) and fertilized natural grassland with ryegrass (*Lolium multiflorum*) and red clover (Trifolium pratense; PNM) overseeded. Assessments of carbon and organic nitrogen stock in the soil were carried out in 2015, in the same area mentioned above, up to a depth of 50 cm, following the standardized methodology proposed to members of the PECUS project. Still in order to understand the soil-plant-animal relationship that is established in this natural system when used for raising livestock, soil and root mass of the plants were also physiochemically assessed.

Some valuable results have already been reached and made available to the scientific community and farmers, but much remains to be done and investigated.

RESULTS

- Organic carbon stock in the soil (without considering the vegetation and its roots) varied between 90 and 120 t/ha, considering the depth of 0 to 50 cm;
- A positive and significant relationship was found between the carbon and nitrogen stock in the soil and root mass, indicating that correct animal grazing management leads to an increase in the production of roots and an increase in the Corg and Norg stock;
- The greater diversity of the botanical composition is positively related to the greater Corg stock in the soil;
- CO_2 was the main GHG issued, however with very low values (oscillating between 0 and 250g C/ha/day), during autumn/winter with an average rate of 25 g C/ha/day and in spring summer with an average rate of 100 g C/ha/day);
- The emission of greenhouse gases fluctuated throughout the year, showing a strong dependence on climatic factors (rain and temperature, mainly);
- N_2O emission was very low (about 63 g N_2O/ha during a 30 day period), only noticed in the areas that received nitrogen fertilization (about 180 g N_2O/ha within 30 days after fertilization).

CHALLENGES

- Images of areas and vegetation using drones demonstrates high potential for estimating the carbon stock in the soil;
- In addition to being essential for precision livestock, using sensors in the soil and accumulating a large amount of data, can help us to better understand the soil-plant-animal relationship that regulates the way these natural systems function with livestock;

- The relationship between the structure of vegetation and its impact on the carbon and nitrogen stock needs to be further studied;

- The C balance in this type of system is more complex than in agricultural systems and depends on other emission factors that have not yet been evaluated.

SOLUTIONS

- Management practice recommendations for producers, aiming at maintaining Corg and Norg stocks and maintaining field resilience have been widely disseminated in technology transfer tools.

DATA PUBLISHED IN:

VOLK, L. B. da S.; GENRO, T. C. M.; TRINDADE, J. P. P. Nitrous oxide emissions from soil of natural grassland under different intensifications in Pampa biome. In: INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN AGRICULTURE, 2., 2016, Campo Grande, MS. Proceedings [...]. Brasília, DF: Embrapa, 2016. p. 75-78.

VOLK, L. B. da S.; GENRO, T. C. M.; TRINDADE, J. P. P. Total organic carbon stock in Luvisol under natural grassland with different intensifications in Pampa biome. In: INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN AGRICULTURE, 2., 2016, Campo Grande, MS.

Proceedings [...]. Brasília, DF: Embrapa, 2016. p. 375-379. (Embrapa Gado de Corte. Documentos, 216).

PROJECT COORDINATORS

Dr. Leandro Bochi da Silva Volk

Embrapa Pecuária Sul

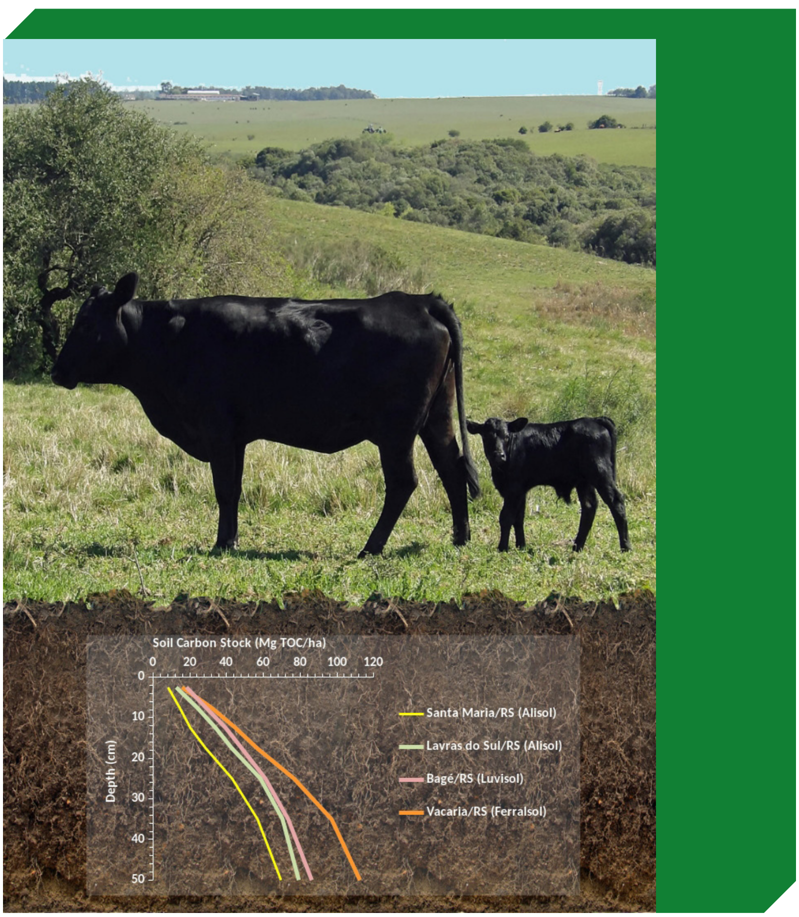
e-mail: leandro.volk@embrapa.br

Dra. Teresa Cristina Moraes Genro

Embrapa Pecuária Sul

e-mail: cristina.genro@embrapa.br

Figure: Stocks of total organic carbon in four soils under grazed natural grassland.



Crédits: Leandro Bochi de Silva Volk

PASTORAL SOIL CARBON STOCKS FOR DAIRY PRODUCTION SYSTEMS

Patrícia Perondi Anchão Oliveira[1]; Paulo Henrique Mazza Rodrigues[2]; Maria Fernanda Ferreira Menegucci Praes[2]; Fernando Antônio Fernandes[3]; André de Faria Pedroso[1]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pecuária Sudeste; 2 Universidade de São Paulo; 3 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Pantanal.

In agriculture and livestock production, considering the context of climate change, land use is in focus; because soil can either be a source of emissions or drain Greenhouse Gases (GHG), depending on the management systems carried out (IPCC, 2001). Important alternatives such as managing pastures in production systems in order to increase the addition of organic matter and carbon (C) retention in the soil avoid GHG emissions and provide C drains, avoiding global warming (BAYER et al., 2006).

The objective of this study was to evaluate the impact of pasture management on C stocks, with a view to increasing the sustainability of dairy farming. The C stock and the accumulation rate in the soil were compared on the surface (0 to 30 cm layer) and in depth (30 to 100 cm layer) in soils of extensive and intensive irrigated pasture areas, with the native forest as reference.

The study was developed at Embrapa Pecuária Sudeste, SP, Brazil in the Atlantic Forest Biome. C in Soil was evaluated in pastures under two types of management in dairy pastoral production systems in a dystrophic red-yellow latosol: EXT - pastures with extensive management with low stocking rate and IIR - irrigated pastures with intensive management and high rate of animal stocking. The EXT pasture was composed of two paddocks (3 ha each) with Brachiaria spp. and Cynodonnlemfuensis Vanderyst, managed with continuous stocking, without soil correction or fertilization. Pastures in the IIR system were established with *Panicum maximum Jacq* cv. Tanzania, overwintered annually with Avena byzantina cv. São Carlos and Loliun multifloram Lan. Cv. BRS Ponteio in the fall. The IIR system consists of two similar areas containing 1.6 ha, divided into 27 paddocks of 600 m2 each, managed with rotating stocking, with one day of occupation and 26 day rest periods. The pastures in the IIR system received lime and potassium chloride superphosphate fertilizers respectively, reaching 20 mg P.dm^{-3} and 4% K in the CTC (cation exchange capacity) of the soil. Nitrogen was applied at a dose of 600 kg ha^{-1}year^{-1}.

These areas were grazed by dairy cows (pure HPB and crossbred JEx HPB), which received supplements and concentrate (formulated according to NRC, 2001) in the proportion of 1 kg concentrate: 3 liters of milk. Forage offer was adjusted using the "put and take" method.

The reference forest was the Seasonal Semideciduous Forest of the Atlantic Forest Biome. Soil samples were collected from pastures and forest areas at eight depths: 0-5, 5-10, 10-20, 20-30, 30-40, 40-60, 60-80 and 80-100 cm; with six repetitions per treatment (three per area). The samples collected at each depth using the kopecky ring were dried at 1050C and weighed, to determine volumetric density. These samples were then ground to 0.150 mm for the analysis of C concentration by the method of total combustion in CHN equipment. C stocks at each depth were calculated and corrected for density, using the forest as a reference (ELLERT AND BETTANY, 1996). C stocks were also calculated at depths of 0-30 and 0-100 cm. The data obtained was analyzed using the mixed procedure of the SAS® program (SAS INSTITUTE, 2002).

RESULTS

- The type of pasture and the depth of the soil layer influenced the concentration of C in the soil. The concentration of C was higher in the EXT system, compared to the IIR system and the forest, which presented similar concentrations. Carbon concentration was higher in the most superficial layers of the soil (0-5 cm), decreasing in depth;
- The type of pasture did not affect C stocks. The depth of the soil layers influenced the stocks of C, and in the 0-100 cm layer the C stock was 121% greater than the stock in the 0-30 cm layer. Sthal et al. (2016) reported that C stocks can be considered in deeper layers of soil, up to 100 cm.

SOLUTIONS

- Pastures managed intensively and extensively (taking into account the criteria for adjusting the forage supply and avoiding overgrazing) maintain or increase C stocks in relation to the forest;

- Brazilian soils are deep and have the capacity to store carbon in depth, which can be explained by the deep growth of roots in tropical pastures.

DATA PUBLISHED IN:

OLIVEIRA, P. P. A.; RODRIGUES, P. H. M.; PRAES, M. F. F. M.; FERNANDES, F. A.; PEDROSO, A. de F. Soil carbon content and stock in tropical pastures in a milk production system. In: INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN AGRICULTURE, 2., 2016, Campo Grande, MS. Proceedings [...]. Brasília, DF: Embrapa, 2016. p. 385-388. (Embrapa Gado de Corte. Documentos, 216).

REFERENCES:

BAYER, C .; MARTIN NETO, L .; MIELNICZUK, J .; PAVINATO, A., DIECKOW, J. Carbon sequestration in two Brazilian Cerrado soils under no-till. Soil Till. Res., N. 86, p. 237-245, 2006.

ELLERT, B. H.; BETTANY, J. R. Calculation of organic matter and nutrients stored in soils under contrasting management regimes. Canadian Journal of Soil Science, n. 75, p. 529-538, 1996.

IPCC – Intergovernmental Panel on Climate Change. Climate Change 2001: The scientific basis. Cambridge: Cambridge University Press.

Continued in Annex

PROJECT COORDINATORS

Dra. Patrícia Perondi Anchão Oliveira

Embrapa Pecuária Sudeste

e-mail: patricia.anchao-oliveira@embrapa.br

Dr. André de Faria Pedroso

Embrapa Pecuária Sudeste

e-mail: andre.pedroso@embrapa.br

Figure: Intensive irrigated pasture

Crédit: Teresa Cristina Alves.

SOIL CARBON STOCKS IN INTEGRATED SYSTEMS IN THE ATLANTIC FOREST BIOME

Alberto Carlos de Campos Bernardi[1]; Sergio Novita Esteves[1]; José Ricardo Macedo Pezzopane[1]; Teresa Cristina Alves[1]; Alexandre Berndt[1]; André Farias Pedroso[1]; Paulo Henrique Mazza Rodrigues[2]; Ladislau Martin Neto[3]; Patrícia Perondi Anchão Oliveira[1]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pecuária Sudeste; 2 Universidade de São Paulo; 3 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Instrumentação

The Crop-Livestock-Forest Integration (ICLF) systems have been used as a sustainable agricultural intensification strategy that integrates annual activities of cultivation, trees, and livestock in the same area and during the same harvest (BALBINO et al., 2011a, b). The system is based on crop rotations and no-till practices that increase the quantity and quality of soil organic matter. The ICLF system is one of the Brazilian government's strategies in the "Low Carbon Agriculture" program to reduce or offset carbon emissions while simultaneously improving harvest efficiency. The intensification of production observed in the ICLF system improves the physical, chemical and biological conditions of the soil; increases cycling and nutrient utilization efficiency; reduces production costs; diversifies and stabilizes income on rural properties and makes it possible to recover areas with degraded pastures (SALTON et al., 2014). In addition, ICLF promotes a change in the land-use system, with the integration of the components of the productive system, aiming at reaching increasingly higher levels of product quality, environmental quality, and competitiveness (CORDEIRO et al., 2015).

Changes in land use alter the biogeochemical processes of the soil, reflecting on the C stock and the flux of gases between the soil and the atmosphere (MAIA; PARRON, 2015). Consequently, organic matter has been used as a key indicator of soil quality in ICLF systems, considering its influence on the other essential attributes for the soil to perform its functions (MARCHÃO et al., 2009; SALTON et al., 2014; CONCEIÇÃO et al., 2017).

This research aimed to evaluate the carbon stocks in the soil in integrated agricultural production systems in the Atlantic Forest biome.

The area of the experiment is located in São Carlos - SP, Brazil (21 ° 57'S, 47 ° 50'W, 860 m alt) in a sandy-clay dystrophic Red-Yellow Latosol and Cwa climate. The area consists of five production systems, with two repetitions of areas of 3 ha each (total of 30 ha), constituted as follows: I) Extensive grazing system (EXT) in continuous stocking in a pasture of Brachiaria grass (Urochloa decumbens), with no inputs; II) Rotational grazing system (INT) in Piatã grass pasture (U. brizantha cv. BRS Piatã), with application of lime and fertilizers; III) Crop-Livestock Integration System (ICL), with the rotation of corn and Piatã grass every 3 years, under rotating and alternating grazing with application of lime and fertilizers; IV) Silvopastoral system (IPF), composed of Piatã grass pastures wooded with Eucalyptus urograndis clone GG110 under rotational grazing and application of limestone and fertilizers; v. Forestry Livestock Integration System IFL), rotation of corn with Piatã grass and wooded with Eucalyptus urograndis clone GG110, under rotational grazing and application of lime and fertilizers. In addition, there is a control area referring to the natural vegetation of the semideciduous seasonal forest of the Atlantic Forest biome. In 2016, during the fifth year after implementing the production systems, the accumulation of carbon in the soil was evaluated up to a depth of 1.0 m. The combustion technique in a total C analyzer determined the C content and the density of the soil using volumetric rings. C stocks in the soil were calculated in an equivalent mass of soil, using the soil mass of the natural vegetation system as a reference.

RESULTS

- After five years, C stocks in the soil (in Mg ha-1) were: LFI, 179.9; INT, 173.1; CLFI, 160.2; CLI, 136.4; and EXT, 121.0 Mg ha-1. The stocks of LFI, INT and ICLF were significantly ($p < 0.001$) higher and EXT significantly lower than the C stocks in natural Atlantic Forest Biomes (129.7 Mg ha-1);
- This is a long-duration project, and a new sampling will be carried out within ten years of implantation of the integrated systems.

CHALLENGES

- Provide quantitative data on the C stock in integrated systems;

- Expand knowledge about the potential for carbon sequestration in the soil in integrated systems;
- Establish management plans to maintain the productive balance and environmental benefits of integrated systems with the presence of trees;
- Strengthen the adoption of innovations by technicians and farmers;
- Support the formulation of public policies.

SOLUTIONS

- Results suggested that, in the local edaphoclimatic conditions of the study, both the agroforestry systems (ICLF and ILF) and the well-managed pastures (INT) lead to a high accumulation of carbon in the soil, even in the short term, such as the five years of this study;
- The change in land use, based on appropriate soil management strategies, such as a balanced supply of nutrients, conservation practices, adequate pasture management, no-till, crop rotation, and increased carbon accumulation in the soil.
- The results suggest the use of pasture recovery and intensification to increase C sequestration and mitigate greenhouse gas emissions.

DATA PUBLISHED IN:

BERNARDI, A. C. C.; ESTEVES, S. N.; PEZZOPANE, J. R. M.; ALVES, T. C.; BERNDT, A.; PEDROSO, A. F.; RODRIGUES, P. H. M.; OLIVEIRA, P. P. A. Soil carbon stocks under integrated crop-livestock-forest system in the Brazilian Atlantic Forest region. In: WORLD CONGRESS OF SOIL SCIENCE, 21., 2018, Rio de Janeiro. Proceedings [...]. Viçosa, MG: Sociedade Brasileira de Ciência do Solo, 2019. p. 483. v. II: Soil Science Beyond Food and Fuel.

REFERENCES:

BALBINO, L. C.; BARCELLOS, A. O.; STONE, L. F. (ed.) Marco referencial: integração lavoura pecuária floresta. Brasília: Embrapa, 2011a.

BALBINO, L. C.; CORDEIRO, L. A. M.; PORFÍRIO-DA-SILVA, V.; MORAES, A.;MARTÍNEZ, G. B.; ALVARENGA, R. C.; KICHEL, A. N.; FONTANELI, R. S.; SANTOS, H. P.; FRANCHINI, J. C.; GALERANI, P. R. Evolução tecnológica e arranjos produtivos de sistemas de integração lavoura pecuária floresta no Brasil. Pesquisa Agropecuária Brasileira, v. 46, p. ixii, 2011b.

CONCEIÇÃO, M. C. G.; MATOS, E. S.; BIDONE, E. D.; RODRIGUES, R. A. R.; CORDEIRO, R. C. Changes in soil carbon stocks under integrated crop-livestock-forest system in the Brazilian amazon region. Agricultural Sciences, v. 8, n. 9, p. 904-913, 2017.

Continued in Annex

Figure: Forest livestock crop integration system

Credit: Gisele Rosso.

PROJECT COORDINATORS

Dra. Patrícia Perondi Anchão Oliveira

Embrapa Pecuária Sudeste

e-mail: patricia.anchao-oliveira@embrapa.br

Dr. André de Faria Pedroso

Embrapa Pecuária Sudeste

e-mail: andre.pedroso@embrapa.br

Dr. José Ricardo Macedo Pezzopane

Embrapa Pecuária Sudeste

e-mail: jose.pezzopane@embrapa.br

CARBON STOCKS AND SOIL HUMIDIFICATION IN PASTURES WITH DIFFERENT LEVELS OF INTENSIFICATION IN BRAZIL

Aline Segnini[1]; Alfredo Augusto Pereira Xavier[1]; Pedro Luís Otaviani-Junior[1]; Patrícia Perondi Anchão Oliveira[2]; André de Faria Pedroso[2]; Maria Fernanda Ferreira Menegucci Praes[3]; Paulo Henrique Mazza Rodrigues[3]; Débora Marcondes Bastos Pereira Milori[1]

1 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Instrumentação; 2 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Pecuária Sudeste; 3 Universidade de São Paulo.

The intensive management of tropical pastures in Brazil has great potential for mitigating the emission of greenhouse gases due to the high production of forage and the high accumulation of carbon in the soil. The objective of this study was to evaluate different levels of intensification of pastures in beef cattle production systems in relation to the native forest in terms of carbon stocks in the soil and the humification of organic matter. The soil-plant system of pastures of four beef cattle production systems were evaluated: intensive with high animal stocking, dryland brachiaria grassland grazing intensively managed with medium stocking and degraded pastures. The soil under the Forest was also evaluated. Evaluations of soil texture and density, carbon content (CHN elemental analyzer), organic matter content and humidification index in LIFS (Laser-Induced Fluorescence Spectroscopy) were carried out, which is important because it complements the stock data carbon, since the LIFS technique assesses the recalcitrant C in the soil, which can be a sensitive indicator of changes in land use and soil management. Carbon stocks in the 0-30 and 0-100 cm layers were calculated.

RESULTS

- Carbon stocks (0 - 100 cm) varied from 99.88 to 142.33 Mg ha^{-1} in degraded pasture and brachiaria grass pasture with medium animal stocking, respectively;

- Carbon stocks in colinião-grassland pasture systems with high animal stocking and brachiaria grass pasture with medium animal stocking were 14% and 24% higher, respectively, than the carbon stock in the semi-deciduous Atlantic Forest biome, and suggest the capacity of adequate management of tropical pasture to accumulate C and mitigate greenhouse gas emissions from beef cattle pasture systems;

- The humification indexes obtained in this work indicated the presence of more labile C in pastures with greater accumulation of C (high and medium rainfed upland systems), mainly in the more superficial layers of the soil, indicating recent accumulation of organic matter resulting from the adequate pasture management.

CHALLENGES

- Avoid degradation of pastures, as soil organic matter is lost, making it impossible to rely on carbon sequestration to mitigate greenhouse gas emissions;

- Prevent the more labile C accumulated in production systems from being lost due to improper handling of pastures;

- It is necessary to develop technologies to increase carbon sequestration in irrigated systems.

SOLUTIONS

- This experiment showed the ability of adequate pasture management, even without the inclusion of trees in production systems, to increase carbon stocks and contribute to mitigate greenhouse gas emissions;

- Results suggest the importance of quantifying the C stocks associated with the stability of C. Low C stocks associated with high levels of humification (less labile C) are characteristic of degraded pasture soils, where significant amounts of organic matter have been lost due to inadequate pasture management.

DATA PUBLISHED IN:

SEGNINI, A.; XAVIER, A. A. P.; OTAVIANI-JUNIOR, P. L.; OLIVEIRA, P. P. A.; PEDROSO, A. F.; PRAES, M. F. F. M.; RODRIGUES, P. H. M.; MILORI, D. M. B. P. Soil carbon stock and humification in pastures under different levels of intensification in Brazil. Scientia Agrícola, Piracicaba, v. 76, n. 1, p. 33-40, 2019. DOI: http://dx.doi.org/10.1590/1678-992x-2017-0131.

PROJECT COORDINATORS

Dra. Patrícia Perondi Anchão Oliveira

Embrapa Pecuária Sudeste

e-mail: patricia.anchao-oliveira@embrapa.br

Dr. André de Faria Pedroso

Embrapa Pecuária Sudeste

e-mail: andre.pedroso@embrapa.br

Table: Stocks of C at two depths in four beef cattle production systems in pasture and in native vegetation

Depth (cm)	Treatments				
	IHS	DHS	MSD	DP	FO
	Mg ha^{-1}				
0-30	44.59ab	53.79ab	63.7a	38.94b	49.55ab
0-100	109.86b	129.63ab	142.33a	99.88b	114.72b

Source: Authors.

Caption: IHS = Intensive irrigated with high animal stocking; DHS = Rainfed intensive with high animal stocking; DMS = Rainfed intensive with medium animal stocking, SD = Degraded pasture with extensive management; FO = native vegetation ("semideciduous seasonal Atlantic Rainforest"); ab = means followed by different letters on the same line are different from each other (p ≤ 0.05) according to the Tukey test.

Figure: Detail of the canopy of the colonião-grass pasture

Crédit: Patrícia Perondi Anchão Oliveira.

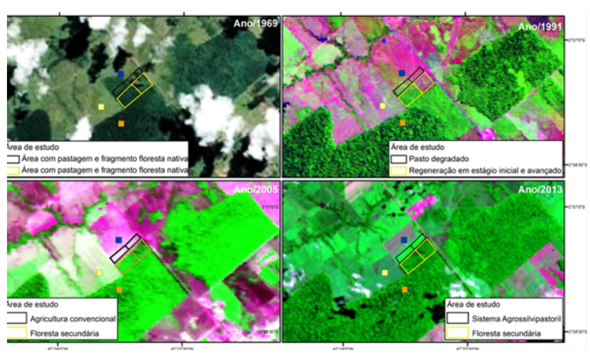
SOIL QUALITY INDICATOR IN AN INTEGRATED LIVESTOCK SYSTEM WITH LOW CARBON EMISSION IN THE AMAZON BIOME

Siglea Sanna de Freitas Chaves[1]; Lucieta Guerreiro Martorano[2]; Marcello Neiva de Mello[3]; Carlos Tadeu dos Santos Dias[4]; Plínio Barbosa de Camargo[5]; Paulo Campos Christo Fernandes[6]

1 Associate Professional Continuing Education Program in Economics and Business Management (Pecege) at the University of São Paulo; 2 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Amazônia Oriental; 3 Universidade Federal da Amazônia; 4 Universidade Federal do Ceará; 5 Centro de Energia Nuclear na Agricultura; 6 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Cerrado.

Under the Component 7 Project, research actions were developed to assess the dynamics of organic matter in the soil (SOM) in agricultural production systems in the Amazon Biome. The objective of this study was to evaluate the carbon stock in the soil in improved pastures, in the municipality of Paragominas, in the Southeast of the State of Pará. The research was carried out in the area of Fazenda Vitória (Vitória Farm), destined to be the technological reference unit (URT) of Embrapa Amazônia Oriental. The local soil is classified as a Yellow Latosol with a clay texture. For the research, the following chronosequence was evaluated: native vegetation (NV), used as a reference, classified as dense ombrophilous forest (located close to pasture); degraded pasture (PD), intended for extensive livestock, formed by Brachiaria humidicola, with high weed infestation and managed with fire for renovation; improved pasture in integration with paricá - *Schizolobium amazonicum* - (PP) and improved pasture in integration with African mahogany - Khaya grandifoliola (PM). Soil collections were carried out in different years, throughout the study (Figure 1), with Camargo et al. (1999) evaluated the VN and PD areas in 1993, and the PP and PM areas were evaluated in 2013. The process of improving the pasture (transition from PD to PP and PM), started in 2009, with the correction of soil fertility, for later implementation of the crop-livestock-forest integration system. The crop component was developed by June 2012, following the pasture succession model (*B. brizantha cv. Piatã)* and corn (Zea mays), grown in strips (20 m wide) and separated by forest components. From the second semester of 2012, the livestock and forest components were kept in the area, during the phase in which the animals were included for direct grazing. In the improved pastures (PP and PM), the samples were collected according to the recommendations of the PECUS Network protocol, in 0-10, 10-20 and 20-30 cm layers. The collections in the VN and PD areas were performed according to Camargo et al. (1999), also in the same layers. The carbon concentration (C) and the isotopic composition of the soil (δ13C) were evaluated in an elementary analyzer (Carlo Erba), coupled in a continuous flow isotopic ratio mass spectrometer (Delta Plus). Soil density (Ds) was calculated according to Embrapa (1997). The calculation of the C stock, which corresponds to the product of the C content (gkg^{-1}) by Ds (gcm^{-3}) and the depth of the layer, was adjusted according to the reference area (VN), according to Ellert and Bettany (1995). The origin of OMS in pastures differed from the area of native vegetation in the 0-10 cm layer. The pasture areas showed similarity in relation to $\delta^{13}C$, with about 22% of the soil C identified in these areas originating from plants in the C4 photosynthetic cycle. This fact is related to the clay texture of the soil that favors the physical protection of OMS in aggregates, a factor that reduces the process of decomposition of the OMS of the previous vegetation cover (C3). It is also inferred that the contribution of C3 plants in the soil of the PP and PM areas is related to the incorporation of weed biomass (of the C3 cycle) that remained in the area before the pasture improvement process. There was no significant difference in the C stock between improved pastures (average of 55 Mg ha^{-1}) and VN (55 Mg ha^{-1}) in the 0-30 cm layer. The lowest C stock was identified in the DP area (42.4 Mg ha^{-1}), which differed from the others up to 20 cm in depth. The increase in the C stock in the improved pasture indicates improvements in soil quality. The increase in OMS in these areas increases the resilience capacity in integrated agricultural systems, with the C stock being an indicator of environmental sustainability when comparing these systems to degraded pastures that use fire as an annual renewal strategy.

Figure: Chronosequence in the Fazenda Vitória area (Paragominas, PA) in the years 1969, 1991, 2005 and 2013. In all the images, the orange dots indicate a fragment of native forest, the yellow dots indicate a homogeneous pasture and the blue dots (in the years 1969, 1991 and 2005) indicate managements similar to the black rectangle. In 2013, the area delimited by the black rectangle (identified as the agrosilvopastoral system) corresponds to the improved pastures evaluated in the present study.



PRELIMINARY RESULTS

- The carbon stock in the soil (0-30 cm) of the vegetation area was similar to the areas of recovered pastures (close to 55 Mg ha-1) and differed from the degraded pasture area (42.4 Mg ha-1);
- Most of the carbon stored in the soil of the recovered pastures comes from plants with a C3 type photosynthetic route. The greatest contribution of pastures (C4 plants) occurred in the 0-10 cm layer, with 21% in the PM and 23% in the PP, remaining below 15% in the subsurface layers. The identification of the origin of soil organic matter is a tool that has the potential to be used as an indicator of C increase in pasture soil, over time, taking the edaphoclimatic characteristics of the environment and the management of the system into account;
- The improvement of pastures with the implementation of the crop-livestock-forest integration system (CLFI) shows that Embrapa's technology transfer strategy in the Paragominas region was successful. The research carried out at Fazenda Vitória showed an increase in carbon fixation in the soil of the area managed according to the ICLFsystem, showing favorable contributions to environmental sustainability, after the pasture recovery process.

CHALLENGES

- Recover pastures on their way to degradation, in the Amazon Biome, by adopting specialized agricultural techniques, aiming at the rational use of natural resources and increase of carbon stocks in the soil;
- Recompose the loss of organic matter and soil compaction due to inadequate management of agricultural cultivation and livestock production areas, encouraging the development of specialized conservationist systems to increase the resilience of the productive areas and prevent the degradation of the productive area;
- Disclosure of economically viable agricultural practices, capable of mitigating GHG emissions and optimizing productivity. It is necessary to encourage the recovery of pastures to mitigate GHG emissions in pastures that are undergoing degradation in the Amazon.;
- Generate scientific information regarding soil quality indicators in integrated agricultural systems, in order to provide information to support public policies for the sustainable agricultural development of the Amazon Biome.

SOLUTIONS

- The results suggest the importance of developing research on agricultural systems that advocate the rational use of natural resources;
- The evaluation of the dynamics of the organic matter of the soil, along the chronosequence, pointed out that investment in recovery and improvement of pastures is viable and environmentally correct, since it increased the carbon stock in the PP and PM areas;
- The increase in the carbon stock in the soil after the recovery of pastures is an indicator of the environmental sustainability of the production system.

REFERENCES:

CAMARGO, P. B.; TRUMBORE, S. E.; MARTINELLI, L. A.; DAVIDSON, E. A.; NEPSTAD, D. C.; VICTORIA, R. L. Soil carbon dynamics in regrowing forest of eastern Amazonia. Global Change Biology, Oxford, v. 9, p. 693-702, 1999.

ELLERT, H; BETTANY, J. R. Calculation of organic matter and nutrients stored in soils under contrasting management regimes. Canadian Journal of Soil Science, Ottawa, vol. 75, p. 529-538, 1995.

EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária. Centro Nacional de Pesquisa de Solos. Manual de métodos de análise do solo. Rio de Janeiro: Embrapa, 1997.

MARTINELLI, L. A.; OMETTO, J. P. H. B.; FERRAZ, E. S.; VICTORIA, R. L.; CAMARGO, P. B.; MOREIRA, M. Z. Desvendando questões ambientais com isótopos estáveis. São Paulo: Oficina de Textos, 2009.

DATA PUBLISHED IN:

CHAVES, S. S. F.; BIASE, A. G.; MELO, M. N.; DIAS, C. T. S.; MARTORANO, L. G. Análise de agrupamento e componentes principais na avaliação de sistemas integrados de produção agropecuária no nordeste paraense. In: ENCONTRO MINEIRO DE ESTATÍSTICA, 12.; SEMANA DA ESTATÍSTICA, 3., 2013, Uberlândia, MG.

CHAVES, S. S. F.; MARTORANO, L. G.; CAMARGO, P. B.; EL-HUNSNY, J. C.; FERNANDES, P. C. C.; VALENTE, M. A. Estoque de carbono no solo em área de pastagem convencional e sistema agrossilvipastoril em Paragominas. In: SIMPÓSIO DE ESTUDOS E PESQUISAS EM CIÊNCIAS AMBIENTAIS NA AMAZÔNIA, 2., 2013, Belém, PA.

CHAVES, S. S. F.; MARTORANO, L. G.; FERNANDES, P. C. C.; MONTEIRO, D. C. A.; EL-HUNSNY, J. C. Avaliação do potencial de expansão do sistema integração lavoura-pecuária- floresta na recomposição de paisagens sustentáveis em Paragominas, PA. In: SIMPÓSIO DE PESQUISA INTERDISCIPLINAR DA AMAZÔNIA LEGAL, 1., 2011, Belém.

Continued in Annex

PROJECT COORDINATORS

Dra. Patrícia Perondi Anchão Oliveira

Embrapa Pecuária Sudeste

e-mail: patricia.anchao-oliveira@embrapa.br

Dr. Lucieta Guerreiro Martorano

Embrapa Amazônia Oriental

e-mail: lucieta.martorano@embrapa.br

STATISTICAL MODELING OF SOIL CARBON IN SPECIALIZED INTEGRATED-CROP-LIVESTOCK-FOREST PRODUCUTION SYSTEM IN PARAGOMINAS-PA

Marcello Neiva de Mello[1]; Carlos Tadeu dos Santos Dias[2]; Lucieta Guerreiro Martorano[3]; Siglea Sanna Freitas[4]; Adriele Giaretta Biase[5]; Paulo Campos Christo Fernandes[6]

1 Universidade Federal da Amazônia; **2** Universidade Federal do Ceará; **3** Empresa Brasileira de Pesquisa Agropecuária - Embrapa Amazônia Oriental; **4** Profissional associado Programa de Educação Continuada em Economia e Gestão de Empresas (Pecege) da Universidade de São Paulo; **5** Tech Inovação Tecnológica para a Agropecuária; **6** Empresa Brasileira de Pesquisa Agropecuária - Embrapa Cerrado.

The Brazilian Amazon is considered the largest remaining tropical forest in the world and provides important ecosystem services, such as the maintenance of several species of flora, fauna, and water cycling, in addition to storing a large amount of carbon in its soil-plant system. Therefore, existing knowledge is that converting native forests to pastures, as well as the use of fire to renew pastures, may threaten the balance of ecosystem functions. Agricultural production systems developed in the Amazon biome must be managed using techniques that advocate the rational use of natural resources. For this reason, there is an increasing interest in evaluating and modeling the concentration of Carbon (C) and Nitrogen (N) in the soil, in different land use systems, because the dynamics of these elements are directly related to the sustainability of the productive arrangement and the mitigation of possible environmental impacts. The approach of non-linear models is becoming more and more common, citing as an example studies such as de Oliveira et al. (2000) which compares models to describe the growth of Guzerat breed females. Paz et al. (2004) also used models to explain the association between genetic polymorphisms and growth in cattle. In this context, Zeviani et al. (2012) used non-linear models to describe the release of nutrients in the soil, demonstrating different possibilities for applying statistical analysis with mixed non-linear models to assess and explain natural phenomena. Thus, this chapter presents modeling results that explain the dynamics of C and N concentrations at different depths of the soil in the CLFI system. The survey was carried out at Fazenda Vitória, located in the municipality of Paragominas, southeastern Pará, enclosed by geographic coordinates 02º59'58.37 "S and 47º21 '21.29" W. Three different patterns of land and forage use were studied: I. Agrosilvopastoral system formed by B. brizantha cv. piatã between cultivation strips of Schizolobium amazonicum (paricá); II. Agrosilvopastoral system formed by B. brizantha cv. piatã between cultivation strips of Khaya spp. (African mahogany); III. Secondary forest. Soil collection was carried out in 2013, with three replications in each area, in the following layers: 0-10, 10-20, 20-30, 30-40, 40-60, 60-80, 80-100, 100- 130 and 130-150 cm. For the evaluation of the C and N content (g kg^{-1}), soil samples (TFSA) were analyzed by a Carlo Erba CHN 1110 elemental analyzer. Data was used to test the mixed nonlinear models and to describe the average behavior of the responses of C and N levels in pastures and in the secondary forest. The repeated measure in space (depth) was considered as well as the heterogeneity of variances in this space. In general, the levels of C and N in the i-th sample (individual), in the j-th depth of the u-th system can be represented by $Y_{iju} = \beta_{0u} X_{ij}^{-\beta 1u} + \varepsilon_{iju}$ where xij is the depth at the i-th sample (i = 1, ...,N), at the j-th depth (j = 1, ..., ni). In terms of mixed models, we have $Y_{iju} = \beta_{0u} X^{-(\beta_{1u} + b_{1i})} ij + \varepsilon_{iju}$ is the mean value of the grade under study in the system, β1u is the rate of accumulation of this grade, b1i is the random effect associated with β1u, independently and identically distributed as N(0, σ^2b) and εiju is the random error associated to Yiju, independently and identically distributed as N(0,$\sigma^2\varepsilon$), and independent from b1i. Robust methods that allow modification of matrix structures should be used to capture such heterogeneity, based on the mixed nonlinear model. Among all those tested, the f2C model with a structure assuming equal covariance for random effects and a varPower structure for residues, was the one that best adjusted to the observed data on carbon in the soil, validated through residue assesment.

RESULTS

- High variability in the most superficial layers of C and N contents in the soil;
- Several models tested, based on the likelihood ratio test, modifying structures of intra-individual covariance matrixes;
- The model with the variance function was the one that best suited the data observed in the livestock production system in Paragominas.

CHALLENGES

- High cost for collecting the soil and carrying out chemical assessments in the laboratory;

- The number of repetitions increases the statistical significance, but the high costs for carrying out assessments are factors that must be considered when assessing results carried out in the field and statistical modeling;
- A larger number of soil samples is needed, along the profiles, to ensure greater accuracy in the model for estimating C incorporation in soils with pasture management in the Amazon biome, as was the case in the study in Paragominas.

SOLUTIONS

- The adoption of a production system that prioritizes the recovery of pastures has the capacity to increase carbon in the soil;
- The mixed model used proved to be efficient for describing C and N over long soil profiles, being a valuable tool for monitoring and estimating the dynamics of C in the soil.

DATA PUBLISHED IN:

MELLO, M. N. Modelo não-linear misto aplicado a análise de dados longitudinais em um solo localizado em Paragominas, PA. 2012. Dissertação (Mestrado em Ciências: Estatística e experimentação agronômica) – Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba, 2012.

MELLO, M. N.; DIAS, C. T. S.; MARTORANO, L. G.; CHAVES, S. S. F.; FERNANDES, P. C. C. Modelos não lineares mistos para descrever o teor de carbono orgânico no solo. Revista Brasileira de Biometria, v. 36, n. 1, p. 230-240, 2018.

MELLO, M. N.; DIAS, C. T. S.; MARTORANO, L. G.; CHAVES, S. S. F.; OLIVEIRA, P. P. A. Nonlinear mixed model applied to the analysis of longitudinal data in a soil located in Paragominas, PA. In: SIGEE - SIMPÓSIO INTERNACIONAL SOBRE GASES DE EFEITO ESTUFA NA AGROPECUÁRIA, 2., 2016, Campo Grande.

REFERENCES:

OLIVEIRA, H. N.; LOBO, R. B.; PEREIRA, C. S. Comparação de modelos não-lineares para descrever o crescimento de fêmeas da raça Guzerá. Pesquisa Agropecuária Brasileira, Brasília, v. 35, n. 9, p. 1843-1851, 2000.

PAZ, C. C. P.; PACKER, I. U.; FREITAS, A. R.; TAMBASCO, D. D.; REGITANO, L. C. A.; ALENCAR, M. M. Influência de polimorfismos genéticos sobre os parâmetros da curva de crescimento de bovinos de corte. Revista Brasileira de Zootecnia - Brazilian Journal of Animal Science, Viçosa, Vol. 33, n. 4, p. 858-869, 2004.

ZEVIANI, W. M.; SILVA, C. A; CARNEIRO, W. J. O.; MUNIZ, J. A. Modelos não lineares para a liberação de potássio de estercos animais em latossolos. Ciência Rural, Santa Maria, v. 12, n. 10, p. 1798-1796, 2012.

PROJECT COORDINATORS

Dra. Patrícia Perondi Anchão Oliveira

Embrapa Pecuária Sudeste

e-mail: patricia.anchao-oliveira@embrapa.br

Dra. Lucieta Guerreiro Martorano

Embrapa Amazônia Oriental

e-mail: lucieta.martorano@embrapa.br

Figure: Sistema agrossilvipastoril formado por B. brizantha cv. piatã entre faixas de cultivo de Khaya spp. (mogno africano). Fazenda Vitória – Paragominas, PA

Crédit: Paulo Fernandes

Figure: Soil profile evaluated in a agrosilvopastoral system made up of B. brizantha cv. piatã between strips of Schizolobium amazonicum (paricá). Yellow clayey Latossol. Fazenda Vitória - Paragominas.

BIOMASS AND CARBON STOCK FROM EUCALYPTUS TREES IN INTEGRATED LIVESTOCK PRODUCTION SYSTEMS

José Ricardo Macedo Pezzopane[1]; Cristiam Bosi[2]; Alberto C. de Campos Bernardi[1]; Marcelo Dias Muller[3]; Patrícia Perondi Anchão Oliveira[1]

1 Empresa Brasileira de Pesquisa Agropecuária – Pecuária Sudeste; **2** Universidade de São Paulo; **3** Empresa Brasileira de Pesquisa Agropecuária – Gado de Leite.

Livestock has been associated with greenhouse gas (GHG) emission, considering it is the sector in agribusiness responsible for the largest emission, especially of enteric methane. To mitigate this problem, production systems based on recovered pastures and/or the capacity to increase carbon stocks (C) in the soil and decrease the C footprint have been proposed (OLIVEIRA, 2015; FIGUEIREDO *et al.*, 2017).

It is in this context that integrated systems are included: crop-livestock (CLI) or agropastoral, crop-forest (CFI) or silvopastoral and the crop-livestock-forest (CLFI) or agrosilvopastoril integration systems. These systems have the potential to mitigate GHG emissions through C removal from the atmosphere and C storage in biomass and soil, especially when the tree component is present (OLIVEIRA *et al.*, 2017; DUBE *et al.*, 2002; ALMEIDA *et al.*, 2011; CARVALHO *et al.*, 2014; SALTON *et al.*, 2014).

The trees can be included in already established pastures implanted simultaneously with pastures (silvopastoral systems) and also in systems where the pasture is renewed or rotated with crops (agrosilvopastoral systems) (BALBINO *et al.*, 2011; GIL *et al.*, 2015). The potential for accumulation of C by the tree component in the silvopastoral system is still poorly studied in Brazilian conditions and depends, among other factors, on the species, management and population density (TSUKAMOTO FILHO, 2003; GUTMAIS, 2004; OFUGI *et al.*, 2008, MULLER *et al.*, 2009).

This research aimed to estimate the C biomass stock of Eucalyptus urograndis trees (Clone GG100) grown in different integration models at five years of age (Figure 1). The area of the experiment is located in São Carlos - SP, Brazil (21 ° 57'S, 47 ° 50'W, 860 m alt) in a sandy-clayey dystrophic Red-Yellow Latosol and Cwa climate. The trees were planted in a pasture area of Brachiaria brizantha cv. Piatã, in April 2011. Single rows were established with 2 meter spacing between plants within the line and 15 meters between rows, totaling a density of 333 trees per hectare. A clone of the hybrid Eucalyptus urograndis (GG 100) was used.

The production system was conducted with two experimental areas (area repetition), of approximately 3 ha each, using rotated pasture management, divided into six paddocks with an area of approximately 5000 m^2 each and with an occupation period of six days and a thirty-day rest period. Thus, the experimental area contained 12 paddocks. Pasture renewal took place in one third of each area per agricultural year (2 paddocks), where the grass was reseeded simultaneously with the corn crop (Zea Mays L. var. DKR 390 PRO 2) for silage production. Thus, three renovation systems were established in the experimental area, which differed from each other in relation to the trees planting time. An agrosilvopastoral system with renewal of the pasture two years after planting the trees (CLFI-2), an agrosilvopastoral system with renewal of the pasture in the third year after planting the trees (CLFI-3) and a silvopastoral system where at the time of the evaluation of the trees the pasture had not yet been renewed (SSP).

RESULTS

- Equations for estimating the volume of wood and biomass of the tree component were generated in systems for crop-livestock-forest integration;
- Five years after the implementation of the systems, the variation in volume accumulation per year in the systems analyzed in this work ranged from 26.4 (SSP) to 31.2 m3 ha^{-1} year^{-1} (CLFI^{-2}).When the biomass production was evaluated according to tree trunks, it varied from 11.4 (SSP) to 13.5 Mg ha^{-1} ano^{-1} (ICLF $^{-2}$);
- With regard to C stocks in stems, the data obtained in this work (*E. urograndis*) are equivalent to a carbon accumulation of 5.2 (SSP) to 6.1 Mg ha^{-1} ano^{-1} (ICLF^{-2});
- This is a long duration project and new sampling will be carried out at 8 and 12 years of implantation of the integrated systems.

CHALLENGES

- Provide data on the potential for production and C stock in the biomass of trees in integrated systems;

- Based on the production of trees and other members of the systems, promote the establishment of management plans for the tree component to maintain the productive balance and environmental benefits of the integrated systems with the presence of trees;
- Support the formulation of public policies.

SOLUTIONS

- The results obtained until the evaluation allowed the establishment of equations for estimating the volume and biomass of trees in integrated crop-livestock-forest systems based on simple measurements of diameter at 1.3 m in height (DBH) and height of trees;
- The system model with pasture renewal in the second year of implantation provided the highest values of wood production, biomass and C at 5 years of the systems implementation;
- The amount of C stored in tree trunks will contribute to the mitigation of GHG emissions.

DATA PUBLISHED IN:

OLIVEIRA, P. P. A.; PEZZOPANE, J. R. M.; MÉO FILHO, P.; BERNDT, A.; PEDROSO, A. de F.; BERNARDI, A. C. C. Balanço e emissões de gases de efeito estufa em sistemas integrados. In: JAMHOUR, J .; ASSMANN, T. S. (org.). CONGRESSO BRASILEIRO DE SISTEMAS INTEGRADOS DE PRODUÇÃO AGROPECUARIA, 1.; ENCONTRO DE INTEGRAÇÃO LAVOURA-PECUARIA NO SUL DO BRASIL, 4. Pato Branco: UTFPR Câmpus Pato Branco, 2017. v. 1, p. 23-32. (Palestras: intensificação com sustentabilidade).

PEZZOPANE, J. R. M.; BOSI, C.; BERNARDI, A. C. C.; MULLER, M. D.; OLIVEIRA, P. P. A. Biomass and carbon pools of Eucalyptus trees in integrated crop-livestock-forest systems. In: EUCALYPTUS 2018 – MANAGING EYCALYPTUS PLANTATIONS UNDER GLOBAL CHANGES, 2018,

Montpellier Abstracts book [...]. Montpellier: Cirad, 2018. v. 1. p. 37.

REFERENCES:

ALMEIDA, R. G.; OLIVEIRA, P. P. A.; MACEDO, M. C. M.; PEZZOPANE, J. R. M. Recuperação de pastagens degradadas e impactos da pecuária na emissão de gases de efeito estufa. In: SIMPÓSIO INTERNACIONAL DE MELHORAMENTO DE FORRAGEIRAS, 3., 2011, Bonito, MS. Anais [...]. Campo Grande: Embrapa Gado de Corte, 2011. p. 384-400.

BALBINO, L. C.; CORDEIRO, L. A. M.; PORFÍRIO-DA-SILVA, V.; MORAES, A.; MARTÍNEZ, G. B.; ALVARENGA, R. C.; KICHEL, A. N.; FONTANELI, R. S.; SANTOS, H. P.; FRANCHINI, J. C.; GALERANI, P. R. Evolução tecnológica e arranjos produtivos de sistemas de integração lavoura pecuária floresta no Brasil. Pesquisa Agropecuária Brasileira, v. 46, p. ixii, 2011.

CARVALHO, J. L. N.; RAUCCI, G. S.; FRAZÃO, L. A.; CERRI, C. E. P.; BERNOUX, M.; CERRI, C. C.. Crop-pasture rotation: a strategy to reduce soil greenhouse gas emissions in the Brazilian Cerrado. Agric. Ecosyst. Environ., V. 183, p. 167-175, 2014. DOI: http://dx.doi.org/10.1016/j.agee.2013.11.014.

DUBE, F.; COUTO, L.; SILVA, M. L.; LEITE, H. G.; GARCÍA, R.; ARAÚJO, G. A. A.. A simulation model for evaluating technical and economic aspects of an industrial eucalyptus-based agroforestry system in Minas Gerais, Brazil. Agrofor. Syst., V. 55, n. 1, p. 73-80, 2002.

Figure: Evaluation of eucalyptus roots in the ICLFsystem for biomass quantification and carbon stock.

Crédit: José Ricardo Macedo Pezzapane.

PROJECT COORDINATOR

Dr. José Ricardo Macedo Pezzopane

Embrapa Pecuária Sudeste

e-mail: jose.pezzopane@embrapa.br

Dr. Alberto Carlos de Capos Bernardi

Embrapa Pecuária Sudeste

e-mail: alberto.bernardi@embrapa.br

Dra. Patrícia Perondi Anchão

Embrapa Pecuária Sudeste

e-mail: patricia.anchao-oliveira@embrapa.br

SUSTAINABLE PRODUCTION SYSTEMS, CROP-LIVESTOCK INTEGRATION AND CROP-LIVESTOCK-FOREST INTEGRATION SYSTEMS

Roberto Guimarães Júnior[1]; Luiz Gustavo Ribeiro Pereira[2]; Robélio Leandro Marchão[1]; Karina Pulrolnik[1]; Lourival Vilela[1]; Fabiano Alvim Barbosa[3]; Arminda Moreira de Carvalho[1]; Giovana Alcântara Maciel[1]; Raphael Amazonas Mandarino[4]; Darliane de Castro Santos[5]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Cerrados; **2** Empresa Brasileira de Pesquisa Agropecuária – Embrapa Gado de Leite; **3** De Heus Animal Nutrition; **4** União Pioneira de Integração Social; **5** Instituto Federal Goiano.

The general objective of this work was to study sustainability indicators of beef cattle production systems in the Cerrado and Amazon Biomes. The study carried out in the Cerrado biome involved the evaluation of three different integrated production systems: crop-livestock integration systems, crop-livestock-forest integration and pasture in the process of degradation.

The variables analyzed as indicators of sustainability were the emission of enteric methane, weight gain and the ratio between emission of enteric methane and indicators of dry matter consumption and performance of Nellore heifers (279 kg ± 21.4 live weight) in different systems. The forage used was Brachiaria brizantha cv. BRS Piatã and the tree species eucalyptus urograndis (Eucalyptus grandis x E. urophylla) planted in north-south orientation, with the following treatments: CLI1 - forage grown with one year of formation under the (CLI) system; CLI6 - forage grown with six years of formation under a well-managed CLI system over the years and; CLFI1 - forage with a year of formation via CLFI, cultivated in eucalyptus subforest with spacing of 22 m (417 trees.ha-1) between rows. In addition to the aforementioned indicators, the dry mass availability and the leaf: stem ratio of the pasture were evaluated in the dry and rainy seasons. The experimental design was completely randomized in a factorial scheme 3 (treatments) for 2 (periods). Evaluations were conducted from April 2013 to May 2014. Heifers raised in CLI issued more methane per kilo of dry matter ingested and, consequently, presented greater losses of crude energy in the form of methane (6.15% in the drought and 8.65% in the rainy season) compared to the other systems studied. Comparing integrated systems, both with first year pasture, the presence of trees (CLFI1) did not provide significant increases in animal weight gain. On the other hand, the weight gain per area (kgPV.ha-1) in the CLI1 system was 54% greater than the others during the drought and 47% higher than CLFI1 during the wet season. Emissions of enteric methane were affected by the periods of the year, with higher gross emissions (g/day and kg/year) during the wet season.

It is concluded that the integrated systems, based on first year pasture (with 1 year of formation), were more efficient, because they present lower values for the indicators of energy loss from the diet via enteric fermentation (Ym) and CH 4 emission per kg of dry matter ingested.

Measurements were made over a period of one year, in the central month of the seasons, spring, summer, autumn and winter. Associated with measurements of enteric methane emission by beef cattle, assessments of total dry matter consumption and individual and area weight gain were carried out. These results were used to define the coefficients of gross GHG emissions (emission of methane per animal) and relative emissions, such as emission of methane per kilo of dry matter ingested, emission of methane per kilo of animal weight gain and area and loss of diet energy in the form of methane.

RESULTS

- Unpublished data was generated on enteric methane emission and animal performance of beef cattle in different livestock production systems in the Cerrado region of the Federal District.

CHALLENGES

- Implementing the sulfur hexafluoride tracer technique, due to the high demand for labor and peculiarities of this methodology;
- Raising resources for the development of the work.

SOLUTIONS

- Technical indicators on enteric methane emission by cattle in production systems in the Cerrado;
- Technical indicators on animal performance and pasture characteristics *Brachiaria brizantha* cv Piatã in silvopastoral systems.

DATA PUBLISHED IN:

MANDARINO, R. A. Indicadores de sustentabilidade da pecuária de corte no cerrado e na Amazônia. 2016. Tese (Doutorado em Zootecnia) – Escola de Veterinária da Universidade Federal de Minas Gerais, Belo Horizonte, 2016.

SANTOS, D. C; GUIMARÃES JÚNIOR, R.; VILELA, L.; MACIEL, G. A.; FRANÇA, A. F. S. Implementation of silvopastoral systems in Brazil with Eucalyptus urograndis and Brachiaria brizantha: productivity of forage and an exploratory test of the animal response. Agriculture Ecosystems & Environment, v. 266, p. 174-180, 2018.

SANTOS, D. C.; GUIMARÃES JÚNIOR, R.; VILELA, L.; PULROLNIK, K.; BUFON, V. B.; FRANÇA, A. F. S. Forage dry mass accumulation and structural characteristics of Piatã grass in silvopastoral systems in the Brazilian savannah. Agriculture, Ecosystems & Environment, v. 233, p. 16-24, 2016.

Continued in Annex

Parameter evaluated	Frequency	Instruments
Dry Matter Intake	4 times a year (spring, summer, autumn and winter), during one year	External LIPE indicator
Emission of enteric methane	4 times a year (spring, summer, autumn and winter), during one year	SF_6 tracer gas technique
Animal weight gain	4 times a year (spring, summer, autumn and winter), during one year	Scale, containment,
Forage productivity	Monthly	Forage cutters, scales, ventilated greenhouse
Pasture nutritional value	Monthly	Laboratory equipment for analysis of crude protein, NDF, FDA, lignin and in vitro digestibility of dry matter

Figure: Nellore cattle in ICLFsystem using tubular yokes for measuring enteric methane

Crédit: Raphael Amazonas Mandarino.

PROJECT COORDINATOR

Dra. Patrícia Perondi Anchão

Embrapa Pecuária Sudeste

e-mail:patrícia.anchao-oliveira@embrapa.br

Dr. Roberto Giolo de Almeida

Embrapa Gado de Corte

e-mail: roberto.giolo@embrapa.br

POTENTIAL OF ENVIRONMENTAL SERVICES USING EUCALYPTUS IN INTEGRATED PRODUCTION SYSTEMS

André Dominghetti Ferreira[1,2]; Valdemir Antônio Laura[1,2]; Alexandre Romeiro de Araújo[1]; Roberto Giolo de Almeida[1]; Manuel Claudio Motta Macedo[1]; Davi José Bungenstab[1]; Luan Silva do Nascimento[2]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Gado de Corte; **2** Universidade Anhanguera.

Introducing the tree component in crop-livestock-forest integration (ICLF) systems allows for high potential of carbon sequestration and environmental services, reflecting greater land use efficiency and lower environmental impacts. Thus, the objective of this work was to evaluate productivity and the potential for mitigating greenhouse gas (GHG) emissions from the tree component in ICLF systems with two spatial arrangements. The experiment was carried out in the Cerrado biome, in Mato Grosso do Sul, in a Dystropheric Red Latosol and in a climatic transition zone between Cfa and humid tropical Aw. Two ICLF systems were assessed, implemented in 2008/2009, with Brachiaria brizantha cv. BRS Piatã in succession to soybeans, in cycles of one year of farming followed by three years of pasture, for the production of beef cattle, and with eucalyptus trees (Eucalyptus urophylla x E. grandis, clone H13) in simple rows. The systems differed regarding the spatial arrangement of the trees: eucalyptus in single rows in an arrangement of 14 meters between rows by 2 meters between trees in the row (ILPF14x2m), totaling 357 trees/ ha; and eucalyptus in single rows in an arrangement of 22 meters between rows by 2 meters between trees in the row (ILPF22x2m), totaling 227 trees/ha.

RESULTS

The spatial arrangements did not affect the individual performance of the trees until 86 months after planting, and the average values observed for the variables, diameter at breast height (DBH), height and volume of wood per tree were: 24.25 cm; 26.60 m and 0.43 m^3, respectively. However, the volume of wood per hectare increased with the density of trees, from 153.50 m^3/ha for ILPF14x2m and 92.37 m^3/ha for ILPF22x2m. The higher density of trees, consequently, provides greater carbonsequestration (measured as CO_2eq) and, therefore, greater potential for mitigating GHG emissions produced by cattle. In the ICLF14x2m system, the amount of carbon sequestered in tree trunks only up to 86 months was 158.97 t CO_2eq/ha, enough to mitigate GHG emissions of 12.7 animals per hectare per year (considering an animal of 450 kg with an annual emission of 1.88 t CO_2eq). For the ILPF22x2m system, the amount of carbon sequestered was 95.66 t CO_2eq/ ha, enough to mitigate GHG emissions of 7.6 animals per hectare per year. Thus, it can be concluded that ICLF systems with eucalyptus, in spatial arrangements with densities from 227 to 357 trees/ha, do not influence the individual development of trees up to 86 months after planting, however, the higher density of trees provides greater wood productivity and, consequently, greater potential for mitigating the GHG emissions of grazing animals.

DATA PUBLISHED IN:

FERREIRA, A. D.; LAURA, V. A.; ARAÚJO, A. R.; ALMEIDA, R. G.; MACEDO, M. C. M.; BUNGENSTAB, D. J.; NASCIMENTO, L. S. Potential

of environmental services of eucalyptus on integrated production systems. In: INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN

AGRICULTURE, 2., 2016, Campo Grande, MS. Proceedings [...]. Campo Grande, MS: Embrapa Gado de Corte, 2016. p. 200-204.

PROJECT COORDINATORS

Dr. Roberto Giolo de Almeida

Embrapa Gado de Corte

e-mail: roberto.giolo@embrapa.br

Dr. André Dominghetti Ferreira

Embrapa Gado de Corte

e-mail: andre.dominghetti@embrapa.br

ENTERIC METHANE EMISSIONS FROM NELLORE HEIFERS IN INTEGRATED AND EXTENSIVE SYSTEMS

Rodrigo da Costa Gomes[1]; Alexandre Berndt[2]; Roberto Giolo de Almeida[1]; Manuel Claudio Motta Macedo[1]; Max Wender França Martins[3]; Leandro Sannomiya Sakamoto[2]; Daniella F. Vilas Boas[2]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Gado de Corte; **2** Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pecuária Sudeste; **3** Universidade Católica Dom Bosco.

Brazilian beef cattle production is based mainly on extensive livestock systems, which, in general, have low productivity and higher emissions of greenhouse gases (GHGs) per kilo of meat produced. Integrated systems appear as an alternative to overcome this scenario, with the potential to increase productivity and reduce the impacts related to GHG emissions. From 2014 to 2015, an experiment was carried out in the Cerrado biome, in Mato Grosso do Sul, with the objective of evaluating the emission of enteric methane from beef cattle in three production systems: pasture under extensive management (Brachiaria decumbens established in 1992/1993; EXT), pasture in crop-livestock integration (Brachiaria brizantha cv. BRS Piatã for three years after soybean no-tillage; ILP); and pasture in crop-livestock-forest integration (idem ILP + 227 *Eucalyptus urophylla* x *E. grandis* trees per hectare, implanted in 2009; ICLF), with assessments carried out during the dry and wet seasons. Two batches of experimental animals (Nellore heifers) were used; in 2014, weighing between 442 to 501 kg of live weight and at 30 to 36 months of age and, in 2015, between 271 to 382 kg of live weight and 18 to 24 months of age. Enteric methane was measured using the tracer gas (SF) technique, over a minimum period of five days at each season of the year.

PRELIMINARY RESULTS

Methane emissions were higher in 2014 than in 2015 (183 vs. 118 g/animal/day. This may be related to differences in heifers' age and live weight over the years, as in 2015 the heifers were younger and lighter than those used in 2014. However, the main explanation for the differences in methane emissions over the years is due to differences in forage availability. For example, considering the wet season, the CLI and ICLF systems presented 4.3 and 3.6 t/ha of dry fodder in 2014, respectively, while availability decreased to 2.2 and 1.2 t/ha in 2015, respectively. Differences in forage availability may have affected the intake of dry matter by grazing animals, which, in turn, may have led to differences in methane emissions between 2014 and 2015. Methane emissions were higher during the wet season compared to during the dry season, regardless of the year. On average, the differences between the seasons were around 9%. The reasons for these results may be the same that explain the differences in methane emissions over the years, as less forage availability is expected during the winter in the conditions of the Brazilian Cerrado. In 2014, there was no difference for methane emissions during the wet season, with an average of 191 g/animal/day. On the other hand, during the dry season, the ICL system showed a higher methane emission (197 g/animal/day) than the extensive system (158 g/animal/day), however, the ICLF system did not differ from the others (170 g/animal/day). In 2015, there were no differences between the systems in each season, with an average of 123 g/animal/day in the wet season and 113 g/animal/day in the dry season. As previously explained, the availability of forage can affect dry matter consumption and, in turn, emission of enteric methane. Therefore, this may explain why the differences between the systems observed in 2014 were not observed in the following year. In conclusion, differences in methane emissions between grazing systems, including extensive and integrated systems, may exist, however these differences seem to be mainly motivated by the availability of forage in the systems, which, in turn, may vary depending on climatic and environmental factors and pasture management.

DATA PUBLISHED IN:

GOMES, R. C.; BERNDT, A.; ALMEIDA, R. G.; MACEDO, M. C. M.; MARTINS, M. W. F.; SAKAMOTO, L. S.; VILAS BOAS, D. F. Enteric methane emission of Nellore cattle in extensive grazing or integrated systems. In: INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN AGRICULTURE, 2., 2016, Campo Grande, MS. Proceedings [...]. Campo Grande, MS: Embrapa Gado de Corte, 2016. p. 277-281.

PROJECT COORDINATORS

Dr. Roberto Giolo de Almeida

Embrapa Gado de Corte

e-mail: roberto.giolo@embrapa.br

Dr. Rodrigo da Costa Gomes

Embrapa Gado de Corte

e-mail: rodrigo.gomes@embrapa.br

GREENHOUSE GAS EMISSIONS FROM SOILS FROM DIFFERENT ANIMAL PRODUCTION SYSTEMS IN THE BRAZILIAN CERRADO

Alexandre Romeiro de Araújo[1]; Michely Tomazi[2]; Manuel Claudio Motta Macedo[1]; Roberto Giolo de Almeida[1]; André Dominghetti Ferreira[3]; Liange de Oliveira Diehl[4]; Thais Melo[5]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Gado de Corte; **2** Empresa Brasileira de Pesquisa Agropecuária – Embrapa Agropecuária Oeste; **3** Empresa Brasileira de Pesquisa Agropecuária – Embrapa Café; **4** Empresa Brasileira de Pesquisa Agropecuária – Embrapa Trigo; **5** Anhanguera University.

Greenhouse gas (GHGs) emissions are mainly associated with changes in land use in Brazil, especially the conversion of forests to pastures or agricultural systems. The objective of this study was to evaluate the GHG emissions from soil, methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O), in three production systems. The study was carried out in the Cerrado biome, in Mato Grosso do Sul, in a Dystrophic Red Oxisol and in a climatic transition zone between Cfa and wet tropical Aw. The evaluated systems were: extensive pasture of B*rachiaria decumbens cv. Basilisk* without maintenance fertilization; crop-livestock integration with Brachiaria brizantha cv. BRS Piatã and annual maintenance fertilization (CLI); and crop-livestock-forest integration with *Brachiaria brizantha* cv. *BRS Piatã*, annual maintenance fertilization, in addition to simple eucalyptus lines in a 22 x 2 m arrangement (CLFI); an adjacent area with natural vegetation in the Cerrado was evaluated as a reference. 13 samples of soil GHG emissions were carried out during the period from February 2014 to April 2015, by means of static chambers, being considered five repetitions within two experimental blocks.

RESULTS

The accumulated annual N_2O emission of the ICLF system was higher (68 mg/m²), followed by the Cerrado (42 mg/m²) and extensive pasture (6mg /m²), and the CLI system (44 mg /m²) did not differ from the ICLF system and the Cerrado. The lower emission observed in the extensive pasture may be related to the absence of nitrogen fertilization in this system. For CH_4, the CLI system presented the highest accumulated annual emission (491 mg/m²) while the Cerrado presented itself as a drain (-441 mg /m²) and the ICLF systems (-108 mg /m²) and extensive pasture (43 mg/m²) presented intermediate values and did not differ from each other. The accumulated annual CO^2 emission was higher for the CLI system (2,666 g/m²), followed by the ICLF systems (1,783 g/m²) and extensive pasture (1,660 g/m²), which did not differ from each other, and by the Cerrado (1,076 g/ m²), with the lowest emission, probably due to the greater carbon stability in this natural system. In this study, systems with trees, native (Cerrado) or exotic (CLFI), acted as drains for CH_4; and the highest accumulated annual CO_2 emission in the CLI system can represent a greater flux in the dynamics of organic matter in the soil and not necessarily loss of soil carbon in this system.

DATA PUBLISHED IN:

ARAÚJO, A. R.; TOMAZI, M.; MACEDO, M. C. M.; ALMEIDA, R. G.; FERREIRA, A. D.; DIEHL, L. O.; MELO, T. S. Soil GHG emissions in different livestock production systems in the Brazilian Cerrado. In: INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN AGRICULTURE, 2., 2016, Campo Grande, MS. Proceedings [...]. Campo Grande, MS: Embrapa Gado de Corte, 2016. p. 277-281.

PROJECT COORDINATORS

Dr. Roberto Giolo de Almeida

Embrapa Gado de Corte

e-mail: roberto.giolo@embrapa.br

Dr. Alexandre Romeiro de Araújo

Embrapa Gado de Corte

e-mail: alexandre.araujo@embrapa.br

SOIL CARBON CONTENT IN CROP-LIVESTOCK-FOREST INTEGRATION SYSTEMS

Manuel Claudio Motta Macedo[1]; Alexandre Romeiro de Araújo[1]; Roberto Giolo de Almeida[1]; André Dominghetti Ferreira[1]; Michely Tomazi[2]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Gado de Corte; 2 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Agropecuária Oeste.

Pasture and soil degradation are the main restrictions to conventional animal and grain production systems, respectively, in Brazil, resulting in soil carbon loss. However, soil quality, in terms of carbon content, is an indicator for identifying sustainable production in agricultural systems. In this study, results of the soil carbon content of three integration systems are presented, in a period from 2008 to 2015. The experiment was carried out in the Cerrado biome, in Mato Grosso do Sul, in a Dystropheric Red Oxisol and in a climatic transition zone between Cfa and humid tropical Aw. The evaluated systems were: crop-livestock integration implanted in 2008/2009, with Brachiaria brizantha cv. BRS Piatã in succession to soybeans, in one-year crop cycles followed by three years with pasture with annual maintenance fertilization (CLI); and two crop-livestock-forest integration systems with the same characteristics as the CLI, however, including eucalyptus trees (*Eucalyptus urophylla x E. grandis*, clone H13) in single rows, one system with eucalyptus in single rows in a 14 meters between rows by 2 meters between trees in the row (CLFI14x2m), totaling 357 trees/ha, and another system with eucalyptus in simple rows in an arrangement of 22 meters between rows by 2 meters between trees in the row (CLFI22x2m), totaling 227 trees/ha. In these systems, soybeans were grown conventionally in 2008/2009 and under no-till in 2012/2013. Two transects, composed of 10 sample points each, were performed annually, in May-June, in the 0-20 cm depth layer, and the soil samples were analyzed for total C content in an auto-analyzer.

RESULTS

During a period of seven years, the soil in the CLI system showed a positive trend and higher levels of total C compared to the CLFI22x2m system, followed by the CLFI14x2m system, with lower levels. For CLI, from 2008 to 2015, the total C levels increased from 2.19 to 2.63 g C/100 cm^3 of soil (20.09% increase), for CLFI22x2m, they increased from 1.83 to 2.31 g C/100 cm^3 of soil (increase of 26.23%) and, for CLFI14x2m, increased from 1.56 to 2.02 g C/100 cm^3 of soil (increase of 29.49%). The CLI system showed a higher grass biomass, as there was no competition for light, water and nutrients from trees and provided a greater source of organic matter for soil carbon than ICLFsystems, of pasture combined with trees. Grass biomass seems to be a better source of organic matter, especially root mass, working to increase the carbon content of the soil.

DATA PUBLISHED IN:

MACEDO, M. C. M.; ARAÚJO, A. R.; ALMEIDA, R. G.; FERREIRA, A. D.; TOMAZI, M. Soil carbon contents in integrated crop-livestock-forest systems. In: INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN AGRICULTURE, 2., 2016, Campo Grande, MS. Proceedings [...]. Campo Grande, MS: Embrapa Gado de Corte, 2016. p. 494-495.

PROJECT COORDINATORS

Dr. Roberto Giolo de Almeida

Embrapa Gado de Corte

e-mail: roberto.giolo@embrapa.br

Dr. Manuel Claudio Motta Macedo

Embrapa Gado de Corte

e-mail: manuel.macedo@embrapa.br

3 EMISSION AND REMOVAL FACTORS FOR NON- RUMINANTS

Factors for emission and removal of greenhouse gases from the production of non-ruminants in the national territory

Mirella Nogueira de Souza[1]; Leidiane Ferronato Mariani[2]; Juliana Bragança Campos[3]; Ana Paula Packer[4]; Eleneide Doff Sotta[4,5]; Katia Marzall[5]; Fernanda Garcia Sampaio[4,5]

1 Autonomous Consultant - Specialist in Climate Change and Agriculture; **2** Autonomous consultant - Specialist in Sustainability and Biogas; **3** CNPq DTI- scholarship holder ; Empresa Brasileira de Pesquisa Agropecuária– Embrapa; **5** Ministério da Agricultura, Pecuária e Abastecimento.

This chapter deals with national contributions to the definition of factors of emission and removal of Greenhouse Gases by non-ruminant livestock. In this context, the emission factors of the swine, poultry and aquaculture production chains were analyzed, as they are the three main productive chains of non-ruminants in Brazil.

Pig Farming

Brazil is the fourth largest pork producer and exporter, following China, the European Union and the USA and, despite this, its exported volume represents only 8% of the total traded worldwide (RAMOS, 2016). Brazilian pork production is mostly destined for the domestic market, and in 2015, 85% of the production was absorbed by domestic consumption. Although the consumption of pork in Brazil has similar volumes to that consumed in other countries (15 kg/inhab/year), this is still lower than beef and chicken. While chicken accounts for approximately 42% of family meat purchases, pork accounts for 13% (ABPA, 2016).

Pig farming in Brazil is carried out intensively and mostly in an integrated manner with the industry, in order to avoid the occasional fluctuations that affect farmers production and profitability. Currently, only 25% of production is carried out independently (SEAB-DERAL, 2015). The Brazilian pig herd reached 41.1 million head in 2017, an increase of 3.0% compared to 2016. The South Region concentrates the largest pig herd with Santa Catarina at the top of the state ranking, with 19.7% of the national total sum; Paraná comes next with 16.8% and Rio Grande do Sul with 14.6% (IBGE, 2017).

According to Tavares (2012), the accelerated development of Brazilian pig farming, caused by the demands of the foreign and domestic markets that accompanied the “Livestock Revolution”, promoted the majority adoption of intensive production systems, namely by the implementation of Confined Space Animal Production Systems (SPAC). Pork manure originated in SPAC is an effluent composed of feces, urine, feed waste, excess water from drinking fountains and the cleaning of facilities and animals (BONITO, 2015). When degraded, the waste produced can be a source of gas emissions and dust into the atmosphere, producing about 40 gaseous compounds already identified, which can generate negative impacts on animal and human health.

According to Philippe and Nicks (2014), the CO_2 produced from the manure is originated by three distinct routes, namely: I) catalyzed by the enzyme urea in the process of hydrolysis of urease; II) anaerobic fermentation of organic matter; and III) aerobic degradation of organic matter.

The CH_4 produced by pig farming originates mainly from the decomposition of manure under anaerobic conditions, increasing with the Volatile Solids (VS) content of the excreta, in addition to also being produced by enteric fermentation. N_2O, on the other hand, is a gas generated from manure storage systems as an intermediate product of the nitrification and denitrification processes, with the degradation of organic matter (COSTA, 2009). Nitrification requires aerobic conditions, while denitrification requires anaerobic conditions, which occur primarily in deep bed systems. However, emissions from stored waste can also occur in slatted floor systems (PHILIPPE *et al.*, 2007).

According to Pecoraro (2015), pig production is the second largest contributor to GHG emissions associated with animal production, representing 13% of total emissions. The GHG emission values must be related to the type of system used in the swine production, so that these parameters are used as indicators of sustainability and, thus, an adequate environmental characterization of the activity is carried out. However, one difficulty encountered refers to the lack of standardization of the units and methodologies used in the quantification of the GHGs produced.

In pig farming, emissions are influenced by the type of management associated with manure, the type of floor of the housing, and the rate of ventilation employed, animal nutrition and the climatic conditions of the region where they are located (PHILIPPE; NICKS, 2014). Thus, it is understood that the emission of gases in the swine production systems can be influenced by factors such as the breeding stage, genetics, type of diet, nutritional plan, type of installation, manure management and climatic conditions. Thus, the adoption of emission factors obtained in different environmental and management situations can overestimate or underestimate the impact of emissions from swine production systems.

The Life Cycle Analysis (LCA) of swine production estimates that the reference is 2.30 kg of carbon equivalent (CO2eq) per kg of pork produced, or 4,236 kg CO_2eq per hectare. The comparison with other products of animal origin, also using the methodology of ACV, shows that pig production results in the production of 3.9–10 kg CO_2eq for each kg of pork produced, values close to the production of chicken meat (3.7-6.9 kg CO_2eq) and significantly lower than beef (14–32 kg CO_2eq) (NUNES; MIRANDA, 2013).

Higarashi *et al.* (p. 128) evaluated GHG emissions from swine in a confined industrial system in southern Brazil, measuring emissions in technological arrangements with biodigesters, considering the entire effluent cycle. In these systems, the management adopted in more than 95% of the farms consists of storing the manure in dung for partial stabilization followed by application to the soil for fertilization of crops and pastures. Emission/Removal factors (EF) of CH4from dung steels in integrated systems found was B0 = 0.48 m3kg-1 of VS, which was calculated from field studies. This result is in line with data in the literature, which reports values that vary from 0.29 to 0.53 m^3kg^{-1} VS. However, according to the IPCC Guidelines, the estimated B0 for manure management in Latin America would be 0.29 ± 0.04 m^3 $CH_4.kg^{-1}$ VS, while in Europe and the USA these reference values for B0 would be, respectively, 0.45 ± 0.07 and 0.48 ± 0.08 $m^3CH_4.kg^{-1}$ VS. Thus, based on these considerations, the value of B0 = 0.48 m^3 CH4.kg-1VS would currently be a reference value that could be used only in the South Region. These authors also state that when waste is treated by compost or biodigester N2O emissions are reduced by 17% and 47%, respectively.

Thus, the Table presents a comparison of the CH_4 emission factors for swine manure by several authors. It is important to consider that, depending on the waste treatment, part of the CH_4 emission can be avoided (composting) or mitigated (anaerobic digestion by burning the gas for energy use).

Table: Comparison of methane emission factors in the production system.

References	Applicable region	Bo ($m^3CH_4.kg^{-1}$ VS) (Emission factor)
IPCC {2006);	Latin America	*0.29 ± 0.04*
	Europe	0.45 ± 0.07
	USA	0.48 ± 0.08
EU-Agro Biogas (2015)	Europe	0.34
Chen (1983)	-	0.50
CIBiogás-ER (2015)	Brazil	0.37
BiogasFert (2018)	Brazil	0.32
Higarashi et al.(P. 128)	South Region of Brazil	0.48

Source: Authors.

Muller *et al.* (p. 130) evaluated the effect of the agronomic use of pig slurry (anaerobically treated) and the pig slurry compound on N_2O emissions, on fractions and stocks of C and N and on soil microbiology. They also evaluated measurements of the concentration of N_2O, carbon dioxide (CO_2) and methane (CH_4) inside the swine producing facilities. On average, GHG emissions in swine farms in the physiological day care phase were 0.42 kg of CO_2 swine^{-1} day^{-1}, of 1.07 g CH_4 swine^{-1} day^{-1} and 0.07 g of N_2O swine^{-1} day^{-1}.

Despite research groups' detailed search in all the regions of the country, the studies gathered on the emission of GHG by swine in this Compilation are concentrated in the south, which is justified because it is responsible the largest pig production in Brazil. One of the challenges pointed out for the swine chain is the great heterogeneity of the production systems adopted in Brazil, making it difficult to adopt only one standard factor that represents the national swine herd. The confined industrial system concentrates the largest contingent of the herd and there is a strong tendency to substitute the other systems for this model in other regions of the country. Therefore, the optimization of the processes for the treatment of effluents from industrial swine, aiming at the stabilization of nitrogen forms, reducing losses in the treatment process is an important challenge to be overcome.

CH_4 emissions in the National GHG Inventory (2016) were estimated using the standard factor of the IPCC (2006), which, for manure management in Latin America, is defined as 0.29 ± 0.04 m^3 $CH_4.kg^{-1}$ SV, while in Europe and the USA the established values are0 , 45 ± 0.07 and 0.48 ± 0.08 m^3 $CH_4.kg^{-1}$ VS, respectively. N_2O emissions from waste management destined for open anaerobic lagoons and biodigesters, according to the IPCC, have the (EF3) emission factor, which is defined as zero. However, when the system for treating and managing swine manure is composting, CH_4 emissions are reduced to almost zero, but N_2O emissions can become significant without adequate management, considering an N_2O emission factor of 0.01 (IPCC, 2016).

The implementation of GHG emission mitigating treatments, such as the biodigester and composting or the reduction of the storage time in the manure tanks, can contribute to reducing emissions. From the studies compiled, two important actions to be adopted are defined:

I. the splitting of fertilization, associated with the adequate supply of nutrients for the crops, via supplementary mineral fertilization, constitutes an important tool for the reduction of N_2O emissions in soils;

II. and the composting technique after the application of organic fertilizers should be promoted as a technological alternative for reducing N_2O emissions from the soil. In this context, it is important to adopt technologies that prioritize the reduction of N_2O and NH3 emissions in the compost windrows.

In addition, given the relevance of livestock activity in Brazil, the growing search for new alternative sources for energy production and waste recycling suggests the use of animal waste as an economically viable option.

Thus, the process of anaerobic digestion from waste is currently characterized as the key to a more sustainable production system, due to the reduction in the use of conventional energies and commercial fertilizers, in addition to providing a highly efficient method for recycling resources and closing the production cycle. Biogas, a gaseous product of anaerobic digestion, can be used to generate electrical and thermal energy and biomethane fuel. It is also possible to use the liquid fraction of the process, the digestate, as a biofertilizer thanks to its composition which is high in nutrients and organic matter.

In this scenario, the importance of solutions for the treatment of swine manure that undergo: anaerobic digestion using biogas energy (to reduce CH4 emissions) and biofertilizer enhancement; or by composting with adequate management to reduce N2O emissions.

Poultry

In 2017, Brazilian poultry production reached 13,050 million tons, thus consolidating the country as the second largest producer in the world. Of this production, about 33% was destined for the foreign market, occupying the first place in exporting countries. Most of the poultry meat production is for domestic consumption, which, in 2016, had a per capita consumption in Brazil of 41 kg/inhabitant (ABPA, 2018)[1].

The Brazilian poultry meat industry is concentrated in the South, Southeast and Midwest regions, with the common characteristic of producers adopting practices to control the impact of the activity on the environment. However, confined poultry farming systems contribute significantly to the emission of gases, such as N2O, CO2, NH3 e H2S into the atmosphere.

Commonly, poultry chickens are raised in sheds with a bed of wood shavings, sawdust or other material on the floor, which is called a chicken bed. This material is intended to absorb floor moisture, dilute animal excreta and reduce temperature fluctuations. After the end of each cycle, the material undergoes treatment to be reused in a few more bird fattening cycles. Poultry litter is one of the main factors responsible for gas[2] emissions in poultry farming, with ammonia being the predominant gas. Ammonia is widely found in the environment, and its emission results from both biological processes and anthropogenic sources (ONTARIO, 2001).

1 Available at: http://abpa-br.com.br/setores/avicultura/mercado-interno/frango.
2 Available at: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/91032/1/final7197.pdf.

In poultry production systems, ammonia is formed from the microbial decomposition of uric acid eliminated by birds (OLIVEIRA *et al.*, 2003) and its emission increases when bedding temperature, pH and moisture are high (MIRAGLIOTA *et al.*., 2002). The control of the characteristics of chicken litter represents an important management strategy for the reduction of ammonia volatilization, mainly in relation to the pH and humidity of the litter.

Information on the impacts and potentials of GHG mitigation by confined chicken manure management in Brazil is scarce, in addition to the fact that there is no standard method for direct measurements in Brazilian warehouses in tropical conditions.

The work carried out by the United Nations Food and Agriculture Organization - FAO (2013) concludes that non-technified chicken production has 25% higher (6.6 versus 5.518 t CO_2eq) emission than technified production. Similarly, Prudencio da Silva (2014) calculated 26% higher emission values (4.2 versus 3.18 t CO_2eq) for broiler production in the Label Rouge model compared to conventional production in France. Along these lines, a study carried out by Bogglia *et al.* (2010) showed the lowest GHG emissions in conventional production compared to organic production. In terms of technology, studies carried out in Brazil are aligned with international studies. A study by Henn (2014) states that the evolution of technology within the intensive chicken production system promotes a reduction in GHG emissions, while Oliveira *et al.* (2012) and Prudencio *et al.* (2010) found that modern dark house type aviaries have a lower emission intensity than conventional aviaries.

Santana *et al.* (p. 134) sought to develop a sampling system to directly measure N_2O, CH_4 and NH_3 emissions from chicken manure. In order to directly quantify NH_3 emissions, a static semi-open method was adapted, based on the capture, in acidic medium, of the NH_3 volatilized from poultry manure. Additionally, they monitored the daily NH_3, CH_4 and N_2O emissions from chicken manure, considering the typical chicken litter reuse management. The emission factors modeled for chicken manure during four breeding cycles corresponded to 0.14 g of N_2O, 0.35 g of CH_4 and 72.0 g of N-NH_3 bird-housed-1year^{-1}. Bird age and litter reuse were positively related to N_2O, CH_4 and NH_3 fluxes. Projections indicated that the intensification of chicken litter reuse resulted in higher GHG and NH_3 emissions per bird produced. Another significant result of the research was that the scenario of greater litter reuse (six cycles) simulated estimated an emission of 0.5 kg CO_2eq bird-housed^{-1}year^{-1}, corresponding to 0.08 kg CO_2eq bird^{-1} or 0.04 kg CO_2eq per kg of meat. Taking the flock of birds housed in 2015 into account, Brazil issued, in that year, around 545.1 GgCO_2eq.

Agnes *et al.* (p. 138) applied a simplified method for quantifying gaseous emissions in the intensive production of broiler chickens in dark house type facilities, located in the southern region of Brazil. The objective of this work was to acquire NH_3, CH_4, N_2O and CO_2 emission references for production conditions with reuse of poultry litter for long periods, using Cobb 500 males with an average growth period of 41 days. The results found were 0.63 ± 0.1 g bird^{-1}d^{-1}for NH3; 100.2 ± 16g bird^{-1} d^{-1}for CO_2; 0.23 ±0.15 g bird^{-1} d^{-1}for CH_4 and 0.06 ±0.02 g bird^{-1} d^{-1} for N_2O.

Nääs *et al.* (p. 144) evaluated the environmental impact of the chicken production process using the LCA approach in the production of six broiler farms. The data covers the period of one year of poultry production, with a total of six cycles per year. The life cycle inventory included all incoming and outgoing fluxes from the subsystems feed production and chicken rearing, in order to assess the environmental impact of the product from poultry housing to the gate of the poultry farm. The results showed that total GHG emissions from manure management in broiler farms totaled 0.154 per kg of chicken produced.

Direct CH_4 and N_2O and indirect N_2O contributions to global warming potential were 18.9%, 19.3% and 61.8%, respectively. The main factors that contribute to the emission of CH_4 in broiler production are the amount of excreta produced per kg of live weight (0.176 kg VS) and the portion that decomposes anaerobically at the end of each production cycle, when the litter is treated for reuse. The result of the total global warming potential for the broiler production process (subsystem: feed production; subsystem: poultry breeding) was 2.70 kg of CO_2eq per kg of live chicken produced at the farm gate. The poultry rearing stage makes the highest contribution to global warming with 1.95 kg CO_2eq per kg of live chicken produced.

Prudencio da Silva *et al*. (p. 150) used LCA in poultry production systems in Brazil and France and analyzed the effects of production intensity and scale on environmental impacts. Four chicken production scenarios were defined, considering the entire production chain from the production of food to the delivery of the whole chicken, packaged and cooled at the slaughterhouse, these are: extensive production in southwest France (LR - Label Rouge); intensive production, western France (ST - Standard); intensive production, small scale, Southern Brazil (SO); large-scale, intensive production in the Center-West of Brazil (CW). The results found per kg of CO2eq/t of live chicken were: LR = 2,700 kg; ST= 2,220 kg; SO = 1,450 kg and CW = 2,060 kg, thus confirming the trend that the intensive chicken production system produces less impact, per ton of product.

Although national poultry production is mainly distributed in the South, Southeast and Midwest regions of the country, among the studies gathered, only EF information was found for the Southeast and South regions.

According to the 3rd National Inventory of GHG Emissions (2016), poultry farming only participates in the estimation of these emissions through the management of animal waste. Also according to the 3rd Inventory, the IPCC default emission factors (EFp) were used for birds. The IPCC Guide for National Greenhouse Gas Inventories (IPCC, 2006[3]) presents the EFp of CH_4 of manure from poultry feces and urine, at hot temperatures (>25°C), the value of 0.24 m^3 kg^{-1} VS in developing countries, with uncertainties in the order of 30%.> The IPCC also presents the standard value of 40% loss of nitrogen by NH_3 volatilization for birds with litter reuse poultry farms.

According to the observations made by the researchers who contributed to this Compilation, we highlight that quantifying and directly monitoring the gas emissions in the bird breeding systems have been one of the great challenges faced by the scientific community. The main problem is related to the lack of methodological standardization and the cost of continuously applying the methodologies. In addition, the information available in the literature on GHG and NH_3 emissions in aviaries are variable and uncertain, due to the diversity and particular conditions of the facilities, the numerous differences in the rearing system and the complex interactions observed in animal waste. This challenge is even greater in Brazil due to its climatic conditions, territorial expansion, management and breeding of broiler birds, which are still predominantly in open facilities, with limited control of their environmental conditions.

The scenarios of lesser bed reuse, simulated in the surveys, can be considered as GHG mitigation options in broiler aviaries in Brazil. Scientific and technological strategies to assess the chicken meat value chain using LCA and multi-impact assessment approaches would help to understand the entire process flow for mitigating in decision-making.

3 Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl.

Aquaculture

In the last decades, aquaculture has stood out as a competitive and sustainable activity in the production of healthy food, contributing to jobs and income. In Brazil, aquaculture is developed both in excavated tanks and in net tanks in reservoirs and rivers or in the territorial sea.

Environments such as reservoirs have been extensively studied for their contributions to GHG emissions. The Intergovernmental Panel on Climate Change recently approved the refinement of the 2006 inventory rules, including rules for calculating GHG emissions and removing GHGs from freshwater reservoirs that should now be counted in national inventories.

In 2018, according to the Municipal Livestock Survey - PPM, the total production of Brazilian fish farming was 519.3 thousand tons, an increase of 3.4% in relation to the previous year, generating a R$ 3.3 billion production value for the activity. Tilapia is the highlight of fish species with increasing production year by year and represents 60% of the total produced by national fish farming.

Malacoculture, which includes the creation of oysters, mussels and scallops, is a productive activity that contributes greatly to food security and economic development and meets the world's growing demand for animal protein from sustainable production systems. The constant questions about the impacts of animal production systems on the GHG balance call for greater knowledge in relation to the dynamics of emissions and removals from different production chains. Malacoculture, however, is a poorly studied production chain in terms of its carbon footprint. Its GHG emissions are mostly unknown worldwide, making it difficult to understand its carbon balance and compare it with other animal protein production chains.

Silva *et al* (p. 150) researched GHG emissions in fish farming areas in net tanks in order to quantify the balance (production/consumption) of methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O), correlating the balances with biological, physical and chemical environmental factors. In situ measurements were carried out in the reservoirs from Furnas (MG), Chavantes (SP/PR), Ilha Solteira (SP/MS), Sobradinho (BA), Moxotó/Itaparica (PE) and Padre Cícero "Castanhão" (CE) reservoir in areas producing Nile tilapia (Oreochromis niloticus) in net tanks.

In their research, Silva, *et al* (p. 152) analyzed the GHG balance in malacoculture farms in southern Brazil, specifically in areas of Pacific oyster (*Crassostrea gigas*), mangrove oyster (*Crassostrea gasar*), brown mussel (Perna perna) and scallop (*Nodipecten nodosus*) cultivation. In situ measurements were carried out between 2018 and 2019 in the Armação do Itapocoroy cove (Penha), Ribeirão da Ilha (Florianópolis) and Praia de Fora (Palhoça), all in the state of Santa Catarina. The partial results show that the emission of carbon dioxide (CO_2) in malacoculture areas was similar to that of control areas, and, in several cases, carbon was sequestered into the atmosphere. There was no difference in the CO_2, CH_4 and N_2O fluxes measured in the production areas and in the control areas, which indicates that malacoculture does not impact the natural GHG balance.

References

ABPA – Associação Brasileira de Proteína Animal. Relatório Anual 2018. 2018. Available at: www.abps.-br.com.br.

ABPA – Associação Brasileira de Proteína Animal. Relatório Anual 2016. 2016. Available at: www.abpa.com.br/setores/suinocultura/publicacoes/relatorios-anuais.

BOGGLIA, A.; PAOLOTTI, L.; CASTELLINI, C. Environmentalimpactevaluationofconventional, organic andorganic-pluspoultryproductionsystemsusinglifecycleassessment. World's PoultryScience Journal, v. 66, p. 95-114, 2010.

Continued in Annex

EMISSION OF GREENHOUSE GASES (GHG) IN TECHNOLOGICAL ARRANGEMENTS FOR THE PRODUCTION AND USE OF BIOGAS

Martha Mayumi Higarashi[1]; Juliano Corulli Corrêa[1]; Airton Kunz[1]; Rodrigo da Silveira Nicoloso[1]; Paulo Armando Victória de Oliveira[1]; Paulo Cezar Cassol[2]; Celso Aita[3]; Marcio Luis Busi da Silva[4]; Melissa Paola Mezzari[5]

1 Embrapa Suínos e Aves; **2** Universidade do Estado de Santa Catarina, Centro de Ciências Agroveterinárias; **3** Universidade Federal de Santa Maria, Centro de Ciências Rurais; **4** Rice University; **5** University of Texas Health Science Center at Houston.

Despite observations on possible impacts of pig farming on issues related to global warming, the real contribution of the sector still raises doubts and controversies, mainly due to the lack of reliability in the existing data and lack of information regarding tropical conditions.

As part of the actions of the BiogásFert Network, greenhouse gas (GHG) emissions from a swine farm in a confined industrial system in southern Brazil were evaluated, measuring emissions in technological arrangements with biodigesters, considering the entire effluent cycle. In these systems, the management adopted in more than 95% of the farms consists of storing the manure in dung for partial stabilization followed by application to the soil for crop and pasture fertilization. During storage, waste mainly issues CH_4 and NH_3 and its application to the soil results in an increase in the emission of CO_2 and N_2O. Substituting manure tanks for biodigesters can reduce the contribution of confined systems to GHG emission fluxes, resulting from the retention and combustion of CH_4, which is converted into CO_2 and energy.

Methodologies approved by the IPCC were used, employing dynamic chambers for sampling and gas compositions were determined using the Innova 1412 photoacoustic equipment.

Manure tank emission factors in integrated systems

The CH_4 emission factor found was B0= 0.48 m^3 $kg^{-1}$of VS, the same calculated from field studies. This result is in line with data in the literature, which reports values that vary from 0.29 to 0.53 m^3kg^{-1}VS. However, according to the IPCC Guidelines, the estimated B0 for manure management in Latin America would be 0.29 ± 0.04 m3 $CH_4.kg^{-1}$VS, while in Europe and the USA these reference values for B0 would be, respectively, 0.45 ± 0.07 and 0.48 ± 0.08 $m_3CH_4.kg^{-1}$VS.

Therefore, the emission factor found was closer to the European and American B0than that of Latin America. This may have occurred because the measures were carried out in a region where livestock production is highly industrialized,thus, production systems as well as animal diet and genetics did not differ much from those adopted by these countries.

However, due to the heterogeneity of the production systems in Brazil, these values may not express the emissions of national pig farming. So, based on these considerations, the value of B0=0.48 m^3 $CH_4.kg^{-1}$SV would currently be a reference value that could be used only in the southern region. However, it is necessary to emphasize that there is a strong tendency for this model to be replicated in other Brazilian regions.

Agricultural practices to mitigate GHG emissions in the production and use of biogas

Through continuous monitoring of GHG emissions from digestate storage tanks and deposits of raw waste, the global warming potential (GWP in Eq $CO_2.kg^{-1}$ waste) was determined. The tank that stores the biodigester effluent with TRH = 30 days issues 84% less GHG (in PAG) than the manure tank, and it was estimated that the arrangement with the biodigester (where the gases produced in the biodigester and the burning of CH_4 are considered) issue 53% less gases.

Simulations carried out show that reducing manure storage time in the tanks from 120 to 50 days, following the Santa Catarina Normative Instruction 11/2014, results in an 80% reduction in the methane emission from the deposits.

Contribution of biofertilizers in agricultural production systems to GHG emissions

Significant advances in knowledge about the contribution of the use of biofertilizers in agricultural production systems to GHG emissions have already been achieved. An example widely used in the south of the country is the cultivation of corn in the summer and black oats for soil coverage in the winter. In this system, the application of untreated manure increased N_2O emissions from the soil under no-tillage in 59%. When waste is treated by composting or biodigestion, N_2O emissions are reduced by 17% and 47%, respectively.

Another important information is that the untreated manure and the biofertilizer were efficient in providing nitrogen for corn similar to the way mineral fertilizers and organic compost can be used to recover degraded areas due to the supply of organic matter to the soil.

In this sense, there was no significant difference between the carbon stocks of the soil fertilized with mineral fertilizers, untreated manure or biofertilizer. However, the application of organic compost in no-till areas promoted a C sequestration rate of 1 $Mg.ha^{-1}.year^{-1}$in relation to soil fertilized with mineral fertilizers. The results obtained point to a synergic effect in terms of GHG mitigation through the treatment of manure by biodigestion or composting and the recycling of biofertilizer as a source of nutrients for agriculture or for the recovery of areas degraded by fertilization with organic compost.

RESULTS

- The CH_4 emission coefficient from manure farms found for the southern region of Brazil was B00= $0.48m^3.kg^{-1}$ of SV, which proves that, as the production system intensifies, the trend is that the emission factor of Brazilian swine production will be equal to that of industrialized countries.

- Considering only manure tank emission compared to the biodigester arrangement (burning of methane and emission from the post-biodigester pond), a reduction of 53% in the GWP was estimated. Still, it was found that the use of untreated manure for fertilizing crops greatly increases N_2O emission, but the use of digestate and, mainly, of compost is able to mitigate this increase.

CHALLENGES

- Very heterogenous production systems in Brazil. The confined industrial system was chosen for the study, because it concentrates the largest contingent of the herd and because there is a strong tendency of other systems migrating to this model.

SOLUTIONS

- Implementation of treatments to mitigate the emission of greenhouse gases, such as the biodigester and composting or the reduction of the storage time in the tanks (considering the time required for partial stabilization and the demand for manure for use in fertilization).

DATA PUBLISHED IN:

GRAVE, R. A.; MEZZARI, M. P.; SILVA, M. L. B.; CASSOL, P. C.; NICOLOSO, R. S. Determining the mechanisms of nitrous oxide emission under contrasting soil disturbance levels and organic amendments. In: INTERNATIONAL CONFERENCE RAMIRAN, 16., 2015, Hamburg. Abstract Book [...]. Hamburg, 2015.

GRAVE, R. A.; NICOLOSO, R. S.; CASSOL, P. C.; SILVA, M. L. B.; MEZZARI, M. P.; AITA, C.; WUADEN, C. R. Determining the effects of tillage and nitrogen sources on soil N_2O emission. Soil & Tillage Research, v. 175, p. 1-12, 2018.

GRAVE, R. A.; NICOLOSO, R. S.; SILVA, M. L. B.; MEZZARI, M. P.; HIGARASHI, M. M.; CASSOL, P. C.; DALLA COSTA, M. Correlating Denitrifying catabolic genes with soil N_2O emissions under contrasting soil disruption and organic amendments. In: 2014 ASA, CSA & SSSA INTERNATIONAL ANNUAL MEETING, 2014, Long Beach, CA. Conference Proceedings [...]. Long Beach, 2014.

Continued in Annex

Figure: Pig farm in a confined industrial system in southern Brazil

Crédit: Luiza Biezus

PROJECT COORDINATORS

Dra. Martha Mayumi Higarashi

Embrapa Suínos e Aves

e-mail: martha.higarashi@embrapa.br

NITROUS OXIDE EMISSIONS FROM PIG FARMING

Vilmar Müller Júnior[1]; Guilherme Wilbert Ferreira[1]; Cledimar Rogério Lourenzi[1]; Gustavo Brunetto[2]; Sandro José Giacomini[2]; Jorge Manuel Rodrigues Tavares[3]; Jucinei José Comin[1]; Paulo Belli Filho[1]
1 Federal University of Santa Catarina; **2** Federal University of Santa Maria; **3** University of Lisbon.

N_2O is one of the main greenhouse gases (GHG), contributing to the increase in the magnitude of global warming. This gas makes up one of the stages of the N cycle, being produced naturally by soils. However, adding fertilizers to the soil, including organic fertilizers, promotes changes in the biogeochemical cycles of nutrients, which can maximize N_2O emissions. The agronomic valuing of swine manure, according to pre-established technical parameters, is part of the strategy to minimize the impacts of these effluents on the environment, in addition to contributing to the cycling of nutrients within the rural property. However, the system adopted for the pre-treatment of these effluents can change their behavior after they are applied to the soil. In the State of Santa Catarina, pig farming, as well as the disposal of manure in the soil must be licensed according to the technical criteria set out in Normative Instruction Nº. 11 (IN 11, FATMA - Foundation of Fundação do Meio Ambiente de Santa Catarina), aiming to reduce impacts mainly from the imbalance of N, P, Cu and Zn nutrients present in the manure. However, the IN 11 focuses on the impacts of manure on soil and water, with no criteria related to N2O emissions after adding the waste to the field. This is why it is important to evaluate the effect of the agronomic use of swine waste (treated anaerobically) and of swine manure compost on N_2O emissions, fractions and stocks of C and N, and soil microbiology. Thus, the proposal aims to systemically integrate, agronomic aspects combined with the approach proposed by environmental engineering. The focus of the work is to evaluate the implications of the agronomic valuing of swine manure, according to the legal criteria in the state of Santa Catarina, on nitrous oxide emissions (N_2O), carbon (C) and nitrogen (N) stocks and soil microbiology. In addition to emissions in the field, after the application of manure to the soil, they also evaluated measurements of the concentration of N_2O, carbon dioxide (CO_2) and methane (CH_4) inside swine producing facilities. The field experiment was conducted during two black oat and corn cultivation cycles during 2018/2019. Data on the concentration of greenhouse gases from 98 samples analyzed inside piglet producing farms are also presented.

PRELIMINARY RESULTS

Swine genetics: piglets obtained from the crossing of MS 60 males (Embrapa) with F1 Landrace x Large White females.

In pig farming facilities:

- Concentrações de N_2O, CO_2 e CH_4 no interior das instalações (fase fisiológica de creche) de 0,53; 11,35; e 1453,32 ppm-v, o equivalente a 1,4; 2,2; e 2,9 vezes a concentração externa de N_2O, CO_2 e CH_4, respectivamente;
- Em média, as emissões de GEE em granjas de suínos na fase fisiológica de creche são de 0,42 kg de CO_2 por suíno dia, e de 1,07 g e 0,07 g. suíno-1. dia-1 para CH_4 e N_2O, respectivamente;
- Essas concentrações mais elevadas são oriundas de processos metabólicos dos animais e dos dejetos presentes no interior das instalações.

In the areas where manure is applied as a fertilizer:

- Higher N_2O fluxes were observed in the treatment with fertilization based on the use of liquid swine manure, associated with supplementary mineral fertilization.

Accumulated net N_2O emission throughout the black oat and corn cycles:

- Swine liquid manure associated with supplementary mineral fertilization: 2.546 kg N_2O ha^{-1};
- Composed of liquid swine manure associated with supplementary mineral fertilization: 0.071 kg N_2O ha^{-1}.

Emission factor in the fertilization systems evaluated:

- Swine liquid manure associated with supplemental mineral fertilization: 2.28%;
- Swine liquid manure compound associated with supplemental mineral fertilization: 0.06%;

- Acceptable value for organic waste: 1.25%;
- The use of the swine manure compound provided a better division of the nitrogen supply for the crops, which reduces losses by leaching and volatilization of ammonia (NH_3) after soil application;
- Although the emission factor of the liquid manure associated with supplemental mineral fertilization is above what was verified in the treatment based on fertilization with compost, it still remains within the values verified in the literature.

CHALLENGES

- Reconcile the agronomic valuing of pig manure with the reduction of the risk associated with environmental impacts arising from the high concentration of nutrients and heavy metals in these manures;
- To optimize the processes of treatment of the stabilization of nitrogen forms, reducing losses in the treatment process and after adding these materials to the soil;
- Reduce greenhouse gas emissions after the application of organic fertilizers to the soil, without harming the agronomic yield of agricultural crops.

SOLUTIONS

- Splitting fertilization, associated with the adequate supply of nutrients for the crops, via supplementary mineral fertilization, constitutes an important tool for the reduction of N2O emissions in soils;
- We suggest paying special attention to initiatives that promote the composting technique as a technological alternative for reducing N_2O emissions after applying organic fertilizers to the soil. We stress the importance of using appropriate technologies for the composting process, which prioritize the reduction of N_2O and NH_3 emissions in the composting windrows.

DATA PUBLISHED IN:

MÜLLER JÚNIOR, V. Emissões de óxido nitroso em solos adubados com dejetos suínos (Tese de doutorado em fase de elaboração).

TAVARES, J. M. R. Modelagem do consumo de água, produção de dejetos e emissão de gases de efeito estufa e amônia na suinocultura. 2016. Thesis (Doctorate) - Graduate Program in Chemical Engineering, Federal University of Santa Catarina, Florianópolis, 2009.

Figura: Pig breeding system

Crédito: Vilmar Müller Júnior

PROJECT COORDINATORS

Dr. Cledimar Rogério Lourenzi

Universidade Federal de Santa Catarina

e-mail: lourenzi.z.r@ufsc.br

Dr. Gustavo Brunetto

Universidade Federal de Santa Maria

e-mail: brunetto.gustavo@gmail.com

Dr. Jucinei José Comin

Universidade Federal de Santa Catarina

e-mail: j.comin@ufsc.br

Dr. Paulo Belli Filho

Universidade Federal de Santa Catarina

paulo.belli@ufsc.br

GREENHOUSE GAS AND AMMONIA EMISSIONS FROM BROILER BREEDING WITH MULTIPLE BED REUSE

Ingrid Kely da S. Santana[1]; Luciano B. Mendes[2]; José Fernando Machado Menten[3]; Brigitte Josefine Feigl[1]; Carlos Clemente Cerri[1]

1 University of São Paulo; Center for Nuclear Energy in Agriculture; **2** International Institute for Applied Systems Analysis; **3** Universidade de São Paulo, Departamento de Zootecnia.

The Brazilian industry of animal products, including poultry meat, is in search of sustainable forms of production, in order to meet the current consumer market demands. Considering that approximately 100% of the production of broiler chickens comes from settlements, GHG emissions from the management of animal waste play an important role. However, information on the impacts and mitigation potentials of these gases by handling confined broiler manure in Brazil is scarce, in addition to the lack of a standard method for direct measurements in Brazilian warehouses under tropical conditions. Given this complexity, this research project sought to apply techniques with lower interference, as well as to develop a sampling system to directly measure

N_2O, CH_4 e NH_3 emissions from broiler manure. To develop this method, the static chamber principal was used as a closed reference as well as gas chromatography (GC) analysis to estimate GHG emissions. In order to directly quantify NH_3 emissions, a static semi-open method was adapted, based on the capture, in acidic medium, of volatilized NH_3 from poultry manure. Additionally,

we sought to monitor the daily NH_3, CH_4 and N_2 emissions from chicken manure, considering the typical chicken litter reuse management. Empirical models were proposed to predict N_2O, CH_4 and NH_3 emissions in light of the number of litter reuses, the age of the birds and the physicochemical properties of the broiler litter.

Description of the greenhouse gas sampling system in poultry (SISAVE) for monitoring greenhouse gas flows

In order to facilitate bird management and improve control of the conditions for monitoring the flux of gaseous pollutants, a system was developed entitled: Greenhouse Gas Sampling System in Poultry (SISAVE). SISAVE follows the principle of 448L closed static chambers (HUTCHINSON; MOSIER, 1981; JACINTHE; DICK, 1997; SAGGAR *et al.*, 2004; JONES *et al.*, 2005).

The birds were kept inside a metabolic cage, measuring 0.70 m × 0.70 m × 0.50 m in height and made with a steel structure, with walls of wire mesh (25 mm openings).

To evaluate nitrogen losses in the form of ammonia (NH_3), the method developed by Araújo et al. (2009) and compared by Jantalia et al. (2012) was used. It is composed of a static free semi-open chamber (SALE), made from a transparent plastic bottle of polyethylene terephthalate (PET), with a capacity of 2 L and with an area of around 0.008m^2. The chambers followed the "closed static chambers" principle, widely used to measure gas flux in various agricultural sources, such as the soil, both in pasture grazing systems (SIQUEIRA NETO *et al.*, 2016) and in pastures (BARNEZE *et al.*, 2014; CARVALHO *et al.*, 2014; MAZZETTO *et al.*, 2015) livestock confinement (COSTA JUNIOR et al., 2015) and liquid surfaces such as sugarcane vinasse (OLIVEIRA *et al.*, 2015). CH_4 and N_2O concentrations were evaluated using the gas chromatography method, while NH_3 was assessed using the chemical analysis by flow injection (FIA) technique as described by Araújo *et al.*, 2009.

Calculation of emission factors

The regression models generated were used to determine the CH_4, N_2O and NH_3 emission factors. Emissions were calculated over an entire year, in each calculation the number of cycles of reuse was changed for the values of 1, 2, 3, 4, 5 and 6. In this study, we consider an emission factor of pollutants (EF) for broiler sheds as the total mass of the pollutant released by the useful area allocated to 1 bird, in the period of a 1 year cycle. Thus, the considered unit of an emission factor was g bird- housed^{-1} year^{-1}.

Nitrogen mass balance

The calculation of the N balance for each litter reuse cycle was performed in order to assess the accuracy and validate the NH_3 and N_2O emission factors determined experimentally. The mass balance was obtained by the inflows and outflows of N in the production of broilers during the four breeding cycles, with the reuse of the chicken litter.

The input of N-initial litter (g N bird^{-1}) was determined at the beginning and end of each cycle based on the total N content (gkg^{-1}) of the litter, as well as the amount of litter (kg bird^{-1}).

The N-feed (g N bird^{-1}) was determined according to the feed intake (g bird^{-1}) by the birds, as well as the crude protein content (CP,%) in the feed in the four stages of rearing 23,09; 21,28; 19,81; 18,60%, respectively, determined based on diet composition. Finally, we assume that the food protein contains 16% N.

The N-retained was estimated based on the metabolic assay performed by Vasconcellos et al. (2011), assuming that birds retain 65% of the N consumed and the remainder is excreted (35%). Losses of N in the form of gaseous emissions of $NH_3$and N_2O (g N Bird^{-1}) throughout a breeding cycle were those obtained empirically. Thus, the unaccounted N was determined by the difference between N input and output in the system.

Scenario assessment and future projections

The regression models obtained for CH_4, N_2O and NH_3 were used to estimate the annual emission factors in several alternative scenarios where the number or time of reuse varies between 1 and 6. In addition, the projections of CO_2eq emissions from Brazilian broilers were estimated until 2024 for each scenario (Figure1), based on the OECD-FAO (2015) production projections.

RESULTS

- The values of humidity of the chicken litter (%) and litter pH of the chickens raised in the metabolic cages were not significantly different from the litter values measured for chickens raised on a concrete floor, inside the same warehouse. The results suggest that the creation of broilers inside the metabolic cages, and not in the soil, did not negatively affect the physicochemical properties of the litter.

- The EF modeled for chicken manure during four breeding cycles corresponded to 0.14 g of N_2O, 0.35 g of $CH_4$and 72.0 g of N-NH_3bird-housed^{-1} yr^{-1}(Table 1). The age of the birds and the litter reuse were shown to be positively related to N_2O, CH_4 and NH^3 fluxes. Projections suggest that the intensification of reuse of poultry litter resulted in higher GHG and NH^3 emissions per bird produced.

- The percentage of GHG contribution to CO_2eq emissions was 3% (8.8 g CO_2eq poultry-housed-1year-1) for CH_4, 13% (41.7 g CO_2eq poultry-housed^{-1} year^{-1}) direct emissions of N_2O and 84% (276.5 kgCO_2eq bird-housed^{-1} yr^{-1}) indirect by the loss of volatized NH_3. This proportion confirms the significant participation of NH_3 in poultry farming as a gas that is harmful to the environment and the importance of considering it in GHG inventories, due to its high production in the poultry activity.

- The scenario of greater litter bed reuse (six cycles) simulated in this research estimated an emission of 0.5 kg CO_2eq bird-housed^{-1} year^{-1} corresponding to 0.08 kg CO_2eq bird^{-1} or 0.04 kg CO_2eq per kg of meat. Considering the flock of birds housed in 2015, Brazil issued about 545.1 Gg CO_2eq.

- The annual CO_2eq emission factors were combined with the OECD-FAO (2015) meat production projections for Brazil from the year 2000 to 2024 (Figure 1). The assumption made in this study of reuse of chicken litter in 6 breeding cycles is quite conservative, since in practice farmers even reuse the litter up to 10 or 12 times, depending on the season and availability of the litter.

- The N entry through the poultry litter increased considerably with each reuse cycle. After each breeding cycle, the total N retained in the carcass, the N accumulated in the litter and the N losses via gaseous emissions ranged from 45 to 65%, from 24 to 47% and from 4 to 6%, respectively. Losses due to NH_3 volatility were higher in the 4th cycle, with 14 g N bird^{-1}. The N not accounted for in the mass balance ranged between 5 and 10 g N bird^{-1} over the four reuse cycles, representing 2 to 5% of all N introduced in the system. This percentage of non-accountable N is considered insignificant when compared to other studies that deal with the mass balance of N for livestock systems involving gaseous emissions. The results of this mass balance are original and previously not available in the scientific literature on the poultry farming activity in Brazil.

CHALLENGES

This research covered the stage commonly called "inside the gate" of the broiler production chain, with data related to animals (day old chickens up to 42 d of age) and chicken litter. Greater emphasis was placed on the emission from manure and the reuse of chicken litter, as well as the determination of the first emission factor generated in Brazil for this important source of GHGs. Quantifying and directly monitoring gaseous emissions in poultry rearing systems has been a major challenge facing the scientific community. The main problem is the lack of methodological standardization. In addition, the information available in the literature on GHG and NH3 emissions in aviaries are variable and uncertain, due to the diversity and particular conditions of the facilities, the numerous differences in the breeding system and the complex interactions observed in animal waste. This challenge is even greater for Brazil due to its climatic conditions, territorial expansion, management and breeding of poultry - still prevalent in open facilities - and minimal environmental control.

In view of the complexity of measuring poultry GHG emissions, the biggest challenge the researchers faced was the development of necessary and adequate instrumentation to be able, from then on, to begin to acquire results of the GHG and NH3emissions from broiler manure. In practice, this step has become quite complex, requiring more time and dedication, than initially foreseen in the project. However, this research proposed a practical and innovative methodology, called SISAVE (GHG Sampling System in Poultry), to determine the GHG fluxes in aviaries, mainly those with natural ventilation.

SOLUTIONS

- CO_2eq emissions in typical Brazilian broiler houses were modeled based on empirical data;
- This study is the first to provide CO_2eq emission factors from broiler houses under typical management conditions in Brazil;
- Reducing chicken litter reuse from 6 to 1 cycle would reduce barn CO_2eq emissions by 72%;
- Avoiding the reuse of chicken litter in Brazil would prevent the release of 47 Mt of CO_2eq into the atmosphere in a decade;
- The scenarios of lesser bed reuse, simulated in the surveys, can be considered as GHG mitigation options in broiler aviaries in Brazil. Changing the chicken bed substrate instead of reusing it for six cycles would result in a reduction in emissions of 21% for N_2O, 40% for CH_4 and 78% for NH_3. This emission reduction expressed in CO2eq represents 72%. This information is very useful for planning practices that mitigate gas emissions in broiler production.

Table 1: Cumulative emissions of N-N_2O, C-CH_4 e N-NH_3 for different litter reuse scenarios for 6-reuses and reducing the (re)use of chicken litter starting 2015

Number of cycles	Period of (re) use			Annual basis			
	(mg bird-housed^{-1})			(mg bird-housed^{-1} year^{-1})			(kg bird-housed^{-1} year^{-1})
	N-N_2O	C-CH_4	N-NH_3	N-N_2O	C-CH_4	N-NH_3	CO_2eq
6	96.0	331.9	94781	99.6	341.6	95063	0.50
5	76.9	247.1	75729	92.7	291.3	80320	0.43
4	59.9	177.1	24431	88.8	263.2	59073	0.33
3	41.5	119.4	14533	86.1	248.5	57705	0.32
2	24.7	72.0	12328	82.0	225.0	37325	0.22
1	11.1	32.5	3488	78.3	204.4	21207	0.14

Source: Authors.

*Caption: * The number in parentheses on the same line represents the percentage contribution of the gaseous pollutant to the total CO_2eq.*

DATA PUBLISHED IN:

SANTANA, I. K. da S. Emissões de gases de efeito estufa e amônia oriundas da criação de frangos de corte em múltiplos reúsos da cama. 2016. Tese (Doutorado em Ciências) – Centro de Energia Nuclear na Agricultura, Universidade de São Paulo, Piracicaba, 2016. (Versão em artigo científico submetida para revista cientifica, em fase de revisão em 2019).

REFERENCES:

ARAÚJO, E. S.; MARSOLA, T.; MIYAZAWA, M.; BARROS, L. H.; BODDEY, R. M.; URQUIAGA, S.; ALVES, B. J. R. Calibração de câmara semiaberta estática para quantificação de amônia volatilizada do solo. Pesquisa Agropecuária Brasileira, Brasília, v. 44, p. 769-776, 2009.

BARNEZE, A. S.; MAZZETTO, A. M.; ZANI, C. F.; MISSELBROOK, T.; CERRI, C. C. Nitrous oxide emissions from soil due to urine deposition by grazing cattle in Brazil. Atmospheric Environment, Oxford, v. 92, p. 394-397, 2014.

CARVALHO, J. L. N.; RAUCCI, G. S.; FRAZÃO, L. A.; CERRI, C. E. P.; BERNOUX, M.; CERRI, C. C. Crop-pasture rotation: a strategy to reduce soil greenhouse gas emissions in the Brazilian Cerrado. Agriculture, Ecosystems & Environment, Amsterdam, v. 183, p. 167-175, 2014.

Continued in Annex

PROJECT COORDINATORS

In memoriam: Professor Dr. Carlos Clemente Cerri

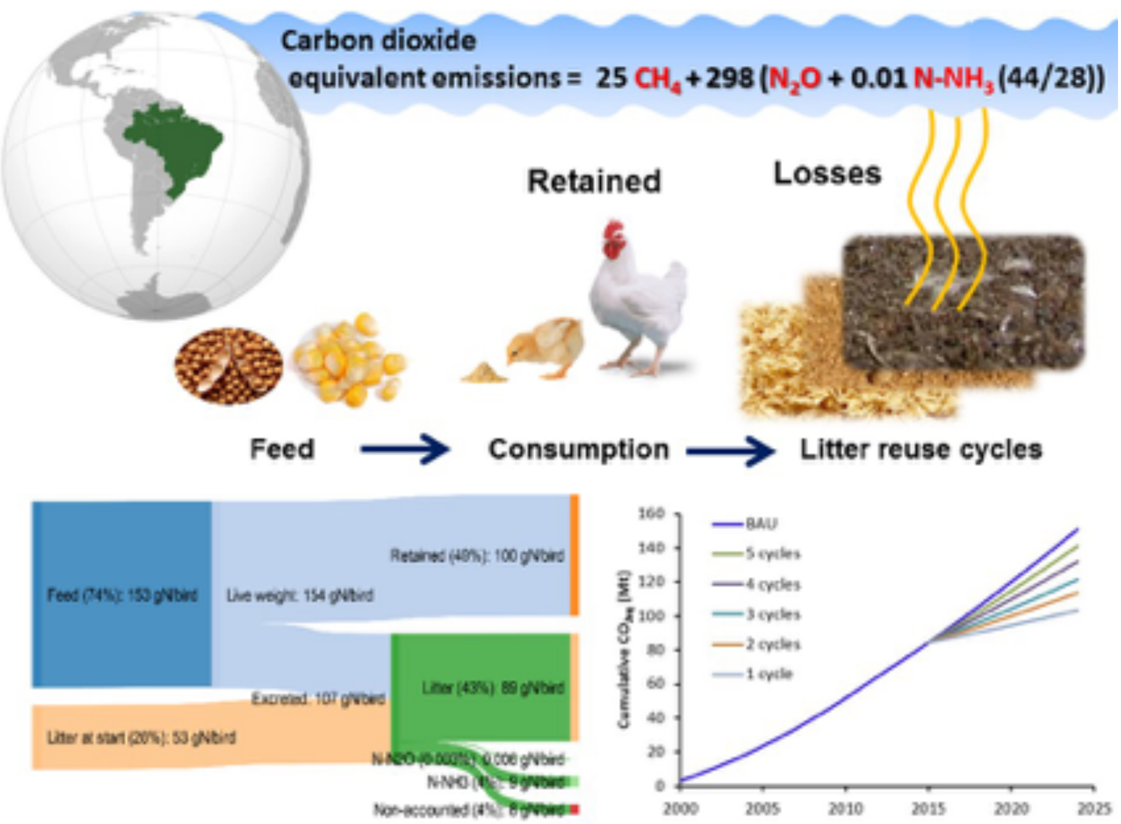
Centro de Energia Nuclear na Agricultura da Universidade de São Paulo (USP)

Dr. José Fernando Machado Menten

Universidade de São Paulo, Escola Superior de Agricultura Luiz de Queiroz

e-mail: jfmenten@usp.br

Table: Sankey diagrams for N fluxes (g bird^{-1}) for the broiler house used in this study in four different (re) use cycles of broiler litter. Projections of CO_2eq emissions from Brazilian poultry houses considering the "business as usual" (BAU) scenario of 6 reuses and reducing the (re)use of chicken litter only starting 2015



GREENHOUSE GAS EMISSIONS DURING BROILER HOUSING ON REUSED LITTER

Graciele Angnes[1]; Paulo Armando Victoria de Oliveira[2]; Thiago Liborio Romanelli[1]
1 Universidade de São Paulo; 2 Empresa Brasileira de Pesquisa Agropecuária - Embrapa Suínos e Aves.

Broiler production plays an important role in the emissions of certain air pollutants, whose impacts on the environment are a growing global concern. Therefore, the emissions that occur during the housing of the animals must be integrated into environmental concerns related to the production chain. This study aimed to apply a simplified method of quantifying gaseous emissions in the intensive production of broilers in dark house installations located in the southern region of Brazil. The purpose of this method was to acquire references for ammonia and greenhouse gas emissions(CH_4, N_2O and CO_2) for production conditions with poultry bed reuse during long periods.

This research was developed in partnership with Embrapa Suínos e Aves and was part of the PECUS Project effort. Thanks to the research that was developed it became possible to explore the simplified method using the concentration ratios and mass balance, where the food composition, and animal and effluent characteristics vary relatively little, allowing them to (HASSOUNA; EGLIN, 2015) be accurately observed. The method made it possible to obtain emission values during broiler housing in dark house installations with a negative pressure ventilation system and the reuse of the poultry litter for 10 to 14 flocks, covering production management in the south of the country.

The experiment was conducted at three commercial broiler farms located in Santa Catarina, Brazil, between October 2014 and May 2015. The birds used during the experiment were Cobb 500 males with an average growth period of 41 days.

The evaluated facilities were integrated into the same agribusiness, and the first batch analyzed was started on the same day to reduce the differences in slaughter age, body weight and feeding regime between the facilities. The dark houses were selected as close to each other as possible to ensure that the external climatic conditions were consistent. Climatic data for the studied region shows that the coldest and hottest months are July (average of 15 ° C) and January (average of 26.1 ° C), respectively. Precipitation is lowest during summer and highest during winter.

In all facilities, the chickens were raised on reused litter. Pine wood shavings were the original material. The poultry litter was reused for 10 batches before the research began. At the end of each production cycle, the top compacted bed litter layer was removed and calcium oxide (CaO) was applied between batches at all facilities. The regular interval between batches was 6 to 10 days. The day before the birds were housed, the brooder was prepared in the center of the facility with the addition of 2 cm of wood shavings. When the birds reached 14 days of age, the litter started to be stirred daily until the 30th day.

The NH_3, CO_2, CH_4 and N_2O gas concentrations (ppm) were measured weekly with using thermo neutral polymer bags - TEDLAR in the morning and afternoon inside and outside the facilities. Air sampling was performed with the aid of a device composed of an air filter, a pump, a Tedlar® bag and Teflon tube (4 mm in diameter), lasted for 30 minutes and was carried out throughout the extension of the entire installation following Hassouna & Eglin, (2015). The gas concentrations were determined using the photoacoustic gas analyzer (INNOVA 1412).

To validate the emission factors, the carbon, nitrogen and phosphorus mass balance was performed accounting for the weight of all inputs and outputs as accurately as possible. Difference between inputs and outputs were then assumed to be lost to the environment in the form of gases. For each element, total excretion was calculated from the difference between total intake and body deposition in slaughtered and dead birds. The body deposition for N, P and C was calculated considering the average body content given by Itavi (2013). The inputs and P concentration from the bed were used to calculate and verify the facility's mass balance, following Paillat *et al.* (2004).

Calculations are verified by estimating the C and N losses and verifying the balance of water losses. Emissions are calculated in quantities of $C\text{-}CO_2$, $C\text{-}CH_4$, $N\text{-}NH_3$ e $N\text{-}N_2O$ issued per unit of time. For example, the amount of carbon issued in the form of CO_2, or nitrogen in the form of NH_3 (ROBIN *et al.*, 2009).

PRELIMINARY RESULTS:

- The average emission rates obtained by the concentration ratio method were 0.63 ± 0.1; 100.2 ± 16; 0.23 ± 0.15 and 0.06 ± 0.02 g bird^{-1} d^{-1} for NH_3, CO_2, CH_4 e N_2O, respectively;

- Although Brazilian emission rates cannot be ideally comparable to emission rates observed in other countries due to different types of management, installations and climate, the results found in this study are similar to the values observed by Miles *et al.*, (2014) and Henn *et al.* (2015).

CHALLENGES

- The direct quantification and monitoring of gaseous emissions in poultry production systems has been a major challenge for the scientific community. The main problem is related to the lack of methodological standardization and the high cost of applying continuous methodologies;

- The biggest challenge of this research project was to develop a data collection protocol that would allow monitoring the largest possible number of poultry houses, the largest number of flocks in the given time, the interval between data collection and gas determination, in addition to the availability of budget and equipment.

SOLUTIONS

- It is important to develop and apply simplified methodologies that allow the quantification of emissions in a large number of production systems, the method used in this research has shown promising results. However, it is worth mentioning that the emission rates presented here refer only to the life cycle of the birds and our assessment did not include the stages of feed production, transport, heating/cooling of the facilities, industrialization, treatment of the poultry litter, maturation and application of the soil.

DATA PUBLISHED IN:

ANGNES, G. Gas concentrations and emissions and nutrient flow in broiler houses with litter reuse. 2017. Tese (Doutorado em Engenharia de Sistemas Agrícolas) – Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba, 2017.

ANGNES, G.; OLIVEIRA, P. A. V.; ROBIN, P.; HASSOUNA, M.; COLDEBELLA, A.; ROMANELLI, T. L. Ammonia emissions in commercial broiler dark house in south of Brazil. In: INTERNATIONAL SYMPOSIUM ON EMISSION OF GAS AND DUST FROM LIVESTOCK - EMILI 2017, 2017, Saint Malo.

ANGNES, G.; OLIVEIRA, P. A. V.; ROBIN, P.; HASSOUNA, M.; ROMANELLI, T. L. Emissão de amônia durante a produção de frangos de corte em aviário tipo dark house no sul do Brasil. In: FERREIRA, I. de F. *et al.* (org.) Ambiência e engenharia na produção animal sustentável: condições de climas quente e temperado. Viçosa: Suprema, 2016. p. 14-18.

ANGNES, G.; ROMANELLI, T. L.; TURMINA, L. P.; OLIVEIRA, P. A. V. Emissão de gases de efeito estufa e amônia durante a produção de frangos de corte em aviários tipo dark house. In: INTERNATIONAL SYMPOSIUM ON EMISSIONS OF GAS AND DUST FROM LIVESTOCK, 2015, Florianópolis. Concórdia: Embrapa Suínos e Aves, 2015. p. 1-5.

REFERENCES:

HASSOUNA, M.; EGLIN T. Mesurer les émissions gazeuses en élevage : gaz à effet de serre, ammoniac et oxydes d'azote. Paris: INRA-ADEME, 2015.
HENN, J. D.; BOCKOR, L.; BORILLE, R.; COLDEBELLA, A.; RIBEIRO, A. M. L.;

KESSLER, A. de M. Determination of the equation parameters of carbon flow curves and estimated carbon flow and CO2emissions from broiler production. Poultry Science, Oxford. v. 94, p. 2303-2312, 2015.

ITAVI. Estimation of rejects d'azote, phosphore, potassium, calcium, cuivre et zinc par les élevages avicoles: mise à jour des references corpen-voilailles from 2006. Paris: ITAVI, 2013.

Continued in Annex

Figure: Dark house broiler production system with negative pressure ventilation

Crédit: Paulo Armando Victoria de Oliveira.

COORDENADORES DO PROJETO

Dr. Paulo Armando Victoria de Oliveira

Embrapa Suínos e Aves

e-mail: paulo.armando@embrapa.br

Dr. Thiago Liborio Romanelli

Escola Superior de Agricultura Luiz de Queiroz – ESALQ/ USP

e-mail: romanelli@usp.br

MODELING CARBON DIOXIDE EMISSIONS IN BROILER PRODUCTION

João Dionísio Henn[1]; Alexandre de Mello Kessler[2]; Andréa Machado Leal Ribeiro[2]; Arlei Coldebella[1]; Luciane Bockor[2]; Rodrigo Borille[2]

1 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Suínos e Aves; 2 Universidade Federal do Rio Grande do Sul, Departamento de Zootecnia.

This work was carried out with the main objective of developing mathematical models capable of estimating the emission of carbon dioxide (CO_2) in the production of broilers, based on the carbon balance (C) in the broiler and litter, considering the growth and body composition, food intake and diet metabolization, excreta production and its carbon content and the consequent CO2emission from the animals' breathing and litter fermentation. The experimental steps involved experiments to evaluate food consumption, growth, deposition of body components (tissues) and their allometric growth in high (Cobb 500) and medium (C44) performance lines, males (M) and females (F), as well as evaluation of carbon balance in bed, as a subsidy for the estimates of CO_2 emitted by the litter, during the period of 1 to 49 days of the broiler flock. The results presented refer, therefore, to the chickens (emissions from breathing) and litter bed (emissions from litter). No data was obtained regarding the stages of production of grains and other inputs, transportation, heating and/or cooling of environments, industrialization and sale of products.

CO_2 production was highly correlated with growth rate, so much so that at 42 days of age, expired CO_2(g/bird) was 3384.4 in Cobb males; 2947.9 in Cobb females; 2512.5 in C44 males and 2185.1 in C44 females. The effect of age was also decisive in the production of CO_2, so that, to reach the same body weight of 2.0 kg, the expired CO_2 (g/bird) was 1794.3 in Cobb males; 2016.5 in Cobb females; 2617.7 in C44 males and 3092.3 in C44 females. A linear multiple regression was applied to all data, obtaining the equations: Expired CO_2 (g/bird) = -70.2845 + 20.3322 * Age (days) - 0.0382 * Live Weight (g) + 0.0215 * Age x Weight Alive (P <0.0001, R2 = 0.995). CO_2 litter emission (g/bird) = 1.8283 + 3.2714 * Age (days) - 0.0945 * Live Weight (g) + 0.00661 * Age x Live Weight (P <0.0001, R2 = 0.941). The sum of CO_2 issued by chicken and litter (g/bird) = -68.4562 + 23.6036 * Age (days) - 0.1327 * Live Weight (g) + 0.0281 * Age x Live Weight (P <0.0001, R2 = 0.994).

In general, an excellent fit was found in the nonlinear model used, with an R2> 0.99 for all responses.> These equations have high predictability for estimating individual CO_2 emissions, at any weight, age or strain, between 1 to 49 days of age.

RESULTS

- In our work, at 42 days of age, the total CO_2 emission was 4,093.3; 3,597.2; 3,054.6 and 2,606.5 g, for Cobb males, females, C-44 males and females, respectively. Per kg of live weight, 1,320; 1,378; 1,545 and 1,574 g of CO_2 were issued, respectively. The litter bed CO_2 emissions represented 17.32; 18.05; 17.74 and 16.17% of the total, respectively;
- The projected total CO_2 emission for 2 kg of live weight of chickens was 2,099; 2,374; 3.126 and 3652 g, for Cobb males, females, C-44 males and females, respectively. In this situation, CO_2 emissions from the bed represented 13.77; 14.23; 15.32 and 17.85% of the total issued, respectively;
- CO_2 emission is proportional to live weight, and its emission rate is proportional to weight gain, so fast-growing animals grow more, consume more food, and emit more CO_2 per unit of time. On the other hand, metabolism maintenance always results in CO_2 emission, without body C retention, so that slower growing animals have a higher proportion of C consumed for maintenance, as they need more time to reach a certain weight, causing them to issue more CO_2 per kg of live weight produced.

CHALLENGES

- In poultry farming, in particular, little data on greenhouse gas (GHG) emissions from poultry farming systems are available and uncertainties about the emission factors are high, which makes it difficult to define public policies and actions in the productive sector that will help achieve the assumed objective and make the activity more sustainable.

SOLUTIONS

The mathematical models obtained represent a practical contribution to the estimation of CO_2 emission by chickens, litter and total, according to different animal weights and ages. However, they still need to be validated in order to be applied to other strains and other environmental breeding conditions.

CO_2 emission from litter fermentation increases non-linearly with the age of the broilers, when new litter is used from the beginning of the flock. The magnitude and evolution of CO_2 emission by chicken litter needs further elucidation. The literature presents results that vary largely, resulting from the use of different methodologies, measurement errors and differences in production systems, uses of inputs and differences in animal performance.

The emission of CO_2 via expiration is strongly correlated with the age, weight, heat production and physical activity of the chicken, which is influenced by the light regimen and management practices, among other factors.

Society, governments and the scientific community agree that climate change is a reality and that the goals of reducing GHG emissions should increase significantly, in order to mitigate the problem. All technology that improves the efficiency of the production system proportionally reduces the emission of GHGs, especially in the nutritional and metabolic efficiency of the chickens.

This work can contribute to making decisions that result in more sustainable poultry farming, which has an organized production chain and demanding consumers, who in the near future may require additional information on the product label. It may contribute information and data to the poultry greenhouse gas emissions and removals inventories; for determining the carbon footprint of poultry products and for the evaluation of mitigation and/or adaptation strategies in the poultry production chain.

Current trends in the number of publications, the allocation of resources for research, governmental demand and the generation of an increasing volume of data on the flow of greenhouse gases, in national agriculture, lead us to believe that mathematical modeling for the quantification of the balance of greenhouse gases and support for public policies, will be an area in development in the near future.

In Brazil, there is a lack of consolidated work in the development of mathematical models of production processes and systems, to balance greenhouse gases. However, some research groups have advanced toward evaluating emission factors based on national data and assessing and re-parameterizing process models developed abroad, based on the local reality.

DATA PUBLISHED IN:

HENN, J. D. Modelagem da emissão de dióxido de carbono na produção de frangos de corte. 2013. Tese (Doutorado em Zootecnia) – Universidade Federal do Rio Grande do Sul, Porto Alegre, 2013. Disponível em: https://lume.ufrgs.br/handle/10183/76776.

HENN, J. D.; BOCKOR, L.; BORILLE, R.; COLDEBELLA, A.; RIBEIRO, A. M. L.; KESSLER, A. M. Determination of the equation parameters of carbon flow curves and estimated carbon flow and CO_2 emissions from broiler production. Poultry Science, v. 94, n. 9, p. 2303-2312, Sept. 2015. DOI: https://doi.org/10.3382/ps/pev178.

HENN, J. D. *et al.* Growth and deposition of body components of intermediate and high performance broilers. Rev. Bras. Cienc. Avic., [Online], v. 16, n. 3, p. 319-328, 2014.Disponível em: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-635X2014000300014&lng=en&nrm=iso. DOI: http://dx.doi.org/10.1590/1516-635x1603319-328.

PROJECT COORDINATORS:

Dr. Alexandre de Mello Kessler

Departamento de Zootecnia da Universidade Federal do Rio Grande do Sul

e-mail: akessler@ufrgs.br

Dr. João Dionísio Henn

Embrapa Suínos e Aves

e-mail: joao.henn@embrapa.br

EFFECTS OF THE INTENSITY AND PRODUCTION SCALE ON ENVIRONMENTAL IMPACTS ON THE POULTRY MEAT PRODUCTION CHAIN: LIFE CYCLE ASSESSMENT OF FRENCH AND BRAZILIAN SCENARIOS - OF BIRD PRODUCTION

Vamilson Prudêncio da Silva[1]; Hayo M. G. van der Werf[2]; Sebastião Roberto Soares[3]; Michael Scott Corson[2]

1 Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina; **2** Institut National de la Recherche Agronomique; **3** Universidade Federal de Santa Catarina.

The environmental impacts associated with poultry production raise a growing concern, which demands studies of these productive systems, employing appropriate methodologies. Life Cycle Assessment (LCA) is a method that presents a solid scientific basis for the quantification of the environmental impacts of livestock. The LCA approach uses a concept based on the computation of all inputs and outputs over the life cycle of a product, often revealing that creation in intensive systems optimizes the use of resources, generating less impact per kg of product than extensive systems. The objective of this work is to analyze the effects of the intensity and also of the production scale on the environmental impacts of chicken production chains, by comparing chains with contrasting characteristics. The intensity concerns the productive practices that aim to increase the outputs per animal or per unit of occupied area. Intensive systems use high levels of inputs (fertilizers, food, buildings) when compared to extensive systems. Intensive systems can have a high density (greater number of animals per m^2) than extensive systems. The production scale represents the size of the facilities and the number of animals raised on the same property. This LCA study applied to poultry production systems in Brazil and France, confirmed the trend of lower environmental impacts in intensive systems, but also showed that the transport distance (both from food to farms and from chickens to the consumer centers) have more influence on environmental impacts than the scale of production. From an environmental point of view, importing chickens from Brazil at the expense of chickens raised in France on soy raised and imported from Brazil, is more advantageous at least in relation to climate change and land occupation, which are both global impacts. Regarding acidification, terrestrial ecotoxicity and energy demand, chickens imported from Brazil have greater impacts than those produced in France. In all systems studied, it was clear that the feed production stage is the one that most contributes to the environmental impacts of chicken meat production. This study was carried out using a new approach to estimate the impacts of soy production in Brazil, considering an estimate of the deforested area (and its impacts on the environment). In addition, the study also showed that in LCA studies involving soy from Brazil, we must take into account its areas of origin, since soy produced in different regions has different levels of environmental impacts.

Actions for the definition of GHG emission coefficients: use the Life Cycle Assessment (LCA) approach given that the equivalent CO_2 (GHG) emission was one of the impact categories studied in this work - for consistency with the method adopted, the category is called "climate change", but the indicator is Kg of CO2equivalent. Four chicken production scenarios were defined, considering the entire production chain - from food production to delivery of the whole, packaged and frozen chicken at the slaughterhouse : extensive production in southwest France (LR - Label Rouge); intensive production, western France (ST - Standard); intensive production, small scale, southern Brazil (SO); intensive production, large scale, central-west Brazil (CW).

Evaluated parameters, frequency and instruments used: at each stage of the production chain, gas emissions that affect the greenhouse effect were estimated (with secondary data, therefore without direct measurement with instruments) and amounts were transformed into CO2equivalents. The estimate was made only once for each evaluated system, however, the quantities used in the physical flows (inputs and products) are consolidated averages of each production system. Following the LCA methodology, the method that determines the characterization factors was the CML 2001 (baseline), with modifications, as described in the methodology.

RESULTS

- Description of the systems studied:
    - » Extensive production in southwest France (LR – Label Rouge)
    - » Intensive production, western France (ST – Standard)
    - » Intensive, small-scale production, southern Brazil (SO)
    - » Intensive, large-scale production, central-west Brazil (CW)

- kg of CO_2 equivalent per ton of live chicken
  - LR = 2,700 Kg
  - ST = 2,220 kg
  - SO = 1,450 Kg
  - CW = 2,060 Kg

- Kg of CO_2 equivalent per ton of whole, chilled and packaged chicken, upon slaughterhouse exit:
  - LR = 4,016 kg
  - ST = 3,175 kg
  - SO = 1,948 Kg
  - CW = 2,750 Kg

CHALLENGES

- In terms of environmental impact, there is a general notion that intensive livestock systems have higher impacts than extensive ones. This is more consistent when the impact considered is local or regional, such as eutrophication, acidification or odors. The work showed, however, that if the impact considered has a global amplitude, such as GHG or energy demand, depending on the characteristics of the production chain, the effect can be the opposite, as for the case studied: intensive chicken production systems have lower impacts, per ton of product. The explanation lies in the fact that the type of food used in the systems is basically the same. One aspect that could be explored is which system of food production for animals would have lower impacts for extensive systems;

- Another aspect concerns the fact that, according to some studies, consumers in certain countries consider animal welfare to be important when purchasing meat for consumption. So much so that they are willing to pay more for the product, if they know that the animals lived in conditions of better welfare. However, this is not the case in all countries and is strongly related to the socioeconomic situation. In this study it was not possible to add an impact category related to animal welfare due to the great difficulty in determining characterization factors for the subject, which is highly debatable. But future studies could try to address this issue.

SOLUTIONS

- In 2011, the results of this work showed that about 1% of soy production comes from land previously occupied by forest, while about 3.4% comes from cerrado land. As these values are lower than previous studies, this shows a decrease in deforestation at the time of the study. Even so, it was clearly demonstrated that grain production has higher impacts when considering coupled deforestation, therefore, the incentive to deforestation must be a constant;

- Several soy transportation routes have also been studied. Those using river and rail transport clearly have lower impacts than those using road transport, establishing the need to prioritize the first two types of transport in order to reduce impacts;

- The study also showed that the optimization (rational use) of fertilizers and machinery in the corn and soybeans production phase can significantly reduce environmental impacts. In particular, the use of non-urea-based nitrogen fertilizer is recommended, due to the decrease in NH_3 emissions;

- In previous studies using the LCA approach to estimate the impact of animal feed production, exported to Europe, a single soybean production scenario was used for all of Brazil. This study clearly showed that the differences in the impact categories assessed (including GHGs) are very large among the different Brazilian soy production scenarios. Thus, it is at least recommended, to separate the soy produced in southern Brazil from that produced in the Midwest when considering feed from Brazil;

- In addition to the feed production phase, emissions per ton of chicken produced depend on feed conversion and carcass yield, which demonstrates that genetic improvement greatly influences the environmental impact.

DATA PUBLISHED IN:

PRUDÊNCIO DA SILVA, V. Effects of intensity and scale of production on environmental impacts of poultry meat production chains: life cycle assessment of french and brazilian poultry production scenarios. 2011. Tese (Doutorado em Engenharia Ambiental) – Programa de Pós-Graduação em Engenharia Ambiental, Universidade Federal de Santa Catarina, Florianópolis, 2011..

PRUDÊNCIO DA SILVA, V.; WERF, H. M. G. van der; SOARES, S. R.; CORSON, M. S. Environmental impacts of French and Brazilian broiler chicken production scenarios: an LCA approach. Journal of Environmental Management, v. 133, p. 222-231, 2014.

PRUDÊNCIO DA SILVA, V.; WERF, H. M. G. van der; SOARES, S. R.; SPIES, A. Variability in environmental impacts of Brazilian soybean according to crop production and transport scenarios. Journal of Environmental Management, v. 91, p. 1831-1839, 2010.

ENVIRONMENTAL IMPACTS FROM THE BROILER PRODUCTION PROCESS

Irenilza de Alencar Nääs[1]; Nilsa Duarte da Silva Lima[1]; Raquel Baracat Tosi Rodrigues da Silva[1]
1 Faculdade de Engenharia Agrícola, Universidade Estadual de Campinas (FEAGRI – UNICAMP)

The environmental management of the elements of the broiler production chain includes assessing the environmental impact in order to improve the performance of the processes related to the life cycle of the broiler production on the farm. The objective of the study was to evaluate the environmental impact of the broiler production process using the Life Cycle Assessment (LCA) approach. The production of six broiler farms was evaluated. The data covers the period of one year of broiler production, with a total of six cycles per year. The life cycle inventory included all incoming and outgoing fluxes from the subsystems: feed production and chicken rearing, in order to assess the environmental impact of the product from poultry housing to the gate of the poultry farm. The classification of the impact categories: global warming potential, depletion of abiotic resources (mineral resources), depletion of abiotic resources (fossil resources), depletion of the ozone layer, eutrophication, acidification, aquatic freshwater ecotoxicity, marine aquatic ecotoxicity, terrestrial ecotoxicity, human toxicity, photochemical oxidation and land use.

The results showed that the total emissions of greenhouse gases (GHG) from the management of waste in the broiler farms totaled 0.154 kg CO2-eq per kg of chicken produced. Direct NCH4and N2O and indirect N2O contributions to global warming potential were 18.9%, 19.3% and 61.8%, respectively. The main factors that contribute to the emission of CH4in the broiler production process are the amount of excreta produced per kg of live weight (0.176 kg of volatile solids), and the portion that decomposes anaerobically at the end of each production cycle when the bedding is treated for reuse. The result of the total global warming potential for the broiler production process (subsystem: feed production; subsystem: poultry breeding) was 2.70 kg of CO2eq per kg of live chicken produced at the farm gate. The bird production phase made a major contribution to global warming with 1.95 kg CO2-eq per kg of live chicken produced. The depletion of abiotic resources - mineral resources (5.1 E-8 kg ant.- eq) and the depletion of abiotic resources - fossil resources (1.43 E-01 MJ) presented higher values for the feed production phase, per kg of live chicken produced.

RESULTS

- The total global warming potential (GWP) for the process of broiler production was 2.70 kgCO_2-eq/kg live weight;
- The emission of N_2O from the residue is the main contributor to the PAG in the production of broilers;
- The broiler breeding process was the subsystem with the highest contribution to the potential of global warming with 1.95 kgCO_2-eq per kg of live chicken produced;
- The global warming potential for the feed production process was 0.75 kg of CO_2-eqper kg of live chicken produced.
- The project's future scientific and technological challenges will be to assess the chicken meat value chain with LCA and multi-impact assessment approaches (IPCC, 2006; ISO, 2006ab; IPCC, 2007; JÖNSSON, 2012; FAO, 2013b; GREWER et al., 2017);

CHALLENGES

- Future projects aim to contribute to technological and scientific advancement based on the multi-impact assessment of the chicken meat value chain with the Ex-Ante Carbon Balance tool (EX-ACT VC), which is considered an accounting system based on land, which estimates changes in carbon stocks (emissions or CO_2 sinks), as well as GHG emissions per unit of land, expressed in equivalent tons of CO_2 per hectare and year. Assessing the food value chain may identify strategic options to improve its resilience and, at the same time, generate co-benefits at all stages of the chain (BERNOUX et al., 2010; BOCKEL et al., 2012; COLOMB et al., 2013);
- The challenge of this evaluation will be to gather and build a database for each link in the broiler production chain from industry and producers (processing agroindustry, incentives, integrating companies, chicken producers, and transport companies) in a way that is representative for the calculations of the evaluations and construction of scenarios (baseline

and alternative), considering that it is structured and they are organized in vertical integration, with particularities and interrelating with regional, social and economic aspects.

SOLUTIONS

- Increasing urbanization, demographic pressures and climate change are transforming agricultural and food systems, ranging from production to food processing, and which must evolve to meet these pressures. In this context, adopting climate-friendly agricultural practices is one of the ways to reduce emissions and improve eco-efficiency to ensuring the balance between productivity and sustainability. In current scenarios, these practices include reducing the use of fossil energy; increasing the use of renewable energy; protecting the sustainable use of fresh water; sustainable soil management; waste management; ensuring animal welfare; supporting the well-being and a fair employment of people working in the fields and farming. Therefore, in order to study alternatives that mitigate the impacts caused by the production system, it is essential to evaluate the possible increase emissions of gases with a potential greenhouse effect.

DATA PUBLISHED IN:

LIMA, N. D. S.; NÄÄS, I. A.; GARCIA, R. G.; MOURA, D. J. de. Environmental impact of Brazilian broiler production process: evaluation using life cycle assessment. Journal of Cleaner Production, v. 237, 117752, 2019. DOI: https://doi.org/10.1016/j.jclepro.2019.117752

LIMA, N. D. S. Estimativa dos impactos ambientais no processo produtivo de frangos de corte: estimating the environmental impact of broiler production process. 2019. Tese (Doutorado em Engenharia Agrícola) – Faculdade de Engenharia Agrícola, Universidade Estadual de Campinas, Campinas, 2019.

REFERENCES:

BERNOUX, M .; BRANCA, G .; CARRO, A .; LIPPER, L .; SMITH, G .; BOCKEL, L. Ex-ante greenhouse gas balance of agriculture and forestry development programs. Scientia Agricola, Vol. 67, n. 1, p. 31-40, 2010. DOI: http://dx.doi. org/10.1590/S0103-90162010000100005.

BOCKEL, L .; JONSSON, M .; SUTTER, P .; TOUCHEMOULIN, O. Using marginal abatement cost curves to realize the economic appraisal of climate smart agriculture policy options. Rome, Italy: [S. n.], 2012.

COLOMB, V .; TOUCHEMOULIN, O .; BOCKEL, L .; CHOTTE, J.-L .; MARTIN, S.; TINLOT, M .; BERNOUX, M. Selection of appropriate calculators for landscape-scale greenhouse gas assessment for agriculture and forestry. Environ. Res. Lett., V. 8, 15029, 2013. DOI: 10.1088/1748-9326/8/1/015029.

Continued in Annex

Figure: Broiler chickens in the initial phase of production in the intensive system in Dark house aviaries

Crédit: Nilsa Lima

PROJECT COORDINATORS:

Dra. Irenilza de Alencar Nääs

Universidade Estadual de Campinas – FEAGRI/UNICAMP; Universidade Paulista – UNIP

e-mail: Irenilza.naas@docente.unip.br

Dra. Nilsa Duarte da Silva Lima

Universidade Estadual de Campinas – FEAGRI/UNICAMP

e-mail: nilsa.silva.lima@gmail.com

STRATEGIES TO MITIGATE NITROUS OXIDE EMISSIONS AFTER THE APPLICATION OF ANIMAL WASTE AND UREA IN NO-TILLAGE IN SOUTHERN BRAZIL

Celso Aita[1]; Sandro José Giacomini[1]; Stefen Barbosa Pujol[1]; Claudir José Basso[1]; Ezequiel Cesar Carvalho Miola[2]; Rodrigo da Silveira Nicoloso[3]; Rogério Gonzatto[4]; Martin Chantigny[5]; Philippe Rochette[5]

1 Universidade Federal de Santa Maria; **2** Universidade Federal do Rio Grande; **3** Empresa Brasileira de Pesquisa Agropecuária – Embrapa Suínos e Aves; **4** MOSAIC Fertilizantes; **5** Soils and Crops Research and Development Center, Agriculture and Agri-Food Canada.

The partial or total confinement of animals has been increased in several regions of Brazil, resulting in the accumulation of manure in the places close to the farms. Although the cycling of nutrients from manure in agriculture is a common practice, its impact on gaseous emissions of carbon (C) and nitrogen (N) is still poorly understood.

The general objective of the projects carried out by our research group in the south of Brazil, more specifically in the state of Rio Grande do Sul, was to quantify the gaseous emissions of N in the forms of ammonia(NH3) and nitrous oxide(N_2O) after the use of animal waste in a no-tillage system (SPD) and propose strategies to mitigate them. Due to the large volume produced and the way they are handled, studies prioritized the use of liquid waste generated in dairy cattle (DLB) and, mainly, in pig farming. In addition to the large volume of manure generated in pig farming, pig liquid manure (DLS) is characterized by having high levels of N in ammoniacal (NH_3 + NH_4+), form, which can reach up to 70% of total N content. Depending on its management and the environmental conditions, the application of this reactive N in the soil can have serious negative impacts on the environment, especially regarding the leaching of NO_3- and NH_3 and N_2O emissions to the atmosphere, the latter being one of the main greenhouse gases (GHG), in addition to be directly involved in the destruction of the ozone layer. To mitigate such emissions from crop fertilization with waste, our research projects, already completed and in those in progress, evaluate the efficiency of four main strategies.

Strategy 1. Mode of application of manure in the soil in SPD (subsurface injection x surface application). In most agricultural properties in the regions involved in dairy cattle and pig farming in the country, manure is applied to the soil surface on crop residues. In this condition, the ammoniacal N of the waste is exposed to the action of the sun and the wind, which implies significant losses of NH_3 by volatilization, and contributes to air pollution. One of the most efficient strategies to reduce NH_3 volatilization is the injection of waste into the soil. In a pioneering work by UFSM, conducted in the period from 2011 to 2013 in Argisols (10.3 to 19.2% clay), N losses due to NH_3 volatilization and N_2O gaseous emissions were compared considering surface application and subsurface injection of liquid swine waste into SPD (Aita *et al.*, 2014; Aita *et al.*, 2019). However, considering that Oxisols are prevalent in the regions dedicated to swine and dairy cattle in southern Brazil, the same treatments were evaluated in an Oxisol in the municipality of Frederico Westphalen/RS, with 69% clay and 3.8% of organic matter in the 0-10 cm layer.

Strategy 2. Addition of the dicyandiamide nitrification inhibitor (DCD) to the waste. The nitrification of ammoniacal N from animal waste is a process that occurs quickly in the soil. This causes N_2O production both through the action of nitrifying bacteria and through denitrification. For this reason, the use of products capable of temporarily inhibiting nitrification has been evaluated as a strategy to mitigate N_2O emission after adding animal waste to the soil.

Strategy 3. Waste splitting applications The application of nitrogen fertilizers alongside crops N demand should reduce the amount of NO_3-in the soil and, therefore, reduce the emission of N_2O during denitrification. This was the hypothesis tested in a study conducted in a UFSM Argisol, with the application of swine slurry in the wheat/corn succession. The application of manure in a single dose during crop sowing was compared with the split application of manure (50% of the recommended dose at sowing and 50% in coverage).

Strategy 4. Associated use of waste and urea. The strategy of associating manure with urea was evaluated during two years in an Argisol at UFSM, injecting 50% of the N dose with the manure during crop sowing and applying the other 50% with urea in coverage. This strategy was compared to the injection of 100% of N dose together with the waste during seeding.

Manure was always applied to grasses, in sequence of corn in the summer and oats or wheat in the winter. Assessment of N_2O emissions is conducted using static chambers, following the procedures described by Rochette & Bertrand (2008). The collection of gaseous samples inside the chambers was always carried out in the morning, between 9 and 11 am, and N2O concentrations in the samples was determined using gas chromatography (GC-2014, Greenhouse model, Shimadzu Corp.) equipped with a electron capture detector. In most of our studies, the loss of N by NH_3 volatilization was also evaluated, initially using Nômmik (1973) static chambers and later, the semi-open collectors proposed by Araújo et al. (2009). In all studies the NH_3 and N_2O emissions after the use of manure were compared to the traditional nitrogen fertilization of grasses, which consists in the application of N-urea.

RESULTS

Strategy 1– Effect of the application of manure on the soil

- The injection of manure into the soil reduced the loss of N by NH_3 volatilization by more than 90%, both in summer and winter (AITA et al., 2014, 2019; BAZZO, 2019). However, maintaining greater amounts of N in the soil by injection, the concentration of this nutrient inside the injection grooves, together with C and the liquid fraction of the manure, provided the necessary conditions for the production of N_2O, increasing the emission of this GHG, in relation to the superficial application of waste in Argisol;
- For the average of four manure applications carried out from 2011 to 2013, two in corn and two in winter crops (oats or wheat), the annual accumulated emission of N_2O increased from 4.73 kg N $ha^{-1}yr^{-1}$ with the application of manure on the soil surface to 9.90 kg Nha^{-1} y^{-1} with subsurface (7 to 11 cm) manure injection in the soil;
- The N_2O emission factor (calculated based on the proportion of total N applied annually with manure) corresponded to 1.23% for surface application and 2.69% for soil injection. Despite these average annual values, EFs ranged from 0.42 to 2.60% for surface application and from 1.90 to 4.67% for injection. This wide variation observed in the EF results from differences in the characteristics of the manure applied in each crop each year and, mainly, from the environmental conditions prevailing in the first weeks after the application of the manure;
- The average accumulated annual emission of N_2O with urea was 1.92 kg N ha^{-1}, ranging from 1.04 to 3.61 kg N $ha^{-1}yr^{-1}$.These amounts of N-N_2O issued correspond to an average proportion of 0.39% of the N applied in the form of urea, ranging from 0.22 to 0.67%. Therefore, the EF of N_2O obtained for the application of urea in Argisol is lower than the 1% value established by the IPCC (2006);
- The results obtained for Argisol suggest that, despite variables, the average values of N_2O EF obtained with the use of liquid swine manure in SPD are higher than the value established by the IPCC when the manure is applied to the soil surface (1.23 x 1.0%) and, mainly, when the manure is injected into the soil (2.96 x 1.0%) and, mainly, when the manure is injected into the soil (2, 08 x 1.0%);
- In the Oxisol in Frederico Westphalen, RS, N_2O emissions from the application of liquid swine manure were, on average, 73.9% lower than in the Argisols of Santa Maria. The mean values for the N_2O EF with the superficial manure application, which was 1.23% in the Argisols, decreased to only 0.46% in the Oxisol. As for the injection of waste, the EF decreased from 2.96% in the Argisols to 0.68% in the Oxisol;
- For the treatment with application of urea in the Oxisol, the N_2O EF following wheat/corn was, in an average of two years, only 0.10%, far below the value suggested by the IPCC;
- In assessing the effect of liquid waste produced by dairy cattle (DLB) on N_2O emissions in SPD, due to the low concentration of N in the waste, its use was associated with urea, applying the waste as basic fertilization, in the sowing of corn and wheat, and complementing the need for N of the cultures with the application of urea in cover. The annual emission of N_2O increased from 4.72 kg N ha^{-1} in the surface application of manure to 6.14 kg N ha^{-1} with its injection in the soil, corresponding to an EF of N-N_2O of 0.81 and 1.27%, respectively. N-N_2O EF in the Oxisol was only 0.17% when the DLB was applied on the surface and 0.35% when injected into the soil.

Strategy 2 - Effect of adding nitrification inhibitor to waste

- With the use of DCD, the average annual N_2O emission decreased from 4.73 kg N ha^{-1} to 3.57 kg N ha^{-1} when the manure was applied to the surface of Soil With the injection of waste into the soil, DCD was even more efficient, reducing the accumulated N_2O emission from 9.90 kg N ha^{-1} to 4.09 kg N ha^{-1}. This positive effect of DCD corresponded to an average reduction in N_2O EF from 1.11 to 0.75% with surface application and from 2.08 to 1.02% with the injection of manure into the soil;
- The lesser effect of DCD with the superficial application of manure than with its injection is mainly due to the N loss by NH_3 volatization which occurred when manure was applied to the soil surface, leaving less ammoniacal N to be nitrified in the soil. Therefore, the injection of swine liquid manure in the soil, in SPD, when associated with the use of the nitrification inhibitor DCD, significantly reduces the loss of N by NH_3 volatilization and results in EF values that are close to those observed with the traditional waste use in SPD, which consists of its application on crop residues.

Strategy 3– Effect of split manure use on crops

- The annual amount of N_2O issued in the treatment with the application of manure in a single dose was 21% higher than with the split application (7.77 kg N-N_2O ha-1x 6.43 kg N-N_2O ha^{-1}). In that same study, the split application of urea in corn and wheat resulted in an annual emission of 5.91 kg N-N_2O ha^{-1}, which represents an EF of 1.23%;

- These annual emissions with the application of DLS correspond to an N_2O EF of 1.60% for the application in a single dose and 1.07% for the application in installments. When the DCD nitrification inhibitor was added to the waste, the EF decreased to 0.65% in the single dose and 0.63% in the split application;

- These results, however, do not allow us to conclude that split application of swine liquid wastes "contributes significantly to reducing N_2O emissions. The environmental conditions on the first days after the application of the manure, mainly the occurrence of rains that increase the porous soil space occupied by water (EPSA) to values above 60% are more important to the production and emission of N_2O than the form of manure application in the soil, whether in a single dose or in installments.

Strategy 4 - Effect of the associated use of urea manure in crops

- During the two years evaluated by a specific study regarding this strategy, the emission factors (EF) of N_2O with all the N injected into the soil via manure ranged from 1.10 to 1.30%. When 50% of the N dose was injected with the waste during sowing and the remaining 50% were applied to cover, either with manure or urea, the EF values decreased to values ranging from 0.43 to 1.19%, showing the efficiency of this fertilization strategy in mitigating N_2O emissions in the wheat/corn succession in SPD. When the dose of 50% of the waste was injected into the soil together with the DCD inhibitor and with application of urea coverage the EF decreased to values that ranged from 0.26 to 0.47%, confirming the results of our previous studies, when the use of DCD has always reduced the EF. This occurs similarly with the association of DLS and urea, providing EF values lower than the IPCC value.

CHALLENGES

- Contrary to our expectations, the use of liquid swine manure in Oxisol resulted in significantly lower N_2O emissions than in Argisol and with relatively little difference between the mode of manure application (subsurface injection x surface application);

- The EF values in Oxisol were always below 0.68% and, therefore, below the value proposed by the IPCC (2006). With the use of the DCD inhibitor, the EF values went to less than 0.32%. However, it should be noted that these results refer to only one experimental area in Latosol. The challenge would be to expand the work to other Oxisols, including areas with different usage histories. If the results obtained are confirmed, the EF values for the application of pig slurry in Oxisols would be less than 1% and the subsurface injection of the slurry could be the recommended strategy without the need to use the nitrification inhibitor, which it is not yet sold in Brazil;

- Even though the use of the DCD nitrification inhibitor has been shown to be efficient in reducing emissions and, therefore, the N_2O EF with the application of manure, especially when injected into the soil, its use has not significantly increased the productivity of corn and wheat (Gonzatto *et al.*, 2017). For this reason, a line of research that is starting in our group consists of assessing the efficiency of DCD in mitigating N_2O emissions when the liquid swine manure is injected into the soil, in the dose of N recommended by the research and also in sub and super doses;

- Although few in number, our results with liquid cattle manure suggest that its impact on N_2O emissions is much smaller than the pig slurry and that the EF values are close to or lower than the 1% proposed IPCC value. However, it is necessary to expand our database with the waste generated by dairy cattle.

SOLUTIONS

- The results obtained so far, mainly in Argisols show that:

  » Despite the temporal variation, the mean N_2O EF values for the application of liquid swine manure on the soil surface in SPD are relatively close to the 1% EF value proposed by the IPCC (2006);

» Although the strategy of injecting liquid waste into the soil preserves a greater amount of mineral N, by significantly reducing NH_3 volatilization, this practice favors the production of N_2O, which results in EF values about twice the value proposed by IPCC;

» When the DCD nitrification inhibitor is injected into the soil together with the manure, the EF values approach the values observed for the superficial application of the manure without the inhibitor. Therefore, the injection of pig slurry in Argisols may be a recommended practice to preserve the N of the slurry in the soil and reduce the losses of C and nutrients from the slurry via runoff, provided it is associated with the use of the inhibitor to reduce injection-induced N_2O emissions;

- The set of information obtained in different soils and locations shows that the use of urea as a source of N in grasses, fractioning the dose and applying 1/3 of N in the sowing of crops and 2/3 in coverage, results in emission factors below the 1% proposed IPCC value.

DATA PUBLISHED IN

AITA, C.; CHANTIGNY, M. H.; GONZATTO, R.; MIOLA, E. C. C.; ROCHETTE, P.; PUJOL, S. B.; SANTOS, D. B.; GIACOMINI, D. A.; GIACOMINI, S. J. Winter-season gaseous nitrogen emissions in subtropical climate: impacts of pig slurry injection and nitrification inhibitor. J. Environ. Qual., [Published online], 2019. DOI: 10.2134 / jeq2018.04.0137.

AITA, C.; GONZATTO, R.; MIOLA, E. C. C.; SANTOS, D. B.; ROCHETTE, P.; ANGERS, D. A.; CHANTIGNY, M. H.; PUJOL, S. B.; GIACOMINI, D. THE.; GIACOMINI, SJ Injection of dicyandiamide-treated pig slurry reduced ammonia volatilization without enhancing soil nitrous oxide emissions from no-till corn in Southern Brazil. J. Environ. Qual., V. 43, p. 789-800, 2014. DOI: 10.2134 / jeq2013.07.0301.

AITA, C.; SCHIRMANN, J.; PUJOL, S. B.; GIACOMINI, S. J.; ROCHETTE, P.; ANGERS, D. A.; CHANTIGNY, M. H.; GONZATTO, R.; GIACOMINI, D. A.; DONEDA, A. Reducing nitrous oxide emissions from a maize-wheat sequence by decreasing soil nitrate concentration: effects of split application of pig slurry and dicyandiamide. Eur. J. Soil Sci., V. 66, p. 359-368, 2015. DOI: https://doi.org/10.1111/ejss.12181

GONZATTO, R.; AITA, C.; BÉLANGER, G.; CHANTIGNY, M. H.; MIOLA, E. C. C.; PUJOL, SB; DESSBESEL, A .; GIACOMINI, SJ Response of no-till grain crops to pig slurry application methods and a nitrification inhibitor. Agron. J., v.109 (4), p. 1687-1696, 2017. DOI: 10.2134 / agronj2016.09.0547

Continued in Annex

REFERENCES

ARAÚJO, E. S.; MARSOLA, T.; MYIAZAWA, M.; SOARES, L. H. B.; URQUIAGA, S.;M.; URQUIAGA, S.; ALVES, B. J. R. Calibração de câmara semiaberta estática para quantificação de amônia volatilizada do solo. Pesq. Agropec. Bras., N. 44, p. 769-776, 2009. DOI: 10.1590 / S0100-204X2009000700018.

CONAB – Companhia Nacional de Abastecimento. Acompanhamento da Safra Brasileira Grãos. 2014/15 harvest. v. 2, n. 5. Fifth Survey. Brasília: CONAB, Feb. 2015. p. 1-116. Available at: http: //www.conab. gov.br.

IPCC – Intergovernmental Panel on Climate Change. Guidelines for National Greenhouse Gas Inventories, prepared by the National Greenhouse Gas Inventories Program. Japan: IGES, 2006.

Continued in Annex

Figure: Equipment developed for the injection of liquid animal waste into the soil in no-till system

Crédit: the authors.

PROJECT COORDINATOR

Dr. Celso Aita

Universidade Federal de Santa Maria

e-mail: celsoaita@gmail.com

UNDERSTANDING GREENHOUSE GAS (GHG) EMISSIONS AND REMOVALS IN NET TANK FISH FARMING IN RESERVOIRS

Marcelo Gomes da Silva[1]; Ana Paula Packer[2]; Fernanda Garcia Sampaio[2]; Viviane Cristina Bettanin[2]; Danilo Trovo Garofalo[3]; Daniela Ferraz Bacconi Campeche[2]; Plínio Carlos Alvalá[4]; Consuelo Marques da Silva[1]; Juliana Lopes da Silva[5]; Nathan Oliveira Barros[6]

1 DTI-A Scholarship - CNPq; 2 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Meio Ambiente; 3 Consultor Especialista; 4 Instituto Nacional de Pesquisas Espaciais; 5 Secretaria de Aquicultura e Pesca; 6 Universidade Federal de Juiz de Fora.

The promotion of sustainable tropical aquaculture through the management of natural resources requires scientific foundation for decision making involving the causes and consequences of climate change. Most agricultural activities have been identified as being important sources of greenhouse gases (GHG), increasing climate liabilities and reflecting negatively on the sector's economy, mitigating this demands a greater understanding of the relationship between emission and removal in productive systems. In this context, in line with the objectives of sustainable development, understanding the dynamics of the fish farming environment in net tanks in ponds is extremely important for the implementation of public policies aimed at increasing efficiency in the use of resources and minimizing possible impacts.

The emission of GHG in ponds occurs due to physical-chemical processes resulting from the degradation of organic matter and oxidation of chemical compounds in the water column and sediment. However, little is known about the contribution of fish farming to GHG emission or removal processes in ponds. Besides the environmental issue, the increase in the concentration of GHG in water can be toxic to fish, resulting in animal mortality (Dias and Melo Júnior, 2017).

The main objective of the research is to determine the influence of fish farming in reservoirs through the quantification of the methane(CH4), carbon dioxide (CO2) and nitrous oxide (N2O) flows compared to areas upstream and downstream of the net tanks. In situ measurements were carried out in the Furnas (MG), Chavantes (SP/PR), Ilha Solteira (SP/MS), Sobradinho (BA), Mocotón/Itaparica (PE) and Padre Cicero "Castanho" (CE) reservoirs in areas with Nile Tilapia (Oreochromis niloticus) production in net tanks. Average productivity in the visited fish farms is around 500 tons/year in Furnas, 1,500 t/year in Chavantes and 1,600 t/year in Ilha Solteira. The Castanho reservoir faced severe drought, which resulted in the removal of several net tanks making it impossible to determine aquaculture production during the sampling period.

The diffusive GHG flows are collected with static diffusive chambers and boiling flows (bubbles released from the sediment) are collected with collecting funnels (SILVA et al., 2018). Positive flows are characterized as emission and negative flows represent the sequestration of GHG from the atmosphere. Biogeochemical parameters of water and sediment were measured to correlate with the variation of GHG flows in order to differentiate factors associated with fish farming in relation to natural factors inherent to the dynamics of the reservoirs.

RESULTS

Diffusive methane flows (CH_4)

- There is a wide variation in diffusive methane emission, both in the individual points as well as between the studied reservoirs, considering both areas with fish farming and controls, from values below the quantification limit of the method (<LQ) a 1.033,9 mg C-CH_4 m^{-2} d^{-1};
- The spatial variability of flows in reservoirs was not uniform. Diffusive CH_4 emissions in Furnas, Castanhão and Ilha Solteira were higher in the production areas when compared to the control areas. On the other hand, in Chavantes and Sobradinho the highest emissions occurred in the control areas when compared to the production areas;
- Factors such as the decrease in the useful volume in periods of drought, variation in water temperature and biogeochemical factors directly influenced CH_4 emissions.

Boiling methane (CH_4) flows

- A trend was found in all reservoirs with higher emission in all fish farming areas when compared to controls, with flows ranging from 9.5 to 6,628.4 mg C-CH_4 $m^{-2}d^{-1}$;
- Boiling flows are less constant than diffusive flows, occurring more markedly in cultivated areas. There were no boiling flows in the areas of fish farming and controls in the Sobradinho and Moxotó reservoirs.

Carbon dioxide (CO_2)

- Flows ranged from -960.7 to 2,371.1 mg C-CO_2 $m^{-2}d^{-1}$ in the control areas and -890.5 to 2,722.9 mg C-$CO_2$$m^{-2}d^{-1}$ in the production areas. Negative flow values suggest CO_2 sequestration from the atmosphere;
- The average CO_2 flows were higher in the production areas in Chavantes and Ilha Solteira, while in Sobradinho there were higher flows in the control areas. The CO_2 flow in Furnas was not measured ;
- Carbon sequestration occurred in all areas of Castanhão, with the greatest removal being recorded in the cultivation areas (-107.6 ± 428.3 mg C-CO_2 m^{-2} d^{-1}).

Fluxos de óxido nitroso (N_2O)

- N_2O fluws were not measured in the Furnas, Chavantes and Castanhão reservoirs, with low flows in Ilha Solteira and Sobradinho varying between <LQ and 0,453 mg N-$N_2O$$m^{-2}$ d^{-1}.

CHALLENGES

- Understand the dynamics of flows in environments such as reservoirs due to the susceptibility of the environment to changes in biogeochemical characteristics;
- Assess the influence of the reservoir surroundings and human activities that can result in changes in fish farming areas;
- Lack of defined methodology for studies in fish farming areas;
- Estimate the total area of net tanks in Brazil.

SOLUTIONS

- Elaboration of a consistent database with GHG flow information and biogeochemical parameters from fish farms in net tanks in reservoirs to improve the accuracy of the correlations between flows and parameters;
- Use of large-scale data assessment tools to study land use and human activities with potential influence on GHG flows in reservoirs;
- Standardization of the methodology for determining GHG emissions that allows the comparison of the results obtained.

PROJECT COORDINATORS

Dra. Ana Paula Packer

Embrapa Meio Ambiente

e-mail: paula.packer@embrapa.br

Dra. Fernanda Garcia Sampaio

Embrapa Meio Ambiente

e-mail: fernanda.sampaio@embrapa.br

DATA PUBLISHED IN:

PACKER, A. P. C.; SILVA, M. G.; SAMPAIO, F. G.; ALVALÁ, P. C.; SILVA, C. M.; SILVA, J. L. Mudanças climáticas e a piscicultura. In: SAMPAIO, F. G.; SILVA, C. M.; TORIGOI, R. H.; MIGNANI, L.; PACKER, A. C. P.; MANZATTO, CV; SILVA, JL (eds.). Estratégias de monitoramento ambiental da aquicultura: portfólio de resultados do monitoramento ambiental da aquicultura em águas da União. Brasília: [S. n.], 2018.

SILVA, M. G. Parametrização da emissão de metano na interface água-atmosfera em hidrelétricas. 2015. Tese (Doutorado em Geofísica Espacial/Ciências Atmosféricas) – Instituto Nacional de Pesquisas Espaciais, São José dos Campos, 2015.

SILVA, M. G.; PACKER, A. P. C.; ALVALÁ, P. C.; MARANI, L.; SAMPAIO, F. G. Modelo para amostragem e avaliação de Gases de Efeito Estufa (GEE) em reservatórios com produção aquícola. Jaguariúna: Embrapa Meio Ambiente [Environment]. (Documentos 116).

SILVA, M. G. da; PACKER, A. P.; SAMPAIO, F. G.; MARANI, L.; MARIANO, E. V. C.; PAZIANOTTO, R. A. A.; FERREIRA, W. J.; ALVALÁ, P. C. Impact of intensive fish farming on methane emission in a tropical hydropower reservoir. Climatic Change, Vol. 150, p. 195-210, 2018.

REFERENCES:

DIAS, MIB e MELO JÚNIOR, H do N Dinâmica do oxigênio dissolvido na coluna d'água de piscicultura em tanque-rede em açude do semiárido. In: III workshop

Internacional sobre Águas no semiárido Brasileiro. Campina Grande. 2017. Anais [...]. Campina Grande: UFCG. 2017.

SILVA, M. G.; PACKER, A. P. C.; ALVALÁ, P. C.; MARANI, L.; SAMPAIO, F. G. Modelo para amostragem e avaliação de Gases de Efeito Estufa (GEE) em reservatórios com produção aquícola. Jaguariúna: Embrapa Meio Ambiente, 2018. (Documentos 116).

SILVA, M. G. da; PACKER, A. P.; SAMPAIO, F. G.; MARANI, L.; MARIANO, E. V. C.; PAZIANOTTO, R. A. A.; FERREIRA, W. J.; ALVALÁ, P. C. Impact of intensive fish farming on methane emission in a tropical hydropower reservoir. Climatic Change, v. 150, p. 195-210, 2018.

Figure: Production of Nile tilapia (Oreochromis niloticus) in net tanks in the Ilha Solteira reservoir (SP/MS).

Crédit: Marcelo Gomes da Silva

EMISSION OR REMOVAL: THE ENIGMA OF MARICULTURE IN THE BLUE CARBON BALANCE

Marcelo Gomes da Silva[1]; Ana Paula Packer[2]; Fernanda Garcia Sampaio[2]; Viviane Cristina Bettanin[2]; Danilo Trovo Garofalo[3]; Gilberto Caetano Manzoni[4]; Katia Naomi Kuroshima[4]; José Gustavo Natorf de Abreu[4]; Ana Paula Stein Santos[4]; Maria Letícia Biavatti[4]; Fabrício Flores Nunes[5]

1 DTI-A Scholarship – CNPq; **2** Empresa Brasileira de Pesquisa Agropecuária – Meio Ambiente; **3** Specialist consultant; **4** Universidade do Vale do Itajaí; **5** Acquaculture expert.

Malacoculture, which includes the breeding oysters, mussels and scallops, is a productive activity that contributes greatly to food security and economic development, and can meet the growing demands for animal protein in sustainable production systems. The constant questions about the impacts of animal production systems on the balance of greenhouse gases (GHG) require greater knowledge about the dynamics of emissions and removals from different production chains. Malacoculture, however, is a poorly studied production chain in terms of its carbon footprint, with its GHG emissions being unknown worldwide, which makes it difficult to understand the balance and to compare it with other animal protein production chains.

The oceans represent the largest long-term carbon sink, with an estimated blue carbon sequestration rate in the order of 53 million tons annually (SIIKAMÄKI *et al.*, 2012). In this environment, malacoculture can be one of the factors responsible for the blue carbon sink.

Malacoculture can contribute in two ways, by consuming primary producers and by storing carbon in their shells. Some molluscs, including mussels and oysters, contribute environmentally due to the ability to consume particulate organic nutrients in addition to sequestering blue carbon, not only in the composition of their tissues, but mainly in the synthesis of their shells that remain in the form of carbonate, resisting bacterial decomposition.

It is estimated that the world production of molluscs was 17.1 million tons in 2016 (FAO, 2018), which corresponds to a sequestration of 0.97 to 1.93 million tons of blue carbon annually (SARF, 2012). A study by Ray *et.al* (2019), on a commercial oyster farm in the United States, showed that the cultivation of oysters did not contribute to the emission of methane (CH_4) and non-significant amounts of nitrous oxide (N_2O)and carbon dioxide (CO_2)were recorded.

In order to determine the GHG balance in malacoculture areas in southern Brazil (Figure), the research group has been dedicating itself to surveying information on Pacific oyster (*Crassostrea gigas*), mangrove oyster (Crassostreagasar), brown mussel (*Perna perna*) and scallop (*Nodipecten nodosus*) growing areas in the main production hubs. In addition to the GHG flows, biological, physical and chemical parameters of water and sediment are being collected. In situ measurements were carried out between 2018 and 2019 in the Armação do Itapocoroy bay (Penha), Ribeirão da Ilha (Florianópolis) and Praia de Fora (Palhoça), all in the state of Santa Catarina. In the last decade these 3 locations produced around 154 thousand tons of molluscs, with average productivity in 2018 being 599 tons in Penha, 2,943 tons in Florianópolis and 8,033 tons in Palhoça (CARVALHO FILHO, 2019).

The diffusive GHG flows are collected with static diffusive chambers coupled to floats and an internal volume of 1 liter. The GHG boiling flows, referring to the release of sediment bubbles, collected with collecting funnels. The GHG dissolved in water is obtained by the headspace technique, and the GHG concentration in all samples collected in the field is determined by gas chromatography (SILVA et al., 2018).

In addition to the GHG at each sampling point, parameters such as atmospheric pressure (portable barometer) and air temperature (portable thermometer) are measured. Parameters such as water temperature, pH, redox potential, electrical conductivity, turbidity, dissolved oxygen, total dissolved solids are measured with a multiparameter water analysis probe (Horiba U-53), in addition to depth (HondexPS- 7). Water samples are collected for laboratory determination of inorganic nutrients (NH_4+, NO-, NO_3-, P_3O_4-, S_4O_2-, SiO_4-), chlorophyll-a and total organic phosphorus by colorimetric methods, particulate matter in suspension by gravimetry and particulate organic carbon by titrometry. Sediment samples are collected with a dredger for granulometric and chemical analysis in the laboratory. The determination of organic carbon and carbon/nitrogen ratio (C: N) is done through an elemental analyzer and trace metals (Cd, Cu, Pb, Cr, Ni, Zn) by EAA (Atomic Absorption Spectrophotometry).

RESULTS

- The partial results show that the emission of carbon dioxide (CO_2) in malacoculture areas (15.8 ± 50.5 mg C-CO_2 m^{-2} d^{-1}) was similar to the control areas (17.5 ± 50, 8 mg C m^{-2} d^{-1}), and in several cases there was carbon sequestration into the atmosphere (Figure 2B);

- The methane (CH_4) emission was 0.3 ± 0.5 mg C-CH_4 m^{-2} d^{-1} in areas of malacoculture and 0.5 ± 1.1 mg C-CH_4 m^{-2} d^{-1} in controls;

- The nitrous oxide (N_2O) emission was 0.018 ± 0.020 mg N-N_2O m^{-2} d^{-1} in the culture and 0.018 ± 0.019 mg N-N_2O m^{-2} d^{-1} in the controls;

- There was no difference in the CO_2, CH_4 and N_2O flows measured in the production areas and in the control areas, which suggests that malacoculture does not impact the natural GHG balance.

- The carbon sink is associated with the environmental characteristics of marine environments since there was carbon sequestration at points of cultivation and in control areas;

- The release of bubbles was not registered in the sampled areas, which can be interpreted as a positive factor. Bubbles, mainly in bodies of freshwater, are responsible for expressive amounts of GHGs, mainly in the form of CH_4.

- All physical-chemical parameters analyzed are in accordance with the limits recommended by current legislation or close to values suggested in the literature. This shows that the water quality of these environments is not being influenced by the cultivation activities or even by the anthropic activities in the surroundings.

CHALLENGES

- Understanding the dynamics of flows in environments such as reservoirs due to the susceptibility of the environment to changes in biogeochemical characteristics;

- Lack of defined methodology for studies of GHG behavior in areas of malacoculture.

SOLUTIONS

- Development of a consistent database with GHG flow information and biogeochemical parameters in areas of malacoculture;

- Define processes for the circulation of the cultivation environments, allowing the assessment of the carbon balance and cycle, as well as the residence time of each environment;

- Standardization of the methodology for determining GHG emissions that allows comparing results obtained.

REFERENCES:

CARVALHO FILHO, J. Os números da aquicultura brasileira em 2018. Panorama da Aquicultura, V. 29, p. 58-63, 2019.

FAO – Food and Agriculture Organizataion of the Unites Nations. The state of world fisheries and aquaculture 2018: meeting the sustainable development goals. Rome: [S. n.], 2018.

RAY, N. E.; MAGUIRE, T. J.; AL-HAJ, A. N.; HENNING, M. C.; FULWEILER, R. W. Low greenhouse gas emissions from oyster aquaculture. Environmental Science & Technology, v. 53, p. 9118-9127, 2019.

SARF. Carbon footprint of scottish suspended mussels and intertidal oysters. Scotland: Scottish Aquaculture Research Forum, 2012.

SIIKAMÄKI, J.; SANCHIRICO, J. N.; JARDINE, S.; McLAUGHLIN, D.; MORRIS, D. F. Blue carbon: global options for reducing emissions from the degradation and development of coastal ecosystems. Washington, DC: Resources for the future, 2012.

Figure: Malacoculture area.

Crédit: Ana Paula Stein

PROJECT COORDINATORS

Dra. Ana Paula Packer

Embrapa Meio Ambiente

e-mail: paula.packer@embrapa.br

Dr. Gilberto Caetano Manzoni

Universidade do Vale do Itajaí

e-mail: manzoni@univali.br

Dra. Fernanda Garcia Sampaio

Embrapa Meio Ambiente

e-mail: fernanda.sampaio@embrapa.br

Annex - Bibliographic continuation

Potential for mitigating methane emissions and global warming in lamb meat production systems in southern Brazil

Data published at:

AFONSO, A. M. C. F. et al. Methane emission in two meat lambs production systems on pasture in subtropical climate. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 51., 2014, Barra dos Coqueiros. Anais [...]. Brasilia: SBZ, 2014.

BATISTA, R. Gases de efeito estufa do solo e dos dejetos e estoque de C e N em sistemas de produção de ovinos em pastagem. 2019. Thesis (Doctorate in Zootechnics) - Postgraduate Program in Zootechnics, Federal University of Paraná, 2019. (Thesis in preparation).

BATISTA, R. et al. Methane emission by lambs and ewes in different pasture production systems. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 54., 2017, Foz do Iguaçu. Anais [...]. Brasília: SBZ, 2017. p. 1122.

CHEK, VA et al. Emissão de metano em ovelhas lactantes e desmamadas criadas em pastagens. In: EVENTO DE INICIAÇÃO CIENTÍFICA. Curitiba, 26. 2018. Anais [...]. Curitiba: UFPR, 2018. n. 20183767.

FARO, A, M. C. F. A.; et al. Emissão de metano entérico em sistemas de terminação de cordeiros em pastagens do Sul do Brasil. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 52., 2015, Belo Horizonte. Anais [...]. Brasília: SBZ, 2015.

HENTZ, F. et al. Methane emission of lambs produced on pastures in Brazil. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 51., 2014, Barra dos Coqueiros. Anais [...]. Brasilia: SBZ, 2014.

MONTEIRO, A. L. G.; FARO, A. M. C. F.; PERES, M. T. P.; BATISTA, R.; POLI, C. H. E.; VILLALBA, J. J. The role of small ruminants on global climate change. Acta Sci., Anim. Sci., Maringá, v. 40, 2018. DOI: http://dx.doi.org/10.4025/actascianimsci.v40i1.43124.

MONTEIRO, A. L. G.; PERES, M. T. P.; FARO, A. M. C. F.; BATISTA, R.; DEISS, L.; RIBEIRO FILHO, H. M. N.; BERNDT, A.;

FAÍSCA, L. D. Sheep methane emissions in two feeding systems in summer and winter pastures in South of Brazil. Journal of Animal Science, Vol. 96, n. 3, p. 475, 2018. DOI: https://doi.org/10.1093/jas/sky404.1037.

THOMAZI, N .; et al. Quantify methane emissions from sheep on winter pasture. In: EVENTO DE INICIAÇÃO CIENTÍFICA, 25., 2017, Curitiba. Anais [...]. Curitiba: UFPR, 2017. n. 20171523.

WILCZEK FILHO, R .; et al. Emissão de metano de cordeiros em diferentes sistemas de terminação em pastagens. In: SCIENTIFIC INITIATION EVENT, 26., 2018, Curitiba. Anais [...].Curitiba: UFPR, 2018. n. 20183726.

Emission of enteric methane from Canchim, Angus and Charoles cross-bred cattle, finished in confinement feedlots

Data published in:

BERNDT, A.; SAKAMOTO, L. S.; FERRARI, F. B.; BORBA, H.; MENDES, E. D. M.; TULLIO, R. R. Enteric methane emissions from beef cattle of different genetic groups in confinement in Brazil. In: ANNUAL MEETING OF THE EUROPEAN FEDERATION OF ANIMAL SCIENCE, 66., 2015, Warsaw. Book of abstracts [...]. Warsaw: [S. n.], 2015. v. 66. p. 239.

BERNDT, A.; SAKAMOTO, L. S.; FERRARI, F. B.; BORBA, H.; MENDES, E. D. M.; TULLIO, R. R.; ALENCAR, M. M. Performance of crossbred cattle in confinement in Brazil. In: ANNUAL MEETING OF THE EUROPEAN FEDERATION OF ANIMAL SCIENCE, 66., 2015, Warsaw. Book of abstracts [...]. Warsaw: [S. n.], 2015. v. 66. p. 239.

SAKAMOTO, L. S.; GUILARDI, J. H.; VILAS BOAS, D. F.; MÉO FILHO, P.; MENDES, E. D. M.; ANDRADE, L. L.; TULLIO, R. R.; CECHINATTO, J. P.; LEME, P. R.; BERNDT, A. Enteric methane emissions from crossbred cattle from different breeds of bulls in confinement. In: SIMPÓSIO INTERNACIONAL SOBRE GASES DE EFEITO ESTUFA NA AGROPECUÁRIA, 2., 2016, Campo Grande-MS. Anais [...]. Campo Grande: [S. n.], 2016. v. 2. p. 429-430.

ZIMMERMAN, S.; BERNDT, A.; SAKAMOTO, L. S.; FERRARI, F. B.; MÉO FILHO, P.; VILAS BOAS, D. F.; TULLIO, R. R. Methane and carbon dioxide emissions variability and repeatability from cross breed cattle fed maize silage diets in Brazil. In: GREENHOUSE GAS AND ANIMAL AGRICULTURE CONFERENCE, 6., 2016, Melbourne, Australia. Book of abstracts [...]. Melbourne: [S. n.], 2016. p. 52.

Rotational grazing with elephant grass for dairy cows: grazing strategies, animal productivity and emissions of enteric methane and nitrous oxide

References

BEUKES, P. C.; SCARSBROOK, M. R.; GREGORINI, P.; ROMERA, A. J.; CLARK, D. A.; CATTO, W. The relationship between milk production and farm-gate nitrogen surplus for the Waikato region, New Zealand. J. Environ. Manag., v. 93, p. 44-51, 2012. DOI: https://doi.org/10.1016/j.jenvman.2011.08.013.

BRAZ, S. P.; URQUIAGA, S.; ALVES, B. J. R.; JANTALIA, C. P.; GUIMARÃES, A. P.; SANTOS, C. A. dos; SANTOS, S. C. dos, PINHEIRO, E. F. M., BODDEY, R. M. Soil carbon stocks under productive and degraded brachiaria pastures in the Brazilian Cerrado. Soil Sci. Soc. Am., v. 77, p. 914-928, 2013. DOI: https://doi.org/10.2136/sssaj2012.0269.

CHAPMAN, D. Using ecophysiology to improve farm efficiency: application in temperate dairy grazing systems. Agriculture, n. 6, p. 1-19, 2016. DOI: https://doi.org/10.3390/agriculture6020017.

CUNHA, C. S.; LOPES, N. L.; VELOSO, C. M.; JACOVINE, L. A. G.; TOMICH, T. R.; PEREIRA, L. G. R.; MARCONDES, M. I. Greenhouse gases inventory and carbon balance of two dairy systems obtained two methane-estimation methods. Sci. Total Environ., v. 571, p. 744-754, 2016. DOI: http://dx.doi.org/10.1016/j.scitotenv.2016.07.046.

FOLEY, J. J. A.; RAMANKUTTY, N.; BRAUMAN, K. A.; CASSIDY, E. S.; GERBER, J. S.; JOHNSTON, M.;MUELLER, N. D.; O'CONNELL, C.; RAY, D. K.;WEST, P. C.; BALZER, C.; BENNETT, E. M.; CARPENTER, S. R.; HILL, J.; MONFREDA, C.; POLASKY, S.; ROCKSTRÖM, J.; SHEEHAN, J.; SIEBERT, S.; TILMAN, D.; ZAKS, D. P. M. Solutions for a cultivated planet. Nature, v. 478, p. 337-342, 2011. DOI: https://doi.org/10.1038/nature10452.

FOOTE, K. J.; JOY, M. K.; DEATH, R. G. New Zealand dairy farming: milking our environment for all its worth. Environ. Manag., n. 56, p. 709-720, 2015. DOI: https://doi.org/10.1007/s00267-015-0517-x.

GARNETT, T.; GODFRAY, H. C. J. Sustainable intensification in agriculture: navigating a course through competing food system priorities. Food Climate Research Network and the Oxford Martin Programme on the Future of Food. Oxford: University of Oxford, 2012. Disponível em: https://www.fcrn.org.uk/sites/default/files/SI_report_final.pdf.

GODFRAY, H.; BEDDINGTON, J. R.; CRUTE, I. R.; HADDAD, L.; LAWRENCE, D.; MUIR, J. F.; PRETTY, J.; ROBINSON, S.; THOMAS, S. M.; TOULMIN, C. Food security: the challenge of feeding 9 billion people. Science, v. 327, p. 812-818, 2010. DOI: https://doi.org/10.1126/science.1185383.

GREGORINI, P.; VILLALBA, J. J.; CHILIBROSTE, P.; PROVENZA, F. D. Grazing management: setting the table, designing the menu and influencing the diner. Anim. Prod. Sci., v. 57, n. 7, p. 1248-1268, 2017. DOI: http://dx.doi.org/10.1071/AN16637.

JANSSEN, P. H. Influence of hydrogen on rumen methane formation and fermentation balances through microbial growth kinetics and fermentation thermodynamics. Anim. Feed Sci. Technol., v. 160, p. 1-22, 2010.DOI: https://doi.org/10.1016/j.anifeedsci.2010.07.002.

JOHNSON, K. A.; JOHNSON, D. E. Methane emissions from cattle. J. Anim. Sci., v. 73, p. 2483-2492, 1995. DOI: https://doi.org/10.2527/1995.7382483x.

KLEIN, C. A. M. de; HARVEY, M. Nitrous Oxide Chamber Methodology Guidelines. New Zealand: [S. n.], 2015. p. 146. Disponível em: https://globalresearchalliance.org/wp-content/uploads/2015/11/Chamber_Methodology_Guidelines_Final-V1.1-2015.pdf.

LESSA, A. C. R.; MADARI, B. E.; PAREDES, D. S.; BODDEY, R. M.; URQUIAGA, S.; JANTALIA, C. P.; ALVES, B. J. Bovine urine and dung deposited on Brazilian savannah pastures contribute differently to direct and indirect soil nitrous oxide emissions. Agric. Ecosyst. Environ., v. 190, p. 104-111, 2014. DOI: https://doi.org/10.1016/j.agee.2014.01.010.

LUO, J.; BALVERT, S. F.; WISE, B.; WELTEN, B.; LEDGARD, S. F.; KLEIN, C. A. M. de; LINDSEY, S.; JUDGE, A. Using alternative forage species to reduce emissions of the greenhouse gas nitrous oxide from cattle urine deposited onto soil. Sci. Total Environ., v. 610-611, p. 1271-1280, 2018. DOI: https://doi.org/10.1016/j.scitotenv.2017.08.186.

MACDONALD, K. A.; PENNO, J. W.; LANCASTER, J. A. S.; BRYANT, A. M.; KIDD, J. M.; ROCHE, J. R. Production and economic responses to intensification of pasture-based dairy production systems. J. Dairy Sci., v. 100, p. 6602-6619, 2017. DOI: https://doi.org/10.3168/jds.2016-12497.

MUÑOZ, C.; LETELIER, P. A.; UNGERFELD, E. M.; MORALES, J. M.; HUBE, S.; PÉREZ-PRIETO, L. A. Effects of pre grazing herbage mass in late spring on enteric methane emissions, dry matter intake, and milk production of dairy cows. J. Dairy Sci., v. 99, p. 7945-7955, 2016. DOI: https://doi.org/10.3168/jds.2016-10919.

NASCIMENTO, C. F. M.; BERNDT, A.; ROMERO SOLORZANO, L. A.; MEYER, P. M.; FRIGHETTO, R. T. S.; DEMARCHI, J. J. A. A.; RODRIGUES, P. H. M. Methane emission of cattle fed Urochloa brizantha hay harvested at different stages. J. Agric. Sci., v. 8, p. 163-174, 2016. DOI: http://dx.doi.org/10.5539/jas.v8n1p163.

PONTES, L. S.; BARRO, R. S.; SAVIAN, J. V.; BERNDT, A.; MOLETTA, J. L.; PORFÍRIO-DA-SILVA, V.; BAYER, C.; CARVALHO, P. C. F. Performance and methane emissions by beef heifer grazing in temperate pastures and in integrated crop-livestock systems: The effect of shade and nitrogen fertilization. Agric. Ecosyst. Environ., v. 253, p. 90-97, 2018. DOI: https://doi.org/10.1016/j.agee.2017.11.009.

ROYAL SOCIETY. Reaping the benefits: science and the sustainable intensification of global agriculture. London: The Royal Society, 2009. Disponível em: https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2009/4294967719.pdf.

SAGGAR, S.; JHA, N.; DESLIPPE, J.; BOLAN, N. S.; LUO, J.; GILTRAP, D. L.; KIM, D. G.; ZAMAN, M.; TILLMAN, R. W. Denitrification and N2O:N2 production in temperate grasslands: process, measurements, modelling and mitigating negative impacts. Sci. Total Environ., v. 465, p. 173-195, 2013. https://doi.org/10.1016/j.scitotenv.2012.11.050.

SANTOS, F. A. P.; DOREA, J. R. R.; SOUZA, J. de; BATISTEL, F.; COSTA, D. F. A. Forage management and methods to improve nutrient intake in grazing cattle. In: ANNUAL FLORIDA RUMINANT NUTRITION SYMPOSIUM, 25., Gainesville. Proceedings [...]. Gaomesville, USA: University of Florida, 2014. p. 144-164. Disponível em: http://dairy.ifas.ufl.edu/rns/2014/santos.pdf.

VOGELER, I.; BEUKES, P. C.; BURGRAFF, V. T. Evaluation of mitigation strategies for nitrate leaching on pasture-based dairy systems. Agric. Syst., v. 115, p. 21-28, 2013. DOI: https://doi.org/10.1016/j.agsy.2012.09.012.

WRAGE, N.; VELTHOF, G. L.; BEUSICHEM, M. L. van; OENEMA, O. Role of nitrifier denitrification in the production of nitrous oxide. Soil Biol. Biochem., v. 33, p. 1723-1732, 2001. DOI: https://doi.org/10.1016/S0038-0717(01)00096-7.

Enteric methane emissions in búfalas in eastern Amazonia: Tier2 methodology and sulfur hexafluoride (SF_6)

Data published in:

CASTRO, V. C. G.; FERNANDES, P. C. C.; LOURENCO JUNIOR, J. B.; ARAUJO, G. S. Avaliação da estratificação do conteúdo ruminal de bubalinos suplementados com farelo de amêndoa de dendê. In: SEMINÁRIO DE INICIAÇÃO CIENTÍFICA, 18.; SEMINÁRIO DE PÓS-GRADUAÇÃO DA EMBRAPA AMAZÔNIA ORIENTAL, 2., 2014, Belém. Anais [...]. Belém: [S. n.], 2014.

SANTOS, G. R.; CASTRO, V. C. G.; FERNANDES, P. C. C.; MARTORANO, L. G. Estimativas de presença de gases e conteúdo ruminal em bubalinos suplementados com farelo dendê e óleo de palmiste. In: SEMINÁRIO DE INICIAÇÃO CIENTIFICA, 19.; SEMINÁRIO DE PÓS-GRADUAÇÃO DA EMBRAPA AMAZÔNIA ORIENTAL, 3., 2015, Belém. Anais [...]. Belém: [S. n.], 2015.

Emission of enteric methane in buffalos supplemented with palm kernel cake in the Amazon biome

References

IPCC – Intergovernmental Panel on Climate Change. Guidelines for National Greenhouse Gas Inventories. Agriculture, forestry and other land use. Japan: IGES, 2006. v. 4, p. 10.1-10.84.

JOHNSON, K.; HUYLER, M.; WESTBERG, H.; LAMB, B.; ZIMMERMAN, P. Measurement of methane emissions from ruminant livestock using a SF6 tracer technique. Environ. Sci. Technol., v. 28, p. 359-362, 1994.

MARTORANO, L. G.; VITORINO, M. I., SILVA, B. P. P. C.; MORAES, J. R. S. C.; LISBOA, L. S.; DOFF, S. E.; REICHARDT, K. Climate conditions in the eastern amazon: rainfall variability in Belem and indicative of soil water deficit. African Journal of Agricultural Research, n. 21, p. 1801-1810, 2017. DOI: https://doi.org/10.5897/AJAR2016.11801.

Nitrous oxide emission in tropical pastures of beef cattle production systems

References

SNYDER, C. S.; BRULSEMA, T. W.; JENSEN, T. L. Melhores práticas de manejo para minimizar emissões de gases de efeito estufa associadas ao uso de fertilizantes. Informações Agronômicas, Piracicaba, n. 121, p. 13-14, mar. 2008.

ZANATTA, J. A.; ALVES, B. J. R.; BAYER, C.; TOMAZI, M.; FERNANDES, A. H. B. M.; COSTA, F. de S.; CARVALHO, A. M. de. Protocolo para medição de fluxos de gases de efeito estufa do solo. Colombo: Embrapa Florestas, 2014. 53 p. (Embrapa Florestas. Documentos, 265).

Modeling of nitrous oxide emissions from pure grass pastures and grass-to-legume intercropped system in western Brazilian Amazon

References

MELILLO, J. M. Nitrous oxide emissions from forests and pastures of various ages in the Brazilian Amazon. Journal of Geophysical Research, n. 106, p. 34179-34188, 2001.

MEURER, K. H. E. et al. Direct nitrous oxide (N2O) fluxes from soils under different land use in Brazil—a critical review. Environ. Res. Lett., v. 11, 023001, 2016. Disponível em: http://iopscience.iop.org/article/10.1088/1748-9326/11/2/023001/pdf.

NEILL, C. et al. Nitrogen dynamics in soils of forests and active pastures in the western Brazilian Amazon Basin. Soil Biol. Biochem., v. 27, p. 1167-1175, 1995.

VERCHOT, L. V. et al. Land use change and biogeochemical controls of nitrogen oxide emissions from soils in eastern Amazonia. Global Biogeochem. Cycles, v. 13, p. 31-46, 1999.

Greenhouse gas dynamics and the interface with efficiency, food quality and sustainability in agricultural production systems of the Atlantic Forest biome

Data published at:

BERNDT, A.; LEMES, A. P.; VILAS BOAS, D. F.; SAKAMOTO, L. S.; MÉO FILHO, P. Mensuração de metano entérico em ruminantes sob pastejo. In: PEREIRA, O. G. et al. (org.). VIII SIMFOR: Simpósio sobre Manejo Estratégico de Pastagens. Viçosa: Suprema, 2016. v. 8, p. 117-138.

BERNDT, A.; SAKAMOTO, L. S.; LEMES, A. P.; PEDROSO, A. F.; PEZZOPANE, J. R. M.; ALVES, T. C.; VILAS BOAS, D. F.; CORTE, R. R.; OLIVEIRA, P. P. A. Enteric methane emissions of Nellore steers in different grazing production systems in Brazil. In: GREENHOUSE GAS AND ANIMAL AGRICULTURE CONFERENCE, 6., 2016, Melbourne, Australia. Book of abstracts [...]. Melbourne: [S. n.], 2016. p. 22.

BERNDT, A.; SAKAMOTO, L. S.; LEMES, A. P.; PEDROSO, A. F.; PEZZOPANE, J. R. M.; ALVES, T. C.; VILAS BOAS, D. F.; CORTE, R. R.; OLIVEIRA, P. P. A. Intensive grazing systems can enhance carcass production with the same methane emissions. In: ADSA-ASAS JOINT ANNUAL MEETING, 93., 2015, Orlando. Proceedings [...]. Orlando: Journal of Animal Science, 2015.

CORTE, R. R.; SILVA, S. L.; PEDROSO, A. F.; NASSU, R. T.; TULLIO, R. R.; BERNDT, A.; SAKAMOTO, L. S.; RODRIGUES, P. H. M.; OLIVEIRA, P. P. A. Beef cattle productivity in grazing systems with different levels of intensification. In: SIMPÓSIO INTERNACIONAL SOBRE GASES DE EFEITO ESTUFA NA AGROPECUÁRIA, 2., 2016, Campo Grande-MS. Anais [...]. Campo Grande: [S. n.], 2016. v. 2, p. 286-289.

CORTE, R. R.; SILVA, S. L.; PEDROSO, A. F.; NASSU, R. T.; TULLIO, R. R.; BERNDT, A.; SAKAMOTO, L. S.; RODRIGUES, P. H. M.; OLIVEIRA, P. P. A. Carcass traits of Nellore steers in different Brazil grazing systems. In: ANNUAL MEETING OF THE EUROPEAN FEDERATION OF ANIMAL SCIENCE, 67., 2016, Belfast. Proceedings [...] Belfast: [S. n.], 2016. v. 3, p. 622.

CORTE, R. R.; SILVA, S. L.; PEDROSO, A. F.; NASSU, R. T.; TULLIO, R. R.; BERNDT, A.; SAKAMOTO, L. S.; RODRIGUES, P. H. M.; OLIVEIRA, P. P. A. Effects of intensification of grazing systems on meat quality of Nellore steers in Brazil. In: ANNUAL MEETING OF THE EUROPEAN FEDERATION OF ANIMAL SCIENCE, 67., 2016, Belfast. Proceedings [...] Belfast: [S. n.], 2016. v. 2, p. 392.

SAKAMOTO, L. S.; BERNDT, A.; MAHLMEISTER, K.; LEMES, A. P.; PEDROSO, A. F.; ALVES, T. C.; OLIVEIRA, P. P. A. Enteric methane emissions by Nellore steers grazing different pastures. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 52., 2015, Belo Horizonte-MG. Anais [...]. Belo Horizonte: [S. n.], 2015.

SILVA, E. M.; BERNDT, A.; PEDROSO, A. F.; SAKAMOTO, L. S.; OLIVEIRA, P. P. A.; NASSU, R. T. Qualidade da carcaça de bovinos criados em diferentes sistemas de produção, almejando a sustentabilidade na produção pecuária. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA PARA O PROGRESSO DA CIÊNCIA, 67., 2015, São Carlos-SP. Anais [...]. São Carlos: [S. n.], 2015. v. 1. p. 1.

Soil carbon stocks in pastoral systems for dairy production

References

NATIONAL RESEARCH COUNCIL. Nutrient requirements of dairy cattle. Washington, DC, USA: National Academy Press, 2001.

STAHL, C.; FREYCON, V.; FONTAINE, S.; DEZÉCACHE, C.; PONCHANT, L.; PICON-COCHARD, C.; KLUMPP, C.; SOUSSANA, J. F.; BLANFOR, V. Soil carbon stocks after conversion of Amazonian tropical forest to grazed pasture: importance of deep soil layers. Reg. Environ. Change, v. 16, p. 2059-2069, 2016. DOI: 10.1007/s10113-016-0936-0.

STATISTICAL ANALYSES SYSTEM INSTITUTE. Guide of personal computers. Version 9.2 Inc.. Cary, NC: [S. n.], 2002.

Soil carbon stocks in integrated systems in the Atlantic Forest biome

References

CORDEIRO, L. A. M.; VILELA, L.; KLUTHCOUSKI, J.; MARCHÃO, R. L. (Ed.). Integração lavoura-pecuária-floresta: o produtor pergunta, a Embrapa responde. Brasília, DF: Embrapa, 2015. 393 p. il. (Coleção 500 perguntas, 500 respostas).

MAIA, C. M. B. F.; PARRON, L. M. Matéria orgânica como indicador da qualidade do solo e da prestação de serviços ambientais. In: PARRON, L. M.; GARCIA, J. R.; OLIVEIRA, E. B. de; BROWN, G. G.; PRADO, R. B. (ed.). Serviços ambientais em sistemas agrícolas e florestais do Bioma Mata Atlântica. Brasília, DF: Embrapa, 2015. p. 101-108.

MARCHÃO, R. L.; BECQUER, T.; BRUNET, D.; BALBINO, L. C.; VILELA, L.; BROSSARD, M. Carbon and nitrogen stocks in a Brazilian clayey Oxisol: 13-year effects of integrated crop-livestock management systems. Soil and Tillage Research, v. 103, p. 442-450, 2009.

SALTON, J. C.; MERCANTE, F. M.; TOMAZI, M.; ZANATTA, J. A.; CONCENCO, G.; SILVA, W. M.; RETORE, M. Integrated crop-livestock system in tropical Brazil: toward a sustainable production system. Agriculture, Ecosystems & Environment, v. 190, p. 70-79, 2014.

Soil quality indicator in an integrated livestock system of low carbon emissions in the Amazon biome

Data published in:

BIASE, A. G.; AZEVEDO, L. F. S.; CHAVES, S. S. F.; MELO, M. N.; DIAS, C. T. S.; MARTORANO, L. G.; CAMARGO, P. B.; SILVA, A. R.; REICHARDT, K. Nonlinear modeling with sandwich estimator approach to analyze soil carbon profile. In: SIGEE - SECOND INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN AGRICULTURE, 2., 2016, Campo Grande, MS.

CHAVES, S. S. F. Dinâmica do carbono no solo sob diferentes usos da terra em Paragominas, PA. 2014. Dissertação (Mestrado em Fitotecnia) – Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba, 2014.

CHAVES, S. S. F.; CAMARGO, P. B.; MARTORANO, L. G.; FERNANDES, P. C. C.; REICHARDT, K. Composição isotópica (δ13) do solo em uma cronossequência floresta-pastagem- sistema silvipastoril. In: SIMPÓSIO DE ESTUDOS E PESQUISAS EM CIÊNCIAS AMBIENTAIS NA AMAZÔNIA, 3., 2014, Piracicaba, SP.

CHAVES, S. S. F.; CAMARGO, P. B.; OLIVEIRA JUNIOR, R. C.; MELO, M. N. Teor de carbono no solo de pastagens com diferentes manejos. In: SIMPÓSIO DOS PÓS-GRADUANDOS NO CENA, 11., 2018, Piracicaba, SP.

CHAVES, S. S. F.; MARTORANO, L. G.; CAMARGO, P. B.; FERNANDES, P. C. C.; ALVES, L. W. R.; REICHARDT, K. Influência do manejo da pastagem na dinâmica do teor da matéria orgânica e da densidade do solo. In: SIMPÓSIO DE PÓS-GRADUANDOS DO CENA, 7., 2014, Piracicaba, SP.

CHAVES, S. S. F.; MARTORANO, L. G.; FERNANDES, P. C. C. Temporal profile of agricultural production systems in the municipality of Paragominas, Pará, Amazon, Brazil. In: ANNUAL MEETINGS 2013 – WATER, FOOD, ENERGY & INNOVATION FOR A SUSTAINABLE WORLD, 2013, Florida, American Society of Agronomy, Crop Science Society of America and Soil Science Society of America.

CHAVES, S. S. F.; MARTORANO, L. G.; FERNANDES, P. C. C.; REICHARDT, K.; DIAS, C. T. S.; BIASE, A. G.; MELO, M. N.; CAMARGO, P. B. Assessment of soil carbon content in pastures with different managements. In: SIGEE - SECOND INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN AGRICULTURE, 2., 2016, Campo Grande, MS.

FERNANDES, P. C. C.; CHAVES, S. S. F.; MARTORANO, L. G. Integração lavoura-pecuária-floresta na região Norte: avaliações de carbono do solo na Fazenda Vitória em Paragominas, Pará. In: BUNGENSTAB, Davi José et al. (org.). ILPF: inovação com integração de lavoura, pecuária e floresta. Brasília: Embrapa, 2019. p. 627-642.

MELO, M. N.; DIAS, C. T. S.; MARTORANO, L. G.; CHAVES, S. S. F.; FERNANDES, P. C. C. Modelos não lineares mistos para descrever o teor de carbono orgânico no solo. Revista Brasileira de Biometria, v. 36, 2018.

MELO, M. N.; DIAS, C. T. S.; MARTORANO, L. G.; CHAVES, S. S. F.; OLIVEIRA, P. P. A. Nonlinear mixed model applied to the analysis of longitudinal data in a soil located in Paragominas, PA. In: SIGEE - SECOND INTERNATIONAL SYMPOSIUM ON GREENHOUSE GASES IN AGRICULTURE, 2., 2016, Campos Grande, MS.

Biomass and carbon stock in eucalyptus trees in integrated livestock production systems

References

FIGUEIREDO, E. B.; JAYASUNDARA, S.; BORDONAL, R. O.; REIS, R. A.; WAGNER-RIDDLE, C.; LA SCALA, N. Greenhouse gas balance and carbon footprint of beef cattle in three contrasting pasture-management systems in Brazil. Journal of Cleaner Production, n. 142, p. 420-431, 2017. DOI: dx.doi.org/10.1016/j.jclepro.2016.03.132

GIL, J.; SIEBOLD, M.; BERGER, T.. Adoption and development of integrated cropelivestockeforestry systems in Mato Grosso, Brazil. Agric. Ecosyst. Environ., v. 199, p. 394-406, 2015.

GUTMANIS, D. Estoque de carbono e dinâmica ecofisiológica em sistemas silvipastoris. Rio Claro: UNESP, 2004. Tese (Doutorado em Ciências Biológicas) – Universidade Estadual Paulista, Rio Claro, 2004.

MULLER, M. D.; FERNANDES, E. N.; CASTRO, C. R. T.; PACIULLO, D. S. C.; ALVES, F. F. Estimativa de acúmulo de biomassa e carbono em sistema agrossilvipastoril na zona da mata mineira. Pesquisa Florestal Brasileira, v. 60, p. 11-17, 2009.

OFUGI, C.; MAGALHÃES, L. L.; MELIDO, R. C. N.; SILVEIRA, V. P. Integração lavoura-pecuária (ILPF), sistemas agroflorestais (SAFs). In: TRECENTI, R. et al. (ed.). Integração lavoura-pecuária-silvicultura: boletim técnico. Brasília: MAPA/SDC, 2008. p. 20-25.

OLIVEIRA, P. P. A. Gases de efeito estufa em sistemas de produção animal brasileiros e a importância do balanço de carbono para a preservação ambiental. Revista Brasileira de Geografia Física, v. 8, p. 623-634, 2015.

SALTON, J. C.; MERCANTE, F. M.; TOMAZI, M.; ZANATTA, J. A.; CONCENÇO, G.; SILVA, W. M.; RETORE, M. Integrated crop-livestock system in tropical Brazil: toward a sustainable production system. Agric. Ecosyst. Environ., v. 190, p. 70-79, 2014.

TSUKAMOTO FILHO, A. A. Fixação de carbono em um sistema agroflorestal com eucalipto na região do cerrado de Minas Gerais. 2003. Tese (Doutorado em Ciência Florestal) – Universidade Federal de Viçosa, Viçosa, 2003.

Sustainable production systems, crop-livestock integration and crop-livestock-forest integration

Data Published in:

ASSAD, E. D.; CORDEIRO, L. A. M.; MARCHAO, R. L.; ALMEIDA, R. G.; GUIMARÃES JÚNIOR, R.; BERNDT, A.; SALTON, J. C.; EVANGELISTA, B. A. Potencial de mitigação da emissão de gases de efeito estufa por meio da adoção da estratégia de integração lavoura-pecuária-floresta. In: CORDEIRO, L. A. M. et al. (org.).. Integração lavoura-pecuária-floresta: o produtor pergunta, a Embrapa responde (coleção 500 perguntas 500 respostas). Brasília, DF: Embrapa, 2015. v. 1, p. 289-305.

GUIMARÃES JÚNIOR, R.; MARCHAO, R. L.; PULROLNIK, K.; VILELA, L.; MACIEL, G. A.; SOUZA, K. W.; PEREIRA, L. G. R. Neutralization of enteric methane emissions by carbon sequestration under integrated crop-livestock and crop-livestock-forest systems in Cerrado region. In: SIMPÓSIO INTERNACIONAL SOBRE GASES DE EFEITO ESTUFA NA AGROPECUÁRIA, 2., 2016, Campo Grande. Anais [...]. Campo Grande: Embrapa, 2016.

MANDARINO, R. A.; PEREIRA, L. G. R.; BARBOSA, F. A.; SANTOS, D. C.; VILELA, L.; MACIEL, G. A.; BARIONI, L. G.; GUIMARÃES JÚNIOR, R. Methane emissions from Nellore heifers under integrated crop livestock forest systems. In: LIVESTOCK, CLIMATE CHANGE AND FOOD SECURITY CONFERENCE, 2014, Madri. Abstract Book [...].. Madri: Livestock, Climate Change and Food Security, 2014. v. 1, p. 34.

MANDARINO, R. A.; PEREIRA, L. G. R.; BARBOSA, F. A.; VILELA, L.; MACIEL, G. A.; GUIMARÃES JÚNIOR, R. Methane emissions of Nellore heifers on integrated crop-livestock-forest systems in the Brazilian Cerrado. In: WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FOREST SYSTEMS (WCCLF); INTERNATIONAL SYMPOSIUM ON INTEGRATED CROP-LIVESTOCK SYSTEMS (ICLS3), 3., 2015, Brasília, DF. Proceedings [...]. Brasília, DF: Embrapa, 2015.

PEREIRA, L. G. R.; MACHADO, F. S.; CAMPOS, M. M.; GUIMARÃES JÚNIOR, R.; TOMICH, T. R. Estratégias de mitigação de metano na pecuária leiteira. In: SIMPÓSIO MINEIRO, 6.; SIMPÓSIO NACIONAL SOBRE NUTRIÇÃO DE GADO DE LEITE, 1., 2012, Belo Horizonte-MG. Anais [...].Belo Horizonte: FEP MVZ, 2012. p. 197-231.

RIBEIRO, L. G.; MACHADO, F. S.; CAMPOS, M. M.; GUIMARAES JÚNIOR, R.; TOMICH, T. R.; REIS, L. G.; COOMBS, C. Enteric methane mitigation strategies in ruminants: a review. Revista Colombiana de Ciências Pecuárias, v. 28, p. 124-143, 2015.

VILELA, L.; MARTHA JR., G. B.; MACEDO, M. C. M.; MARCHAO, R. L.; GUIMARÃES JÚNIOR, R.; PULROLNIK, K.; MACIEL, G. A. Sistemas de integração lavoura-pecuária na região do Cerrado. Pesquisa Agropecuária Brasileira, (1977. Impressa), v. 46, p. 1127-1138, 2011.

Emission and removal of greenhouse gases from non-ruminant production in the national territory

References

BONITO, M. A. B. N. Determinação dos fatores de emissão de amoníaco e gases de efeito estufa em salas de gestação suína. 2015. Dissertação (Mestrado) – Universidade Federal de Santa Catarina, Florianópolis, 2015.

COSTA, A. M. G.. Definition of yearly emission factor of dust and greenhouse gases through continuous measurements in swine husbandry. Atmospheric Environment, n. 43, p. 1548-1556, 2009.

FAO – Food and Agriculture Organization of the United Nations. The state of food and agriculture: food systems for better nutrition. Rome: [S. n.], 2013.

IBGE – Instituto Brasileiro de Geografia e Estatística. Produção da pecuária municipal. Rio de Janeiro: IBGE, 2018. v. 46, p. 1-8.

IPCC – Intergovernmental Panel on Climate Change. IPCC Guidelines for National Greenhouse Gas Inventories. Agriculture, Forestry and Other Land Use. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H. S., Buendia L., Miwa K., Ngara T., Tanabe K. (eds.). Japan: IGES, 2006. v. 4. Disponível em: http://www.ipcc -nggip.iges.or.jp/public/2006gl/vol4.html.

MIRAGLIOTTA, M. Y.; NAAS, I. A.; BARACHO, M. S; ARADAS, M. E. C. Qualidade do ar de dois sistemas produtivos de frangos de corte com ventilação e densidade diferenciadas – estudo de caso. Engenharia Agrícola, Jaboticabal, v. 22, n. 1, p. 1-10, 2002.

NUNES, M. L. A.; MIRANDA, K. O. S. Alternativas para a redução da emissão de gases de efeito estufa pela suinocultura. Thesis, São Paulo, ano IV, n. 19, p. 48-62, 2013.

OLIVEIRA, M. C.; ALMEIDA, C. V.; ANDRADE, D. O.; RODRIGUES, S. M. M. Teor de Matéria Seca, ph e Amônia Volatilizada da Cama de Frango Tratada ou Não com Diferentes Aditivos. Revista Brasileira de Zootecnia, v. 32, n. 4, p. 951-954, 2003.

OLIVEIRA, P. A. V.; MONTEIRO, A. N. T. R. Emissão de amônia na produção de frangos de corte. In: CONFERÊNCIA FACTA, Campinas, 2013. Anais [...]. Campinas: Facta, 2013. Disponível em: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/91032/1/final7197.pdf.

ONTARIO. Ministry of the Environment. Ontario air standards for ammonia. Ontario: Ontario Ministry of the Environment, 2001. Disponível em: http://www.wnw.gov.on.ca/envision/envreg/er/documents/2001/airstandards/pa00e0003.pdf.

PECORARO, C. A. Contribuição da produção confinada de suínos na emissão de amônia e gases de efeito estufa mediante avaliação das metodologias contínua e simplificada. 2015. Dissertação (Mestrado) – Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba, 2015.

PHILLIPE, F. X; LAITAT, M.; CANART, B.; VANDENHEEDE, M.; NICKS, B. Comparison of ammonia and greenhouse gas emissions during the fattening of pigs, kept either on fully slatted floor or on deep litter. Livestock Science, v. 111, p. 144-152, 2007.

PHILIPPE, F. X; NICKS, B. Review on greenhouse gas emissions from pig houses: Production of carbon dioxide, methane and nitrous oxide by animal and manure. Agriculture, Ecosystems & Environment, Netherlands, v. 199, p. 10-25, 2014.

PRUDÊNCIO DA SILVA, V.; WERF, H. M. G. van der; SOARES, S. R.; CORSON, M. S. Environmental impacts of French and Brazilian broiler chicken production scenarios: an LCA approach. Journal of Environmental Management, v. 133, p. 222-231, 2014.

RAMOS, C. S. Receita com exportação de suínos em 2015 recuou 20,4% a USD 1,279 bi. Valor Econômico, 2016.

TAVARES, J. M. R. Consumo de água e produção de dejetos na suinocultura. 2012. Dissertação (Mestrado) – Universidade Federal de Santa Catarina, Florianópolis, 2012.

Greenhouse Gas (GHG) emissions in the technological arrangements for the production and use of biogas

Data Published in:

FALKOSKI, C.; HIGARASHI, M. M.; RIBEIRO, S. M.; SARDA, L. G.; NICOLOSO, R. S.; GRAVE, R. A. Emissão de gases de efeito estufa: comparação compostagem x esterqueira. In: JORNADA DE INICIAÇÃO CIENTÍFICA - UnC/Embrapa, 8., 2014, Concórdia, SC. Anais [...]. Concórdia: [S. n.], 2014.

GRAVE, R. A.; NICOLOSO, R. S.; CASSOL, P. C.; AITA, C.; CORRÊA, J. C.; DALLA COSTA, M.; FRITZ, D. D. Short-term carbon dioxide emission under contrasting soil disturbance levels and organic amendments. Soil & Tillage Research, v. 146, p. 184-192, 2015.

GRAVE, R. A.; NICOLOSO, R. S.; CASSOL, P. C.; SILVA, M. L. B.; MEZZARI, M. P.; AITA, C.; WUADEN, C. R. Determining the effects of tillage and nitrogen sources on soil N2O emission. Soil & Tillage Research, v. 175, p. 1-12, 2018.

RIBEIRO, S. M.; HIGARASHI, M. M.; FALKOSKI, C.; SARDA, L. G.; NICOLOSO, R. S.; GRAVE, R. A. Emissão de gases de efeito estufa - biodigestor x esterqueira. In: JORNADA DE INICIAÇÃO CIENTÍFICA - UnC/Embrapa, 8., 2014, Concórdia, SC. Anais [...]. Concórdia: [S. n.], 2014.

SARDA, L. G.; GRAVE, R. A.; FALKOSKI, C.; RIBEIRO, S. M.; NICOLOSO, R. S.; HIGARASHI, M. M. Global warming potential of three swine manure management systems used in Brazil. In: SIGERA, 4., 2015, Rio de Janeiro. Anais [...]. Rio de Janeiro: [S. n.], 2015.

SARDA, L. G.; HIGARASHI, M. M.; NICOLOSO, R.S; OLIVEIRA, P. A. V.; FALKOSKI, C.; RIBEIRO, S. M. S.; COLDEBELLA, A. Methane emission factor of open deposits used to store swine slurry in Southern Brazil. Pesquisa Agropecuária Brasileira, v. 53, p. 657-663, 2018.

WUADEN, C. R.; NICOLOSO, R. S.; GRAVE, R. A.; PIGOSSO, A. Maize nitrogen use efficiency is affected by big slurry composting and anaerobic digestion. In: SIMPÓSIO INTERNACIONAL SOBRE GERENCIAMENTO DE RESÍDUOS AGROPECUÁRIOS E AGROINDUSTRIAIS - SIGERA, 5., 2017, Foz do Iguaçu. Anais [...].. Concórdia: Sbera; Embrapa Suínos e Aves, 2017.

WUADEN, C. R.; NICOLOSO, R. S.; GRAVE, R. A.; PIGOSSO, A. Soil organic carbon pool as affected by tillage systems and organic nitrogen sources. In: SIGERA, 5., 2017, Foz do Iguaçu. Anais [...].Concórdia: Sbera; Embrapa Suínos e Aves, 2017.

Greenhouse gas and ammonia emissions from broiler farming in multiple bed reuse

References

COSTA JUNIOR, C.; CERRI, C. E. P.; CERRI, C. C.; PIRES, A. V. Net greenhouse gas emissions from manure management using anaerobic digestion technology in a beef cattle feedlot in Brazil. Science of the Total Environment, Amsterdam, v. 505, p. 1018-1025, 2015.

HUTCHINSON, G. L.; MOSIER, A. R. Improved soil cover method for field measurement of nitrous oxide fluxes. Soil Science Society of America Journal, Madison, v. 45, p. 311-316, 1981.

JACINTHE, P. A.; DICK, W. A. Soil management and nitrous oxide emissions from cultivated fields in southern Ohio. Soil & Tillage Research, Amsterdam, v. 41, p. 221-235, 1997.

JANTALIA, C. P.; HALVORSON, A. D.; FOLETT, R. F.; ALVES, B. J. R.; POLIDORO, J. C.; URQUIAGA, S. Nitrogen source effects on ammonia volatilization as measured with semi-static chambers. Agronomy Journal, Madison, v. 104, p. 1093-1098, 2012.

JONES, S. K.; REES, R. M.; SKIBA, U. M.; BALL, B. C. Greenhouse gas emissions from a managed grassland. Global Planetary Change, Amsterdam, v. 47, p. 201-211, 2005.

MAZZETO, A. M.; BARNEZE, A. S.; FEIGL, B. J.; GROENIGEN, J. W. van; OENEMA, O.; KLEIN, C. A. M. de; CERRI, C. C. Use of the nitrification inhibitor dicyandiamide (DCD) does not mitigate N2O emission from bovine urine patches under Oxisol in Northwest Brazil. Nutrient Cycling in Agroecosystems, Dordrecht, v. 101, p. 83-92, 2015.

OECD-FAO. OECD-FAO Agricultural Outlook 2015. Paris: OECD Publishing, 2015. DOI:10.1787/agr_outlook-2015-em.

SAGGAR, S.; ANDREW, R. M.; TATE, K. R.; HEDLEY, C. B.; RODDA, N. J.; TOWNSEND, J. A. Modelling nitrous oxide emissions from dairy-grazed pastures. Nutrient Cycling in Agroecosystems, Dordrecht, v. 68, p. 243-255, 2004.

SANTANA, I. K. S.. Emissões de gases de efeito estufa e amônia oriundas da criação de frangos de corte em múltiplos reúsos da cama [Emissions of ammonia and greenhouse gases from the broiler production in multiple reuses of the litter]. 2016. Tese (Doutorado em Ciências) – Centro de Energia Nuclear na Agricultura, Universidade de São Paulo, Piracicaba, 2016.

VASCONCELLOS, C. H. F.; FONTES, D. O.; LARA, L. J. C.; VIDAL, T. Z. B.; SILVA, M. A.; SILVA, P. C. Determinação da energia metabolizável e balanço de nitrogênio de dietas com diferentes teores de proteína bruta para frangos de corte. Arquivo Brasileiro de Medicina Veterinária e Zootecnia, Belo Horizonte, v. 63, n. 3, p. 659-669, 2011.

Greenhouse gas emissions during the housing of broilers under reused bedding

References

MILES, D. M.; MOORE, P. A.; BURNS, R. T.; BROOKS, J. P. Ammonia and nitrous oxide emissions from a commercial broiler house. Journal Environmental Quality, Madison, v. 43, p. 1119-1124, 2014.

PAILLAT, J.-M.; ROBIN P.; HASSOUNA, M. Bilan environnemental du procédé de compostage de lisier de porc sur paille suivant la méthode Guerévez. Paris: INRA, 2004.

Greenhouse gas emissions during the housing of broilers under reused bed

References

FAO – Food and Agriculture Organization of the United Nations. EX-ACT project applications. 2013b. Disponível em: http://www.fao.org/tc/exact/ex-act-applications/on-projects/en/.

GREWER, U.; BOCKEL, L.; SCHIETTECATTE, L.-S.; BERNOUX, M. Ex-Ante Carbon-balance Tool (EX-ACT). Rome: FAO, 2017. Disponível em: http://www.fao.org/fileadmin/templates/ex_act/pdf/EX-ACT_quick_guidance.pdf.

IPCC– Intergovernmental Panel on Climate Change. Climate Change: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, H. L. Miller (eds.). Cambridge, New York: Cambridge University Press, 2007.

IPCC – Intergovernmental Panel on Climate Change. Guidelines for National Greenhouse Gas Inventories. Geneva: IPCC Secretariat, 2006.

ISO – The International Standards Organisation. ISO 14040: Environmental management: Life cycle assessment: Principles and framework. Geneva: ISO 2006a.

ISO – The International Standards Organisation. ISO 14044: Environmental management: Life cycle assessment: Requirements and guidelines. Geneva: ISO, 2006b.

JÖNSSON, M. Assessing the climate change mitigation potential of the EADD-MICCA pilot project with the Ex-Ante Carbon Balance Tool (EX-ACT). Mitigation of Climate Change in Agriculture (MICCA) Programme Background Report, 6. 2012.