Inhibition of enteric methanogenesis in cows induces changes in plasma metabolome highlighting potential emission markers

Bénédict Yanibada, Ulli Hohenester, Mélanie Pétéra, Cécile Canlet, Stéphanie Durand, Fabien Jourdan, Cécile Martin, Maguy Eugène, Diego Morgavi, Hamid Boudra

DOCUMENTOS

135

ISSN1980-6841
August/ 2019

7th GGAA – Greenhouse Gas and Animal Agriculture Conference

August 4th to 8th, Iguassu Falls/Brazil

Proceedings

Embrapa

ISSN 1980-6841
August, 2019

Brazilian Agricultural Research Corporation (Embrapa)
Embrapa Southeast Livestock
Ministry of Agriculture, Livestock and Food Supply

DOCUMENTOS 135

7th GGAA – Greenhouse Gas and Animal Agriculture Conference

August 4th to 8th, Iguassu Falls/Brazil

Proceedings

Alexandre Berndt
Luiz Gustavo Pereira Ribeiro
Adibe Luis Abdalla

Editors

Embrapa Southeast Livestock
São Carlos, SP
2019

Copies can be purchased from:

Embrapa Southeast Livestock
Rod. Washington Luiz, km 234
13560-970, São Carlos, SP
P.Box 339
Phone: +51 (16) 3411-5600
www.embrapa.br
www.embrapa.br/fale-conosco/sac

Design: Maria Cristina Campanelli Brito

1st edition online: 2019

International Cataloging Data in the Publication (ICP)
Embrapa Southeast Livestock

Fica catalográfica

Organizing Committee

Alexandre Berndt, chair, Embrapa Pecuária Sudeste, Brasil

Marta Alfaro Valenzuela, vice chair, INIA Remehue, Chile

Julio Cesar Pascale Palhares, member, Embrapa Pecuária Sudeste, Brasil

Luiz Gustavo Pereira Ribeiro, member, Embrapa Gado de Leite, Brasil

José Ignacio Arroquy, member, INTA EEA, Argentina

Telma Teresinha Berchielli, member, FCAV/UNESP, Brasil

Adibe Luis Abdalla, member, CENA/USP, Brasil

Scientific Committee

Abmael Silva Cardoso (abmael.cardoso@unesp.br); Adibe Luiz Abdalla Filho (adibefilho@cena.usp.br); Agnes van den Pol (agnes.vandenpol@wur.nl); Alda Lúcia Gomes Monteiro (aldaufpr@gmail.com); Alexandre Berndt (alexandre.berndt@embrapa.br); Alexandre Lima Ferreira (axelfire@gmail.com); Alexandre Rossetto Garcia (alexandre.garcia@embrapa.br); Ali R. Bayat (alireza.bayat@luke.fi); Ana Marozzi Fernandes (ana.marozzi-fernandes@embrapa.br); Ana Rita de Araujo Nogueira (ana.nogueira@embrapa.br); Andrea Pickering (andrea.pickering@mpi.govt.nz); Andressa Santanna Natel (andressa.zoo@gmail.com); Angela Schwarm (angela.schwarm@nmbu.no); Antonio Carlos Reis de Freitas (carlos.freitas@embrapa.br); April Leytem (april.leytem@ars.usda.gov); Bruno José Rodrigues Alves (bruno.alves@embrapa.br); Cecile de Klein (cecile.deklein@agresearch.co.nz); Cintia Righetti Marcondes (cintia.marcondes@embrapa.br); Deborah Sian Knox (deborah.knox@mpi.govt.nz); Luis Ortega (luis.ortega@sagarpa.gob.mx); Fábio Luís Henrique (fabiohenrique@usp.br); Falberni de Souza Costa (falberni.costa@embrapa.br); Fernando Antonio Fernandes (fernando.fernandes@embrapa.br); Giacomo Pirlo (giacomo.pirlo@crea.gov.it); Gonzalo Mauricio Becoña (gonbec@gmail.com); Henrique Mendonça Nunes Ribeiro-Filho (henrique.ribeiro@udesc.br); Isabela Carvalho (isabela.carvalho@nutreco.com); Jacobo Arango (j.arango@cgiar.org); Jan Lassen (jalas@vikinggenetics.com); Jean Victor Savian (jvsavian@gmail.com); José Ignacio Gere (jgere@frba.utn.edu.ar); José Ricardo Macedo Pezzopane (jose.pezzopane@embrapa.br); Junichi Takahashi (junichi@obihiro.ac.jp); Kyu-Hyun Park (fecesno1@gmail.com); Laura M Cardenas (laura.cardenas@rothamsted.ac.uk); Leandro Sannomiya Sakamoto (leandrosakamoto@zootecnista.com.br); Luciana Correia de Almeida Regitano (luciana.regitano@embrapa.br); Luisa Maria Cáceres-Ocampos (luisacaceres2010@gmail.com); Luiz Francisco Zafalon (luiz.zafalon@embrapa.br); Luiz Gustavo Ribeiro Pereira (luiz.gustavo@embrapa.br); Maguy Eugene (maguy.eugene@inra.fr); Marci Rose Baranski (mbaranski@oce.usda.gov); Maria Luiza Franceschi Nicodemo (marialuiza.nicodemo@embrapa.br); Nico Peiren (nico.peiren@ilvo.vlaanderen.be); Paulo de Mello Tavares Lima (pmtlima@cena.usp.br); Paulo de Meo Filho (paulo.filho@usp.br); Paulo Mazza Rodrigues (pmazza@usp.br); Rafael Canonenco de Araujo (rafael@grasp.ind.br); Raquel Santiago Barro (raquelbarro@gmail.com); Rebecca Danielsson (rebecca.danielsson@slu.se); Renata Helena Branco (renata@iz.sp.gov.br); Ricardo Andrade Reis (rareis@fcav.unesp.br); Richard Williams (richard.williams@dpi.vic.gov.au); Robert Michael Boddey (robert.boddey@embrapa.br); Roberto Giolo Almeida (roberto.giolo@embrapa.br); Roberto Guimarães Júnior (roberto.guimaraes-junior@embrapa.br); Rodrigo da Costa Gomes (rodrigo.gomes@embrapa.br); Sergio Raposo de Medeiros (raposodemedeiros@gmail.com); Siglea Sanna Noirtin Freitas Chaves (siglea@hotmail.com); Simone Cristina Meo Niciura (simone.niciura@embrapa.br); Teresa Cristina Moraes Genro (cristina.genro@embrapa.br); Thakshala Rupanjanie Seresinhe (tseresinhe@gmail.com); Thomas Cherenet (hjr.mmr@gmail.com); Tommy Boland (tommy.boland@ucd.ie); Tomoyuki Suzuki (suzukito@affrc.go.jp); Veronica Solange Ciganda (vciganda@inia.org.uy); Vibeke Lind (vibeke.lind@nibio.no); Yvette de Haas (yvette.dehaas@wur.nl)

Foreword

GGAA history, purpose, aims and audience

The Greenhouse Gas and Animal Agriculture Conference (GGAA) is the premier international conference summarising the collective state of scientific knowledge on greenhouse gas abatement strategies and production systems adaptation needs for the livestock sector. The gathering features leading scientists and policymakers reviewing the current state of knowledge and presenting significant new developments in policy, measurement, modelling, mitigation and adaptation efforts associated with greenhouse gases from animal agriculture. The Conference takes place every 3 years, moving from continent to continent at each edition. The first conference, GGAA2003, was held in Japan with 200 delegates from 20 countries. Five subsequent GGAA conferences have been convened: GGAA2005, Switzerland; GGAA2007, New Zealand; GGAA2010, Canada, with the biggest in Ireland, GGAA2013, attracting 460 delegates from 41 countries. The GGAA2016 in Australia received more than 300 delegates from 36 countries.

GGAA2019

The GGAA2019 focused on the theme "Science supporting Practices" and happened for the first time in Latin America. Following on from the six previous GGAA conferences, presented the latest research on the measurement, modelling, mitigation of greenhouse gases, while also seeking to discuss adaptation efforts and the impact of these advances for farmers, managers and policy makers. At the GGAA2019 conference, held in Iguassu Falls, Brazil, almost 200 delegates from 39 countries gathered to participate in a program featuring 11 invited keynote speakers, 47 offered presentations and 111 poster presentations. The conference was organised into four sessions covering: Technical advances: from genomics to precision agriculture, that addressed aspects related to Measuring and Modelling GHG; Farm level low carbon initiatives, which addressed Mitigation and Adaptation strategies to provide more Resilient production systems; Regional low carbon initiatives, which considered the Landscape, Regional management and National Commitments; International low carbon initiatives, that presented examples from IPCC, NDCs, FAO, World Bank. Delegates were offered the opportunity to publish their research in this peer-reviewed Special Edition of Animal, Cambridge University Press, with all abstracts published in conference proceedings. Volume One of the GGAA2019 Special Edition will include 20 peer-reviewed papers and will be available within the last quarter of 2019. The 'virtual' Volume Two will present the Proceedings… in a digital way, available in the web site. Taken together, these special editions provide the latest summary of the current state of knowledge on policy developments, measurement, modelling, mitigation and adaptation efforts associated with greenhouse gases from animal agriculture.

VENUE

The city of Iguassu Falls was selected to host the event for the first time in Latin America thanks to its excellent geographical location within the triborder region of Brazil, Argentina and Paraguay. The city boasts an international airport that connects to the leading international airports in South America and can easily be reached by Latin American participants via bus or car. Besides the facilitated access, Iguassu Falls is further complemented by technical and scientific attractions part of the context of the conference, such as waterfalls, a national park, bioenergy and hydroelectric complex which were included as technical visits.

Alexandre Berndt, Chair
On behalf of the GGAA2019 Local Organising Committee and
International Scientific Committee

Table of content

Session 1 - Technical advances: from genomics to precision agriculture

1.1 Nitrous Oxide (Oral)

1.1 Nitrous Oxide (Poster)

1.2 Methane Oral

1.2 Methane (Poster)

1.3 Modelling (Oral)

1.5 Modelling (Poster)

Session 2 - Farm level low carbon initiatives, measuring and modelling GHG

2.1 Mitigation (Oral)

2.1 Mitigation (Poster)

2.1 Adaptation (Oral)

2.1 Adaptation (Poster)

Session 3 - Regional low carbon initiatives, Landscape, regional management and National Commitments

3.1 Regional level (Oral)

3.1 National level (Oral)

3.1 National level (Poster)

Session 4 - International low carbon initiatives

4.1International Policies (Poster)

Session 1

Technical advances: from genomics to precision agriculture

1.1 Nitrous Oxide (Oral)

Application of edge computing for near-continuous monitoring of NH_3 and N_2O emissions

R.H. Grant[1], C.-H. Lin[2], C. Johnston[3], S.L. Hurrell[4], B. Zuelly[5], A.K. Maji[6] and C.B. Smith[7]

[1]Forest Meteorology, PhD, Professor, Department of Agronomy, Purdue University
[2]Agronomy, PhD, Researcher, Department of Agronomy, Purdue University
[3]Soil Science, PhD, Professor, Department of Agronomy, Purdue University
[4]Computer Science, BS, Scientific Application Analyst, Information Technology at Purdue, Purdue University
[5]Information Technology, BS, Systems Engineer, Research Computing at Purdue, Purdue University
[6]Computer Engineering, PhD, Sr. Research Analyst, Information Technology at Purdue, Purdue University
[7]Senior Web Application Developer, Agricultural Information Technology, Purdue University

A facility was developed to provide near-real-time aerially-integrated field-scale measurements of NH3 and N2O emitted from multiple agricultural field treatments. A scanning long path Fourier Transform Infrared Spectrometer measuring NH3 and N2O was interfaced to a cloud-edge computer (EC). Data logger-controlled sequentially sampled air around and within the fields. The N2O in the air was measured by a laser-based analyzer concentrations and air sampling conditions reported to the EC. Long optical path NH3 lasers, sonic anemometers and other atmospheric sensors communicated wirelessly with the EC. A remotely-viewable xymon dashboard for instrument and trailer power status checks reduced time on-site for field staff. EC programs check data quality and merge the data streams for transmission by high-speed WiFi at midnight and input into multiple inverse dispersion models running on a 12 CPU node Beowolf cluster. Resulting system provided prior-day emissions by 6 AM the following day.

Terms for indexing: High-performance computing, Dashboards, Cloud Edge computing, RF communications, WiFi

Deriving nitrous oxide emission factors for manures applied to agricultural land in the UK

Rachel E. Thorman[1], Fiona A. Nicholson[2], Cairistiona F. E. Topp[3], David R. Chadwick[4], Madeleine J. Bell[5], Laura M. Cardenas[6], Joanna M. Cloy[7], Tom H. Misselbrook[8], Robert M. Rees[9], Catherine J. Watson[10], and John R. Williams[11]

[1]PhD, Soil Scientist, ADAS, ADAS Boxworth, Battlegate Road, Boxworth, Cambridge, Cambridgeshire, CB23 4NN, UK

[2]PhD, Senior Soil Scientist, ADAS, ADAS Boxworth, Battlegate Road, Boxworth, Cambridge, Cambridgeshire, CB23 4NN, UK

[3]PhD, Agricultural Systems Modeller, Scotland's Rural College (SRUC), King's Buildings, West Mains Road, Edinburgh, EH9 3JG, UK

[4]PhD, Professor of Sustainable Land Use Systems, School of Natural Sciences, Bangor University, Bangor LL57 2UW, UK

[5]PhD, Environmental Scientist, Scotland's Rural College (SRUC), King's Buildings, West Mains Road, Edinburgh, EH9 3JG, UK

[6]PhD, Atmospheric Chemist, Rothamsted Research, Okehampton, Devon, EX20 2SB, UK

[7]PhD, Soil Scientist, Scotland's Rural College (SRUC), King's Buildings, West Mains Road, Edinburgh, EH9 3JG, UK

[8]PhD, Professor of Sustainable Agriculture Sciences, Rothamsted Research, Okehampton, Devon, EX20 2SB, UK

[9]PhD, Professor of Agriculture and Climate Change, Scotland's Rural College (SRUC), King's Buildings, West Mains Road, Edinburgh, EH9 3JG, UK

[10]PhD, Formerly Senior Principle (Head of Agri-Environment), Agri-Food and Biosciences Institute (AFBI), 18a, Newforge Lane, BT9 5PX, Belfast, UK

[11]Principal Soil Scientist, ADAS, ADAS Boxworth, Battlegate Road, Boxworth, Cambridge, Cambridgeshire, CB23 4NN, UK

Annual nitrous oxide (N_2O) emission factors (EFs) were calculated from measurements of emissions from manures applied to UK arable crops and grassland as part of a wider research programme to reduce uncertainty in the UK national agricultural N_2O inventory. Field studies were undertaken between 2011 and 2013 at 3 arable and 3 grassland sites in the UK. Nitrous oxide emissions were measured for 365d from replicated (x3) plots using the static chamber technique (5 chambers/plot) following the autumn and spring application of different manures (cattle/ pig slurry, cattle/pig farmyard manure (FYM), poultry layer manure and poultry broiler litter) at typical rates, using representative manure application and soil incorporation methods. A nil nitrogen control treatment was also included. Direct N_2O EFs ranged from -1.35 to 2.84% of total nitrogen applied, with the variability driven by a range of factors including differences in manure composition, application method, soil type and climatic conditions. When data from all the site/seasons were pooled, N_2O EFs from poultry manures (0.87%) were found to be greater ($p<0.01$) than from FYM (0.36%) and slurry (0.59%). Emission factors from the autumn application timings (0.83%) were significantly greater ($p<0.05$) than from the spring application timings (0.38%). No difference was found in the EF for bandspread (trailing hose/trailing shoe) compared with surface broadcast slurry.

Data from this project have been used to establish robust Tier 2 country-specific EFs for inclusion in the UK national greenhouse gas inventory.

Terms for indexing and Index terms: arable, grassland, manure type, application timing, application method, N_2O inventory

Nitrous oxide emission factors following land application of manure and livestock grazing in developing countries

Ignacio Beltran[1], Marta Alfaro[2], Francisco Salazar[3], Alasdair Noble[4] and Tony van der Weerden[5]

[1]PhD, Postdoctoral Scientist, Instituto de Investigaciones Agropecuarias INIA, Carretera Panamericana Sur km 8 Norte, Osorno, Chile.

[2]PhD, Deputy National director, Instituto de Investigaciones Agropecuarias INIA, Carretera Panamericana Sur km 8 Norte, Osorno, Chile.

[3]PhD, Senior Scientist, Instituto de Investigaciones Agropecuarias INIA, Carretera Panamericana Sur km 8 Norte, Osorno, Chile.

[4]PhD, Senior Statistician, AgResearch Lincoln, Private Bag 4749, Christchurch 8140, New Zealand

[5]PhD, Senior Scientist, AgResearch Invermay, Private Bag 50034, Mosgiel, New Zealand

Livestock manure (including excreta deposited during grazing) is a significant source of greenhouse gas emissions, contributing 30-50% of global nitrous oxide emissions from agriculture. Several within-country studies have focused on estimating nitrous oxide emission factors following the land application of livestock manure and direct deposition of excreta during livestock grazing. 'Dataman' is an international project that aims to help refine and understand processes influencing nitrous oxide emission factors from manure by collating manure management data from multiple countries. As part of the initial data analysis, this paper focuses on data from seven developing countries spread across South America, Asia and Africa. Data from published research, theses and conferences were identified by searching different publication platforms for a combination of three keyword categories (type of manure, animal and greenhouse gas). The criteria used for identifying suitable publications were: 1) only one type of manure included in the measurements, 2) trials included a non-amended control and 3) nitrous oxide measurements were made for at least 30 days. Thirty-three studies were included in the data analysis, providing 212 observations. Brazil represented 66% of the collated data, followed by Kenya, China, Zimbabwe, Colombia, Argentina and Nicaragua. Urine was the most common nitrogen source (40% of data) followed by dung, slurry, solid manure and broiler litter. Cattle (beef and dairy) were the most common animal type (68% of data) followed by swine, sheep and poultry. We will present preliminary results from our analysis of the nitrous oxide emission factors.

Keywords: dung, manure management, greenhouse gas, slurry, solid manure, urine.

Quantification of sheep urine patch N_2O emission factors from extensively grazed grasslands

Karina A. Marsden[1,2], Jon A. Holmberg[1], Davey L. Jones[1,3], Alice F. Charteris[4], Laura M. Cardenas[4], and Dave R. Chadwick[1]

[1]School of Natural Sciences, Bangor University, Bangor, Gwynedd, LL57 2UW, UK
[2]Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, Parkville, Victoria 3010, Australia
[3]UWA School of Agriculture and Environment, University of Western Australia, Crawley, WA 6009, Australia
[4]Sustainable Agriculture Sciences, Rothamsted Research, North Wyke, Okehampton, Devon, EX20 2SB, UK

Extensively grazed grasslands are understudied in terms of their contribution to greenhouse gas (GHG) emissions from livestock. Such areas are often situated on mountainous terrain and differ widely from intensively managed grasslands (e.g. acidic soils, greater organic matter content, higher rainfall, contrasting vegetation types and lower stocking density). Current IPCC default and UK country specific N_2O emission factors (EFs) for excreta deposited during grazing (EF3) are based on cattle excreta applied to lowland intensively managed areas. We hypothesised sheep urine EFs on extensive grasslands would differ widely from these current IPCC values. Sheep urine EFs were quantified using an automated GHG monitoring system from two upland sites: a semi-improved grassland on an Orthic Podzol soil and an unimproved acid moorland on a highly organic (Histosol) soil type. Sheep urine N_2O-N EFs were negligible across the two sites (all < 0.08 % of the N applied), with evidence to show that low nitrification rates under acidic soil conditions were limiting N_2O emissions at both sites. Our results support the suggestion of disaggregating EFs based on altitude gradients or degree of management intensity. Assuming our data are typical for extensively grazed systems, utilising hill-grazing specific urine patch N_2O-N EFs would reduce the annual estimate of N_2O derived from UK sheep excreta deposited during grazing by ca. 43%. The results also have implications for the C-footprint of upland-reared livestock products.

What is the best proportion of Forage peanut and Marandu grass to reduce N_2O emissions?

Abmael da Silva Cardoso[1], Darlan de Jesus Marcelino[2], Robert Michael Boddey[3], Andressa Scholz Berça[1], Ricardo Andrade Reis[1], Ana Cláudia Ruggieri[1]

[1]Departamento de Zootecnia da Universidade Estadual Paulista "Júlio de Mesquita Filho", UNESP, Jaboticabal, São Paulo, Brazil

[2]Departamento de Agronomia da Universidade do Estado da Bahia, UESB, Euclides da Cunha, Bahia, Brazil

[3]Embrapa Agrobiologia, Seropédica, Rio de Janeiro, Brazil Corresponding author. E-mail: abmael.cardoso@unesp.br

Inclusion of legumes in grassland has been found to be environmentally and economically beneficial for ranchers by providing more sustained forage for cattle. However, data on the impacts of proportion of legumes inclusion on nitrous oxide (N_2O) emissions are lacking. The goal of this stay was to evaluate effects of legume (*Arachi Pintoi cv. mandobi*) and grass (*Urochloa brizantha cv. marandu*) mixture on N_2O emissions. Treatments were 5 proportion of legume-grass: 100:0, 75:25, 50:50, 25:75 and 0:100 in a completely randomized design with 5 repetitions. We quantified N_2O emissions using static closed chamber methodology and gas chromatography. A strong effect of legume grass proportion was observed on N_2O emissions. The greatest emissions occurred in the 100% of grass litter (62.4 mg N_2O $plot^{-1}$), while the emissions from 100% legumes were 23.3 mg N_2O $plot^{-1}$. The inclusion of legume litter decreased N_2O emissions in all mixed treatment and the lowest N_2O emissions were found in the treatment 50:50 legume:grass that were similar to 25:75. Probably the low C and N ratio is driving the N_2O losses. Previous studies have been showed that the proportion of Forage peanut with Marandu grass for animal performance range from 30-50% of legumes. Our results showed that the most beneficial proportion of the legumes to mitigate N_2O emissions are in line with that is most beneficial for forage and animal production. Further studies are required to assess leaching and ammonia losses and to do a complete assessment of sustainability in terms of environmental impact.

Keywords: consorciation, N pollution, N_2O mitigation, forage management

Acknowledgments: We thanks the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) for financial suporte (#2015/16631-5; #2017/11274-5), Conselho Nacional de Desenvolvimento Tecnológico e Científico (CNPq) and the Coordenação de aperfeiçoamento pessoal de nível superior (CAPES) for the scholarships.

1.1 Nitrous Oxide (Poster)

Ammonia emissions from permanent dairy pastures during different seasons in Costa Rica

Claudia Arndt[1], Tom Misselbrook[2], Dave Chadwick[3], Andres Vega[4], Ricardo Gonzalez[5], Johan Aldair Chavarro Lobo[6], and Andre Mazzetto[7]

[1]Dairy Science, PhD, postdoctoral fellow, Programa de Agricultura, Ganadería y Agroforestería, Centro Agronómico Tropical de Investigación y Enseñanza, Turrialba, Cartago, 30501, Costa Rica;

[2]Ammonia emissions, PhD, Principal Research Scientist, Rothamsted Research, North Wyke, Okehampton, Devon EX20 2SB, UK;

[3]Agriculture and Environmental Science, PhD, Professor of Sustainable Land Use Systems, School of Natural Sciences, Bangor University, Bangor, Gwnedd, LL59 5TH, UK;

[4]Agroforestry and Sustainable Agricuture, MSc, Programa de Agricultura, Ganadería y Agroforestería, Centro Agronómico Tropical de Investigación y Enseñanza, Turrialba, Cartago, 30501, Costa Rica;

[5]Animal Sciences, MSc, PhD student, Facultad de Ciencias Agrarias, Universidad de Antioquia, Carrera 75 # 65-87 bloque 47, office 231, Medellín, Colombia;

[6]Agroforestry Engineer, BSc, student, Fundación Universitaria Unitropico, Yopal, Casanare, 30501, Colombia;

[7]Life Cycle Assessment, PhD, postdoctoral fellow, School of Natural Sciences, Bangor University, Bangor, Gwnedd, LL59 5TH, UK.

Agriculture is the largest source of ammonia (**NH_3**) emissions. As NH_3 is an indirect greenhouse gas (**GHG**), NH_3 measurements are crucial to improve GHG emission predictions and inventories. Moreover, NH_3 emissions have also wider implications for environmental and human health. This study measured NH_3 emissions from permanent dairy pastures in Costa Rica. Emissions were measured using a micrometeorological integrated horizontal flux mass balance method during wet, transition, and dry season [January (11.3mm rain/d), February (3.0mm rain/d), and April 2018 (1.5mm rain/d), respectively] on a commercial dairy farm located in tropical rainforest climate at 638 m.a.s.l. During each season, emissions were measured from dung and urine (excretal) deposition by cattle and from subsequent ammonium nitrate (**AN**) fertilizer applications, as it is common practice to fertilize a pasture after each grazing rotation in Costa Rica. Cattle deposited about 41.5, 36.6, and 48.6 kg of excretal N/ha during each measurement period in January, February, and April, respectively, and 14.5 kg N/ha was applied on each occasion as AN fertilizer. Measured NH_3 nitrogen emissions were 0.18, 1.07, and 1.81 kg/ha in January, February, and April, respectively. As expected, emissions increased with decreasing precipitation. Measured emissions were lower than estimates using IPCC Tier 1 methodology, which gave emissions (uncertainty range) of 9.7 (2.0-19.7), 8.8 (1.8-18.2), and 11.2 (1.1-11.4) kg N/ha in January, February, and April, respectively. The methodology does not capture emissions when there is no wind, thus, measurements may include a small underestimation as wind frequency was low during all periods (mean±SD = 57.8±3.2%).

Attribution of measured pasture N_2O emissions to grazing animal excreta and fertiliser applications

Christof Ammann[1] and Karl Voglmeier[1]

[1]Agroscope Research Station, Climate and Agriculture Group, Zürich, Switzerland

Abstract–Fertilised and grazed pastures are considerable sources of the greenhouse gas N2O. While fertiliser applications usually lead to short emission pulses, animal excreta lead to small- scaled emission hotspots resulting in a non-homogeneous source distribution. The strong spatial and temporal source variability represents an inherent problem for the quantification of gaseous emissions from pastures with chamber techniques. The eddy covariance method, integrating emissions over a larger footprint domain, seems better suited to quantify the total N2O emissions of grazed fields. We present results of a pasture experiment with dairy cows in Switzerland where N2O fluxes were measured continuously with the eddy covariance technique during five years. The pasture was managed in an intensive rotational grazing scheme with 2-3 fertiliser applications per year. A data-based partitioning method was used to attribute the observed field-scale emissions to the main source classes (urine/dung patches, synthetic and organic fertiliser applications, and background). The attribution to urine and dung patches and to background was validated during one season by simultaneous chamber measurements. The small-scale chamber fluxes were up-scaled to match the footprint area of the eddy covariance fluxes determined by a dispersion model. This allowed a direct comparison between the two measurement methods, which showed a good agreement. Urine and dung N excretion were estimated based on animal energy demand, feed and milk N content, and digestibility. Finally the specific emission factors for the different N inputs were determined. They were significantly lower for dung compared to urine patches and for organic compared to synthetic fertiliser.

Index terms: nitrous oxide, eddy covariance, emission factor.

Development of a High Throughput Screen to Identify Potential New Nitrification Inhibitors for the Mitigation of Nitrogen Loss by the Ammonia-Oxidizing Bacterium *Nitrosomonas europaea*

Scott A. Ferguson[1], Alan D. Hughes[1], Chen-Yi Cheung[1], Andriy Podolyan[2], Keith C. Cameron[2], Ron S. Ronimus[3], Vincenzo Carbone[3], David Rennison[4], Hong J. Di[2], Margaret A. Brimble[4], and Gregory M. Cook[1]

[1]Department of Microbiology and Immunology, University of Otago, Dunedin, New Zealand
[2]Centre for Soil and Environmental Research, Lincoln University, Christchurch, New Zealand
[3]AgResearch Limited, Grasslands Research Centre, Palmerston North, New Zealand
[4]School of Chemical Sciences, University of Auckland, Auckland, New Zealand

Under aerobic environmental conditions, ammonia (NH_3) present in agricultural fertilisers and released from urea in bovine urine patches is oxidized predominantly by ammonia-oxidizing bacteria (AOB). Key AOB mediating nitrification are *Nitrosomonas* species. While nitrification is of critical importance in the conversion of urea or fertilizer to nitrate, this biological process also represents a major loss of nitrogen (N) from pasture soils. Gaseous loss occurs through the release of nitrous oxide (N_2O), a potent greenhouse gas. To overcome the challenge of N loss, research efforts have focused on finding mitigation solutions for N_2O emissions and nitrate (NO_3^-) leaching in grazing livestock systems. One approach is the use of chemical nitrification inhibitors (NIs) to reduce the microbial metabolism involved in the conversion of ammonium to NO_3^-. However, while effective, current chemical NIs have drawbacks. For example, nitrapyrin and 3, 4-dimethylpyrazole phosphate (DMPP) have not always been suitable for use in grazed pasture systems due to their physicochemical properties (e.g. volatility) or toxicity. To discover new chemical NIs against the key AOB *Nitrosomonas europaea* we developed a high throughput assay based on the nitrite (Griess assay) assay in 96-well microtiter plates. The method was validated using well-characterised inhibitors of ammonium oxidation, and additionally, we screened the commercial Screen-Well® Natural Product Library as a proof-of-principle for our assay. The developed method provides a foundation for screening commercial compound libraries to discover novel NIs for the mitigation of N loss from grazed pasture soils.

Keywords: Ammonia-oxidizing bacteria, Nitrous oxide (N_2O), Nitrite, Ammonium, *Nitrosomonas europaea*, Nitrification Inhibitors, Mitigation, High-throughput Screen.

Effect of excreta type, season and tropical pasture management on NH_3 volatilization: an indirect source of N_2O

Abmael da Silva Cardoso[1], Vanessa Zirondi Longhini[1], Liziane de Figueiredo Brito[1], Rodolfo Nussio Lumasini[1], Ricardo Andrade Reis[1], Ana Cláudia Ruggieri[1]

[1]Departamento de Zootecnia da Universidade Estadual Paulista "Júlio de Mesquita Filho", UNESP, Jaboticabal, São Paulo, Brazil

Corresponding author. E-mail:abmael.cardoso@unesp.br

Ammonia (NH_3) is an important indirect source of nitrous oxide (N2O). According intergovernmental pannel on climate change (IPCC) 1% of N lost as NH3 is emitted as N2O. In this work we aimed to analyze the effect of type of excreta, pasture management and season on NH3 losses from bovine excreta in tropical pasture. We used data from seven trials that measured NH3 volatilization using the semi-open static chamber methodology from 2012 and 2018 in tropical pasture (Urochloa brizantha cv. marandu grass). The treatments were 2 type of excreta (urine and faeces), 2 season (rainy and dry) and 3 pastures management (non-fertilized, fertilized and consorciation legume-grass). Excreta type and season affect NH3 volatilization and this effect follow the same pattern within season and pasture management. Overall NH3 losses from urine averaged 11% and from faeces 4%, which probably occur due to the N form in each excreta. During the rainy season NH_3 volatilization was 6% and during dry season was 9%, maybe because in rainy season more N is leached. The IPCC default NH3 emission factor is 20% that is higher than NH3 losses observed in the 7 sevens trials here investigated. Maybe indirect N_2O emissions are overestimated due the higher EF for NH3 losses from cattle excreta. Based in the 7 experiments conducted by us in tropical pasture, desegregating the EF for NH3 volatilization from cattle excreta is recommended.

Keywords: inventories, N pollution, indirect N_2O, cattle excreta

Acknowledgments: We thanks the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) for financial support (#2012/06718-8; #2017/11274-5), Conselho Nacional de Desenvolvimento Tecnológico e Científico (CNPq) and the Coordenação de aperfeiçoamento pessoal de nível superior (CAPES) for the scholarships.

Effects of Nitrification Inhibitors on NH_3 and N_2O Emissions from Beef Cattle Urine Patches on a Semiarid Native Pasture

Xiying Hao[1], Jessica Stoeckli[2], Courtney Soden[1], Ben W. Thomas[2], Jennifer Owens[1]

[1]Lethbridge Research and Development Centre, Agriculture and Agri-Food Canada, Lethbridge, AB, Canada
[2]Agassiz Research and Development Centre, Agriculture and Agri-Food Canada, Agassiz, BC, Canada
Presenting author: xiying.hao@Canada.ca

We assessed the effects of two nitrification inhibitors [nitrapyrin and dicyandiamide (DCD)] on NH_3 and N_2O emissions, and their emission factors (EF), from beef cattle urine patches on a semiarid native pasture with a sandy soil texture in Southern Alberta, Canada. Gas fluxes were measured over 12 months in Year One (May 26, 2017 and June 1, 2018) and only during the grazing season in Year Two (May 30 to September 19, 2018). Urine, with and without nitrification inhibitors, and a deionized water control were applied twice each year (on Days 0 and 56 of each year). Most (> 95%) NH_3 emissions occurred in the four months after the first urine application, equating to 3.2-4.3% of urine-N, and NH_3 emission was not affected by nitrification inhibitors in either year. Large pulses of N_2O emissions occurred nine months after the last urine application. The N_2O EF is lower with nitrapyrin (EF=0.118%) than urine alone (EF=0.218%) or urine with DCD (EF=0.235%) in Year One. In Year Two, the N_2O EF values over the grazing season ranged from 0.042 to 0.064% and were not affected by either nitrification inhibitor. Urine N_2O EFs for this native pasture were lower than the 2% IPCC default value. Nitrapyrin may reduce the amount of N lost as N_2O from urine patches in semiarid native pastures. When compiling the national greenhouse gas inventory, the contribution of cattle urine on native pastures should take climate and site conditions into consideration.

Keywords: greenhouse gas, ammonium, dry mixedgrass prairies eco-region, native pasture, cattle grazing, emission factor.

Evidence that condensed tannin may mitigate N_2O emission from bovine urine

Débora Siniscalchi[1], Abmael da Silva Cardoso[1], Darlena Caroline da Cruz Correa[1], Ana Cláudia Ruggieri[1] e Ricardo Andrade Reis[1]*

[1]Departamento de Zootecnia da Universidade Estadual Paulista "Júlio de Mesquita Filho", UNESP, Jaboticabal, São Paulo, Brazil

*Corresponding author. E-mail: ricardo.reis@unesp.br

Phytogenic additives can affect the population of microorganisms and consequently the emission of nitrous oxide (N2O). The objective of this study was to quantify the urine N2O emissions of Nellore bulls with increasing additions of condensed tannin. A completely randomized design incubation with three treatments and five replications was performed. The treatments were tannin doses in the proportion of 0, 0.5 and 1% added to the urine. The N2O production was quantified using the static chamber methodology and determination of the N2O concentration by gas chromatography. N2O emission differed between treatments and weeks. In the first week the averages were -0.41, 126.18 and 89.15µg of N-N2O m^{-2} h^{-1} for 0, 0.5 and 1%, respectively. In the second week the averages were 1.18, 1168.13 and 772.32µg of N-N2O $m^{-2}h^{-1}$ for zero, moderate and high doses, respectively. In the third week the averages were 339, 559 and 520 µg of N-N2O m^{-2} h^{-1} for zero, moderate and high tannin dose, respectively. In the fourth week the averages were 138, 18 and 24 µg of N-N2O m^{-2} h^{-1} for zero, moderate and high, respectively. Initially the addition of condensed tannin stimulates N2O production, this effect ceased after 15 days of application, probably due to the action of the tannin on the N-organic, facilitating N2O production. However, when analyzing the data of the whole period of evaluation, N2O emissions decreased with high dose of tannin.

Keywords: Phytogenic Additive, N2O Mitigation, Climate Change, Animal Supplementation.

Acknowledgments: We thanks the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) for financial suporte (# 2015/16631-5) and the Coordenação de aperfeiçoamento pessoal de nível superior for the scholarships.

Greenhouse gas emissions from pen surfaces at a Texas High Plains beef cattle feedyard

Kenneth D. Casey[1], David B. Parker[2], Heidi M. Waldrip[3], Mindy J Spiehs[4], and Bryan L. Woodbury[5]

[1]Ph.D. Associate Professor, Texas A&M AgriLife Research, Amarillo, TX
[2]Ph.D. Research Agricultural Engineer, USDA-ARS, Bushland, TX
[3]Ph.D. Research Soil Chemist, USDA-ARS, Bushland, TX
[4]Ph.D. Research Animal Scientist, USDA-ARS, Clay Center, NE
[5]Ph.D. Research Agricultural Engineer, USDA-ARS, Clay Center, NE

Nitrous oxide (N_2O) and methane (CH_4), are produced by manure management systems at beef cattle feedlots. In April and August 2018 trials, six automated Licor Long-Term chambers were set up on a grid within a recently vacated feedyard pen in semiarid West Texas (average annual rainfall 500 mm). Chambers closed hourly with headspace gas concentrations measured by Los Gatos Enhanced Performance analyzers. The pen surface condition was dry and dusty with friable material overlaying compacted manure of variable thickness during both trials. The temperature during the trials averaged 12.1°C and 23.4°C, respectively. Fluxes were monitored for 48 hours before 12.7 mm of simulated rainfall was added to each chamber base to mimic the most significant, flux perturbating factor. Monitoring continued for a further 48 hours in spring and 96 hours in summer. Rainfall increased N_2O emissions but decreased CH_4 emissions. There was considerable temporal and spatial variation in fluxes. The average N_2O-N flux before the simulated rainfall event during the trials was 0.198 and 2.68 mg m^{-2} h^{-1} respectively. In the 2 days post rainfall, the average N_2O-N fluxes were 0.919 and 4.47 mg m^{-2} h^{-1}, respectively. The average CH_4 fluxes during the trials were 2.022 and 1.56 mg m^{-2} h^{-1}, respectively before the simulated rainfall event. In the post rainfall period, the average CH_4 fluxes were 0.771 and 0.629 mg m^{-2} h^{-1}, respectively. Data from this and other field and laboratory trials will be used to inform emissions inventories and to enhance the process-based understanding of these emission processes.

Index Terms: nitrous oxide, methane, manure.

N_2O emissions in tropical grassland was affect by N source but not by N rates

Darlena Caroline da Cruz Correa[1], Abmael da Silva Cardoso[1], Thais Ribeiro Brito[1], Débora Siniscalchi[1], Ricardo Andrade Reis[1] and Ana Cláudia Ruggieri[1]*

[1]Departamento de Zootecnia da Universidade Estadual Paulista "Júlio de Mesquita Filho", UNESP, Jaboticabal, São Paulo, Brazil

Corresponding author. E-mail: ana.ruggieri@unesp.br

Grasslands cover extensive areas in the tropical areas of the Earth. Nitrogen fertilization of grassland can lead to N_2O emissions a potent greenhouse gas. We aimed to quantify N_2O emissions from different sources of nitrogen fertilizer (urea, ammonium nitrate and ammonium sulphate applied at different rates (0, 90, 180 and 270 kg N ha-1). The experimental design was randomized block with four repetitions. The fertilizers were applied to marandu-grass (*Urochloa brizantha*) during the grass growing season split in 3 times. The static closed chambers methodology was used to quantify N_2O production and gas chromatography to measure N_2O concentrations (minimal detection limit ± 0.03µg). The evaluations occurred for 365 days. Only N source affect N_2O emissions (P=0.007), while N rate (P=0.63) and interactions (P=0.23) did not affected. The annual emissions averaged -11.31, 9.28 and 8.95 µg N-N_2O m^{-2} h^{-1} for urea, ammonium nitrate and ammonium sulphate, respectively. Over the year N_2O consumption occurred in all treatments, mainly in the urea treatment. The calculated EFs, only for the growing season, were 0.01, 0.44 and 0.45% for urea, ammonium nitrate and ammonium sulphate, respectively. These emissions factors are lower than that of 1% used for national inventories of N_2O. Urea appears to be an option to mitigate N_2O emissions.

Keywords: Nitrogen fertilization, tropical grassland, N_2O consumption, grassland management.

Acknowledgments: We thanks the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) for financial suporte (# 2015/16631-5) and the Coordenação de aperfeiçoamento pessoal de nível superior for the scholarships.

Potential N_2O producer located in dairy manure compost surface

Koki Maeda[1], Lashitha Rathnayake[2], Hisashi Satoh[2], Sakae Toyoda[3], Laurent Philippot[4], Shohei Hattori[3], Keiichi Nakajima[1] and Naohiro Yoshida[3]*

[1]NARO, National Agricultural Research Center for Hokkaido Region, Dairy Research Division, 1 Hitsujigaoka, Sapporo 062-8555, Japan

[2]Division of Environmental Engineering, Faculty of Engineering, Hokkaido University,

North-13, West-8, Sapporo 060-8628, Japan

[3]Department of Environmental Chemistry and Engineering, Tokyo Institute of Technology, 4259 Nagatsuta, Midori-ku, Yokohama 226-8502, Japan

[4]INRA, UMR 1229, Soil and Environmental Microbiology, 17 rue Sully BP 86510,

21065 Dijon cedex, France

*Corresponding author (k_maeda@affrc.go.jp), Tel; +81-29-838-6365 Current address: JIRCAS, Crop, Livestock & Environment Division, 1-1 Ohwashi, Tsukuba, Ibaraki 305-8686, Japan.

Compost surface is the important source of the greenhouse gas nitrous oxide (N2O) in the dairy manure composting system. Here we observed N2O, nitric oxide (NO) and oxygen profile determined by microsensor measurement. Also, we performed the incubation experiments with enhanced (by NO2 addition) and suppressed (with antibiotics treatment) N2O production to identify the bacterial group which is responsible for N2O production by tracking the change of the bacterial community with 16S rRNA gene amplicon sequencing. Isotopic analysis of N2O was also performed to understand its source. Significant N2O and NO concentrations (up to 645.3 ppm and 8.4 μM) were observed, which clearly shows that significant nitrification/denitrification is occurring *in situ*. Isotopic signature implies that these N2O coming from bacterial denitrification pathway. The incubation experiment revealed that the bacteria which belong to classes *Sphingobacteria* and *Flavobacteria* seems to be responsible for denitrification and significant N2O production which occurs just after the pile turning events.

Keywords: N2O, compost, denitrifying community, microsensor, isotopocule.

Targeting farm scale features for nitrification inhibitor application: an effective N_2O mitigation strategy?

Karina A. Marsden[1,2], Camila A. dos Santos[3], Johannes Friedl[4], David Rowlings[4], Helen Suter[2], Richard Eckard[2], and Dave R. Chadwick[1]

[1]School of Natural Sciences, Bangor University, Bangor, Gwynedd, LL57 2UW, UK
[2]Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, Parkville, Victoria 3010, Australia
[3]Soil Departament, Federal Rural University of Rio de Janeiro, Seropédica, Rio de Janeiro, Brazil.
[4]Institute for Future Environments, Queensland University of Technology, Brisbane, QLD 4000, Australia

The movement and behaviour of grazing livestock can influence the fate of nitrogen at the farm scale. Features such as gateways, shaded areas, laneways and soil areas around drinking troughs are potential hotspots of emissions of the powerful greenhouse gas, nitrous oxide (N2O). Here, elevated excretal loads can supply substrates (N-rich urine and C-rich dung) which fuel N2O production processes, with elevated compaction also creating favourable conditions for denitrification. Nitrification inhibitors are a potential technology to reduce N losses from dairy pastures, but their effectiveness in reducing both N2O and N2 emissions from features where livestock congregate have not been widely studied. Utilising an automated chamber system N2O emissions were monitored from a Vertosol soil at a dairy pasture in subtropical Australia, with the following treatments: i) control (0 kg N ha^{-1}), ii) urine (344 kg N ha^{-1}) applied to standard pasture, iii) urine applied near a gateway, and iv) urine + DMPP (1L ha^{-1}) applied near a gateway. Overall N2O emissions were slightly higher from the gateway (391 ± 102 mg N2O-N m^{-2}) than the standard pasture (324 ± 40 mg N2O-N m^{-2}), however, DMPP did not significantly reduce cumulative N2O-N (413 ± 34 mg N2O-N m^{-2}) or $NO3^-$ accumulation from urine applied to soil around a gateway. In conclusion, under the conditions of this study, DMPP was not found to be an effective N2O mitigation strategy for soils highly frequented by livestock.

1.2 Methane (Oral)

Breeding for lowered methane emissions in New Zealand Sheep*

Suzanne J Rowe[1], Sharon M Hickey[2], Arjan Jonker[3], Peter H Janssen[4], Ken Dodds[5], Melanie Hess[6], Tricia Johnson[7], Erin Waller[8] and John C McEwan[9]

[1]PhD Senior Scientist. AgResearch, Puddle Alley, Mosgiel, 9092 New Zealand
[2]MSc. Research Scientist. AgResearch, Ruakura, Hamilton, New Zealand
[3]PhD. Research Scientist. AgResearch, Grasslands, Palmerston North, New Zealand
[4]PhD. Principal Scientist. AgResearch, Grasslands, Palmerston North, New Zealand
[5]PhD. Principal Scientist. AgResearch, Puddle Alley, Mosgiel, 9092 New Zealand
[6]PhD. Postdoctoral Scientist. AgResearch, Puddle Alley, Mosgiel, 9092 New Zealand
[7]PhD Senior Scientist. AgResearch, Puddle Alley, Mosgiel, 9092 New Zealand
[8]BSc Field Technician. AgResearch, Puddle Alley, Mosgiel, 9092 New Zealand
[9]BSc Principal Scientist. AgResearch, Puddle Alley, Mosgiel, 9092 New Zealand

New Zealand is heavily reliant on pastoral based agriculture and has a national sheep flock of ~18.5 million breeding ewes. Maternal sheep production is reliant on the ewe overwintering and successfully rearing at least one lamb. The sustainability and profitability of this system, however, is facing a new challenge as awareness grows of the magnitude and impact of ruminant methane emissions on the environment. Ruminant enteric methane emissions are responsible for a third of New Zealand's total greenhouse gas emissions. Strategies limiting methane from ruminants have been put forward to protect the environment and to maintain global food security. Independent breeding strategies exist for increased production and for reduced methane emissions but, to date there has been no data to show whether these breeding objectives might be synergistic, neutral or antagonistic. Ten years ago, a divergent flock of sheep was created to evaluate selection for methane and to monitor the effects of this selection. Initially, sheep were ranked for breeding using methane measures from respiration chambers. Subsequently, a number of proxies have been investigated and effects of selection on methane emissions, production traits, feed intake, carcass and milk quality have been evaluated. Here we describe the main results and describe the flock divergence over the ten-year period. Low methane animals have ~12% less methane than sheep from the high line, appear economically favourable, grow more wool, have different microbiomes and differ in fatty acid profiles in muscle.

Terms for Indexing: genomics, portable accumulation chambers, methane yield, microbiomes, ovine, ruminant emissions.

*Funded by the New Zealand Agricultural Greenhouse Gas Centre and the Pastoral Greenhouse Gas Research Consortium

Development of a bovine rumen-specific amplicon sequencing standard

Paul E Smith[1], Ruth Gómez Expósito[2], Joan E Edwards[3], Sinéad M Waters[4], Matthew S McCabe[5]

[1]B.Agr.Sc, PhD Research Student, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

[2]PhD, Post-Doctoral Researcher, Laboratory of Microbiology, Wageningen University, Postbus 8033, 6700 EJ Wageningen, the Netherlands

[3]PhD, Principal Research Officer, Laboratory of Microbiology, Wageningen University, Postbus 8033, 6700 EJ Wageningen, the Netherlands

[4]PhD, Principal Research Officer, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

[5]PhD, Research Technologist, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

In recent years, amplicon sequencing has been widely adopted to identify rumen microbes that generate approximately 40% of global agriculture's greenhouse gas emissions. This has enabled unprecedented insight into these highly complex and dynamic communities which are largely recalcitrant to in vitro culture. However, rumen NGS analyses are currently often conducted with no validation of the complex laboratory and computational methods that are employed. Surprisingly, many such studies are still published without the inclusion of internal positive controls. While commercial internal microbial mock communities (either cellular and DNA-based) are available for human bacterial and yeast pathogens, controls should be specific to the environment under investigation in order to evaluate biases in library preparation and whether the databases that are used in the analyses are accurate, appropriate and comprehensive. Through the international collaboration *RumenPredict*, a rumen-specific amplicon sequencing standard, comprised of 16S/18S/ITS synthetic sequences from common rumen microbes, has been developed. This standard was sequenced in 3 separate 16S rRNA amplicon Illumina MiSeq sequencing runs. Sequence analysis was conducted using DADA2 to generate amplicon sequence variants. Four 16S rRNA databases (RefSeq, SILVA, RDP and Genome Taxonomy Database) were assessed for the accurate taxonomic assignments. The greatest accuracy of assignments was achieved with the RefSeq database. This allowed correct identification of all 3 of the archaea sequences and 12 of the 13 bacteria to the correct genus level. Good concordance (r_S0.88-0.92) was observed between the taxonomy profiles that were generated by the 3 separate sequencing runs.

Index terms: bos taurus, next generation sequencing, rumen microbiome.

Enteric methane emission and lactational performance of dairy cows fed 3-nitrooxypropanol

Audino Melgar Moreno[1], Camila. F. de Asis Lage[2,3], Krum Nedelkov[2,4], Susanna E. Räisänen[1], Hannah A. Stefenoni[1], Molly E. Young[5], Xianjiang Chen[2,6], Joonpyo Oh[7], Stephane Duval[8], Maik Kindermann[8], Nicola D. Walker[8], and Alexander N. Hristov[9]

[1]Graduate Student, Department of Animal Science, The Pennsylvania State University, University Park, PA 16802, United States

[2]Visiting Scientist. Department of Animal Science, The Pennsylvania State University, University Park, PA 16802, United States

[3]Universidade Federal de Minas Gerais, Brazil

[4]Faculty of Veterinary Medicine, Trakia University, Stara Zagora, Bulgaria

[5]Laboratory Technician, Department of Animal Science, The Pennsylvania State University, University Park, PA 16802, United States

[6]College of Pastoral Agriculture Science and Technology, Lanzhou University, China

[7]Postdoctoral Researcher, Department of Animal Science, The Pennsylvania State University, University Park, PA 16802, United States

[8]DSM Nutritional Products, Switzerland

[9]Professor, Department of Animal Science, The Pennsylvania State University, University Park, PA 16802, United States

This study evaluated effects of 3-nitrooxypropanol (3-NOP), an investigational product, on enteric methane emission and lactational performance of Holstein cows. Forty multi- and primiparous cows (118 ± 28 days in milk) were blocked and fed a control diet or a diet containing 60 mg 3-NOP/kg feed dry matter for 15 consecutive weeks. Enteric gaseous emissions were measured using the GreenFeed system. Data were analyzed using PROC MIXED of SAS as repeated measures. Compared with control, 3-NOP decreased ($P < 0.001$) daily methane emission (411 vs. 302 g/d; SEM = 6.16), yield (16.4 vs. 11.9 g/kg dry matter intake; SEM = 0.25), and intensity (11.5 vs. 8.2 g/kg energy corrected milk; SEM = 0.28). Treatment increased ($P < 0.001$) hydrogen emission (0.44 vs. 2.55 g/cow/d; SEM = 0.119) and had no effect on carbon dioxide emission ($P = 0.27$). Dry matter intake, milk yield, and cow body weight change were not affected ($P \geq 0.45$) by 3-NOP (mean ± SEM: 25.6 ± 0.38 kg/d, 38.4 ± 0.63 kg/d, and 458 ± 50.9 g/d, respectively). Treatment increased ($P = 0.01$) milk fat concentration (3.83 vs. 4.08%; SEM = 0.064), tended to increase ($P = 0.07$) fat yield, increased ($P = 0.04$) milk urea nitrogen (11.6 vs. 12.1 mg/dL; SEM = 0.175) and had no other effects on milk components. In this experiment, 3- NOP decreased daily enteric methane emission by 26% and methane yield (27%) and intensity (29%) without affecting feed intake and milk yield and increased milk fat in lactating dairy cows.

Keywords: dairy cattle, 3-nitrooxypropanol, enteric methane, milk fat.

Heat production and methane emission measured using a face mask method in growing dairy heifers

Tainá Silvestre[1], Luis Gustavo Ribeiro Pereira[2], Fernanda Samarini Machado[2], Thierry Ribeiro Tomich[2], Mariana Magalhães Campos[2] and Paulo Henrique Mazza Rodrigues[3]

[1]Undergraduate student of University of São Paulo, College of Veterinary Medicine and Animal Science, University of Sao Paulo, Pirassununga, Brazil

[2]PhD of Federal University of Minas Gerais, Reseacher of Brazilian Agricultural Research Corporation, Embrapa Dairy Cattle, Juiz de Fora, Brazil

[3]PhD of University of São Paulo, Professor of the College of Veterinary Medicine and Animal Science, University of Sao Paulo, Pirassununga, Brazil

The aim of this study was to estimate heat production (HP) and methane emission (CH_4) from growing dairy heifers that were fed different nutritional plans (NP). Thirty-six heifers (12 Holstein, 12 Gyr and 12 Holstein x Gyr crossbred) were distributed into 2 blocks in a 3x3 factorial arrangement (3 NP x 3 genotypes). Heifers were randomly distributed to one of three different NP: 1) 1.0x maintenance, 2) 1.5x maintenance and 3) 2.0x maintenance. Heifers were fed a diet consisting of 85.0% corn silage and 15.0% concentrate mixture on a dry matter basis. The HP and CH_4 were estimated using the face mask method. Dry matter intake and and metabolizable energy intake were lower ($p<0.05$) for Gyr heifers (3.88 kg/d and 9.41 Mcal/d) compared to the others. Body weight (BW) was affected ($p<0.05$) by genotype, and Gyr heifers also had less BW (240.2 kg) compared to the Holstein-Gyr heifers. The HP, expressed in Mcal per metabolic body weight (Mcal/BW0.75), was affected ($p<0.05$) by genotype, and Gyr heifers presented reduced HP (163.2) compared to Holstein heifers (201.0). An interaction ($p<0.05$) between the genotype and the NP was found in CH4 emission in grams per day and grams per kg of BW0.75. Our findings demonstrates that only in the 1.5x and 2.0x maintenance level Gyr heifers CH_4 emissions were lower compared to Holstein and Holstein x Gyr, respectively. No differences between genotypes and NP were found in the results of the CH4 yield (CH4 in g/kg DMI).

Index terms: cattle, genotype, sustainability

Inhibition of enteric methanogenesis in cows induces changes in plasma metabolome highlighting potential emission markers[1]

Bénédict Yanibada[1], Ulli Hohenester[2], Mélanie Pétéra[3], Cécile Canlet[4], Stéphanie Durand[5], Fabien Jourdan[6], Cécile Martin[7], Maguy Eugène[8], Diego P. Morgavi[9] and Hamid Boudra[10]

1PhD, Research engineer, Université Clermont Auvergne, INRA, VetAgro Sup, UMR Herbivores, Saint-Genès-Champanelle, France

2PhD, Research engineer, Université Clermont Auvergne, INRA, VetAgro Sup, UMR Herbivores, Saint-Genès-Champanelle, France

3MSc, Study engineer, Université Clermont Auvergne, INRA, UNH, Plateforme d'Exploration du Métabolisme, MetaboHUB Clermont, F-63000 Clermont-Ferrand, France

4PhD, Research engineer, Toxalim, Research Centre in Food Toxicology, Université de Toulouse, INRA, ENVT, INP-Purpan, UPS, F-31027, Toulouse, France/ Axiom Platform, MetaToul-MetaboHUB, National Infrastructure for Metabolomics and Fluxomics, F-31027, Toulouse, France

5PhD, Research engineer, Université Clermont Auvergne, INRA, UNH, Plateforme d'Exploration du Métabolisme, MetaboHUB Clermont, F-63000 Clermont-Ferrand, France

6PhD,, Director of research, Toxalim, Research Centre in Food Toxicology, Université de Toulouse, INRA, ENVT, INP-Purpan, UPS, F-31027, Toulouse, France/ Axiom Platform, MetaToul-MetaboHUB, National Infrastructure for Metabolomics and Fluxomics, F-31027, Toulouse, France

7PhD, Director of research, Université Clermont Auvergne, INRA, VetAgro Sup, UMR Herbivores, Saint-Genès-Champanelle, France

8PhD, Research engineer, Université Clermont Auvergne, INRA, VetAgro Sup, UMR Herbivores, Saint-Genès-Champanelle, France

9PhD, Director of research, Université Clermont Auvergne, INRA, VetAgro Sup, UMR Herbivores, Saint-Genès-Champanelle, France

10PhD, Research engineer, Université Clermont Auvergne, INRA, VetAgro Sup, UMR Herbivores, Saint-Genès-Champanelle, France

[1]This study is part of collaborative project led by INRA and funded by 11 institutes and private companies: Adisseo France SAS (Antony, France), Agrial (Caen, France), APIS-GENE (Paris, France), Deltavit (Janzé, France), DSM Nutritional Products AG (Kaiseraugst, Switzerland), Institut de l'Elevage (Paris, France), Lallemand (Blagnac, France), Moy Park Beef Orléans (Fleury-les-Aubrais, France), Neovia (Saint-Nolff, France), Techna France Nutrition (Couëron, France), Valorex (Combourtillé, France).

There is scarce information on whether inhibition of rumen methanogenesis induce metabolic changes on the host ruminant. Understanding these possible changes is important for the acceptance of methane-reducing practices by producers. In this study we explored the changes in plasma profiles associated with the reduction of methane emissions. Plasma samples were collected from lactating primiparous Holstein cows fed the same corn silage- based diet with (Treated, n=12) or without (Control, n=13) an anti-methanogenic feed additive for six weeks. We used a specific anti-methanogenic compound that inhibits the last step of methanogenesis and has no known effect on the host animal metabolism. Methane emissions (g CH_4/d), measured in open-circuit respiration chambers in week five, were reduced by 23% in the Treated group with no changes in milk production, feed intake, body weight, and health status. Plasma metabolome analyses were performed using untargeted (nuclear magnetic resonance and liquid chromatography-mass spectrometry (LC-MS)) and targeted (LC-MS/MS) approaches. We identified 47 discriminant metabolites. Some metabolites, mainly of microbial origin, can be related to rumen methanogenesis and can potentially be used as markers. The other discriminant metabolites are produced by the host or have a mixed microbial-host origin. These metabolites, which increased in treated cows, belong to general pathways of amino acids and energy metabolism suggesting a systemic effect on the animal.

Index terms: *Bos taurus*, methane, metabolomics, NMR, LC-MS

Machine learning ensemble algorithms in predictive analytics of dairy cattle methane emission using imputed *versus* non-imputed datasets

Enyew Negussie[1], Oscar González Recio[2], Yvette de Haas[3], Nicolas Gengler[4], Hélène Soyeurt[5], Nico Peiren[6], Marcin Pszczola[7], Phil Garnsworthy[8], M. Battagin[9], Alireza Bayat[10], Jan Lassen[11], Tianhai Yan[12], Tommy Boland[13], Björn Kuhla[14], Tomasz Strabel[15], Angela Schwarm[16] , Amélie Vanlierde[17] and Filippo Biscarini[18]

[1,10]Animal Genetics, Natural Resources Institute (Luke), Myllytie 1, 31600 Jokioinen, Finland
[2]INIA, 28040 Madrid, Spain
[3]ABGC-WUR, Wageningen, The Netherlands
[4,5]University of Liège, Gembloux, Belgium
[6]ILVO, Merelbeke, Belgium
[7,15]Poznan University, Poznan, Poland
[8]University of Nottingham, Nottingham, UK
[9]Roslin Institute, Edinburgh, UK
[11]Viking Genetics Randers, Denmark
[12]AFBI, Hillsborough, UK
[13]University College Dublin, Dublin, Ireland
[14]Leibniz Institute, Dummerstorf, Germany
[16]ETH, Zürich, Switzerland
[17]CRA-W, BEL-5030 Gembloux, Belgium
[18]CNR-IBBA, Via Bassini 15, 20133 Milan, Italy enyew.negussie@luke.fi (Corresponding Author)

The use of machine learning (ML) algorithms in predictive modelling of CH4 emission from heterogeneous across-country datasets containing missing or imputed data-points is rarely reported. The objective was to use ML ensemble algorithms to predict CH4 output and assess the effects of imputation on within and between-herd prediction accuracies. Data was from dairy cattle CH4 production and related proxies from 16 herds across 10 European countries. Two datasets were used: the first had no dry matter intake (DMI) whilst in the second DMI imputed using non-parametric k-nearest neighbor approach was included. The final dataset contained 48,804 observations from 2,391 cows. Milk yield, fat and protein, days in milk (DIM), DMI, herd, country, CH4 measurement method and breed were the proxies in the prediction model. For the predictive analysis, ML ensemble algorithm Random Forest (RF) was used. The predictive ability of RF models was estimated using three different metrics. Feature importance, in terms of percent increase in node purity showed that DMI, milk, DIM, fat, body weight, protein, herd, CH4 measurement method and breed were important proxies. When DMI was imputed, normalized discounted cumulative gain increased by 0.02 – 0.48 points indicating improved prediction accuracies. Overall, RF model prediction accuracy was 0.82 and 0.81 for with and without imputed DMI, respectively. In predictive modelling involving heterogeneous across- country data ML algorithms proved robust. Traits based on such information could be used to monitor emissions in national, regional inventories as well as farm management tools assisting informed herd improvement decisions.

Terms for indexing: enteric methane, ruminants, random forest, prediction accuracy

Measurement of the enteric emission factor of methane of dairy goats in Taiwan

Churng-Faung Lee[1], Chia-Hui Wang[2], Geng-Jen Fan[3], and Tzong-Faa Shiao[4]

[1]Ph. D of the University of Wisconsin-Madison, Researcher and Chief of Animal Nutrition Division, Livestock Research Institute, Tainan, Taiwan, Republic of China.

[2]Master degree of the National Pingtung University, Assistant of AND, LRI.

[3]Master degree of the National Chung-Hsing University, Assistant Researcher of AND, LRI.

[4]Ph. D of the National Taiwan University, Researcher of Animal Industry Division,
LRI.

It is aimed to establish the country values of GHG emission from livestock sector as the mitigation basis. Four stages of Alpine female goats, nursing, growing, dry, and lactating, were measured sequentially. Their numbers, age and BW were 15 head, 3-mon-old and 15 kg; 8, 8 and 33; 5, 26 and 44; and 8, 38, 54 and 3.1 kg milk yield. Nursing goats were fed on milk replacer and grain mixture. Totally mixed ration for the other three groups included corn silage, alfalfa hay, wet brewer's grains, soybean hull pellet, and grain mixture. After adapted to diet, goats were moved into the ventilation-controlled stainless chamber, with 23.4 m^3 volume, for one to three days. Twelve pairs of gas samples taken from air inlet and exhaust tube in 24 hrs were analyzed for CH_4 and CO_2. Difference of the gas content, air velocity, temperature, and gas recovery of the chamber were calculate for the daily CH_4 and CO_2 emission factors. They are 6.4, 18.4, 26.6, and 57.4 g per head for CH_4 for four groups, respectively. By times the percentage of each group in the herd, the weighted CH_4 emission factor for dairy goat in Taiwan is 12.03 kg a head a year. The CO_2 emission factor is 374.8 kg.

Keywords: Alpine dairy goats, carbon dioxide, chamber, methane

Methane emissions and post-ruminal protein supply of tropical pasture *Brachiaria hybrid* cv. Cayman diets with inclusion of Leucaena

Xiomara Gaviria Uribe[1,3], Joaquín Castro-Montoya[2], Diana María Bolívar[1], Ngonidzasche Chirinda[3], Rolando Barahona[1], Uta Dickhoefer[2] and Jacobo Arango[3].*

[1]Grupo de Investigación BIOGEM, Facultad de Ciencias Agrarias, Departamento de Producción Animal, Universidad Nacional de Colombia. Street 59 A # 63-20 (+57 4) 4309000 Medellín-Colombia; xgaviri0@unal.edu.co, dmboliva@unal.edu.co, rbarahonar@unal.edu.co

[2]Institute of Agricultural Sciences in the Tropics, Animal Nutrition and Rangeland Management in the Tropics and Subtropics, Hohenheim University, Stuttgart, Germany; JoaquinMiguel.CastroMontoya@uni-hohenheim.de, uta.dickhoefer@uni-hohenheim.de

[3]Soils and Tropical Forages Programs of the International Center for Tropical Agriculture (CIAT). Km 17 Palmira-Colombia; x.gaviria@cgiar.org, j.arango@cgiar.org, n.chirinda@cgiar.org

*Correspondence: xgaviri0@unal.edu.co; Tel.: (+57) 350 4785304

Tropical forages with high content of tannins (e.g., *Leucaena* genus), have the capacity to modify rumen fermentation paramenters. However, the concentration and activity of tannins varies between sources and interact with other characteristics of the substrate available for fermentation. This study evaluated the effects of tannins presented in *Leucaena leucocephala* (Ll) and *Leucaena diversifolia* (Ld) in methane emissions and post-ruminal protein supply. For this, Ll and Ld were incubated using the Hohenheim Gas Test, in two proportions (25% and 50%) with *Brachiaria* grass hybrid cv. Cayman with and without polyethylenglycol (PEG). Results showed that inclusion of PEG increased gas production in Ll and Ld treatments confirming the activity of tannins. Greatest increment in gas production (GP) were observed for Ll indicating a greater activity of tannins in this forage legume. Overall, Ll showed higher GP than Ld and GP decreased with increasing levels of legume (50%). Methane production was lower for treatments including Ll and Ld, with active tannins, than for the Ll and Ld+PEG, highlighting the inhibitory effect of tannins on CH4 production. Major CH_4 mitigation was observed for treatments with 25% of inclusion Ld compared with the ones with Ll (15.8 vs 18.5 mg of CH_4/ g DM incubated). The total amount of nitrogen in undegraded feed+microbial mass after the *in vitro* incubation increases in treatments containing tannins from Ll and Ld, indicating an increase in protein degradation. These results suggest that the activity of tannins can modify ruminal fermentation, improving the energy use efficiency for cattle.

Keywords: Condensed tannins, ruminal fermentation, tropical forages, greenhouse gases.

Selective breeding as a mitigation tool for methane intensity of dairy cattle

Yvette de Haas[1], Erwin P.C. Koenen[2] and Roel F. Veerkamp[1]

[1]Animal Breeding and Genomics of Wageningen University and Research, P.O. Box 338, 6700 AH Wageningen, the Netherlands Yvette.deHaas@wur.nl

[2]CRV, P.O. Box 454, 6800 AL Arnhem, the Netherlands

The global livestock sector, particularly ruminants, contribute substantially to the total anthropogenic greenhouse gases. Management and diet solutions to reduce enteric methane (CH_4) emissions are extensively researched. Animal breeding that exploits natural variation in CH_4 emissions is an additional mitigation solution that is cost-effective, permanent, and cumulative. We quantified the effect of including CH_4 production in the Dutch breeding goal using selection index theory. The current Dutch national index contains 15 traits, related to milk yield, longevity, health, fertility, conformation and feed efficiency. From literature we obtained a heritability of 0.21 for enteric CH_4 production, and genetic correlations with milk lactose, protein, fat and dry-matter intake of 0.43, 0.37, 0.77 and 0.42, respectively. Correlations between enteric CH_4 production and other traits in the breeding goal were set to zero. When including CH4 production in the current breeding goal with a zero economic value, CH_4 production increases each year with 1.5 g/d as a correlated response. When extrapolating this, the average daily CH_4 production of 392 g/d in 2018 will increase to 440 g/d in 2050 (+12%). However, in the same period the CH_4 intensity (g CH_4/kg milk) will reduce by 13%. By putting an economic weight on CH_4 production in the breeding goal, selective breeding can reduce the CH_4 intensity even by 27% in 2050. This shows that breeding is a valuable contribution to the whole set of mitigation strategies that could be applied in order to achieve the mitigation goals for 2050 set by the EU.

Keywords: *Bos taurus*, genetics, genomics, selection index theory.

The SF_6-technique is a feasible method to estimate the methane emissions from sheep in Norway

Vibeke Lind[1], Aurelia Jud[2], Şeyda Özkan Gülzari[3] and S. Richard O. Williams[4]

[1]PhD Research Scientist, Norwegian Institute of Bioeconomy Research (NIBIO), PB 115, 1431 Ås, Norway

[2]Research Assistant, Norwegian Institute of Bioeconomy Research (NIBIO), PB 115, 1431 Ås, Norway. Present address: Micarna SA, Route de l'Industrie 25, 1784 Courtepin, Switzerland

[3]PhD, Researcher, Norwegian Institute of Bioeconomy Research (NIBIO), PB 115, 1431 Ås, Norway. Present address: Wageningen Livestock Research, Wageningen University & Research, PO Box 338, 6700 AH Wageningen, The Netherlands

[4]M. Eng. Sci. Senior Research Scientist, Agriculture Victoria Research, 1301 Hazeldean Road, Ellinbank, Victoria 3821, Australia

An annual sheep production system in Norway incorporates grazing natural pastures for five months. Yet no measurements of enteric methane emissions from grazing sheep have been performed under Norwegian conditions. A pilot study was conducted with 12 Norwegian White ewes to test the feasibility of using the sulphur hexafluoride (SF_6) tracer technique under Norwegian conditions. The ewes were split onto one of two pastures, mixed grass (*Bromus inermis* dominated, *Poa pratensis*, *Festuca pratensis*) or white clover (*Trifolium repens*). After five days adaptation to pastures, breathe samples were collected into evacuated one L PVC canisters over three consecutive days where capillary tubes (0.38 to 0.42 mL/min initial flow) restricted flow. Gas samples were analysed by gas chromatography. Feed intakes were not recorded. Average live weights were 64 kg and 66 kg for ewes on grass and clover pastures, respectively. Methane emissions were 23.9 g/d from sheep on mixed grass and 28.2 g/d for sheep on white clover. Methane emissions were not correlated (p=0.33) to ewe live weight. One explanation for the 15% difference in methane emission could be differences in feed intake. The few days of sample collection could also explain some of the observed difference since the technique is recommended to be used over five days to reduce errors in observations. This pilot study shows that using the SF6-technique is a feasible method for future research. More experiments measuring enteric methane emission over a longer period from grazing sheep and cattle under Norwegian conditions are planned for the future.

Keywords: Pasture, clover, mixed grass, grazing.

Uncertainties in enteric methane inventories and measurement techniques[1]

A. N. Hristov[2], E. Kebreab[3], M. Niu[3], J. Oh[2], A. Melgar[2], A. Bannink[4], A. R. Bayat[5], T. M. Boland[6], A. F. Brito[7], D. P. Casper[8], L. A. Crompton[9], J. Dijkstra[10], M. Eugène[11], P. C. Garnsworthy[12], N. Haque[13], A. L. F. Hellwing[14], P. Huhtanen[15], M. Kreuzer[16], B. Kuhla[17], P. Lund[14], J. Madsen[13], C. Martin[11], P. J. Moate[18], S. Muetzel[19], C. Muñoz[20], N. Peiren[21], J. M. Powell[22], C. K. Reynolds[9], A. Schwarm[16], K. J. Shingfield[23], T. M. Storlien[24], M. R. Weisbjerg[14], D. R. Yáñez-Ruiz[25], and Z. Yu[26]

[2]Department of Animal Science, The Pennsylvania State University, University Park, PA 16802

[3]Department of Animal Science, University of California, Davis 91616

[4]Wageningen Livestock Research, Wageningen University and Research, 6700 AH Wageningen, the Netherlands

[5]Milk Production Solutions, Green Technology, Natural Resources Institute Finland, 31600 Jokioinen, Finland

[6]School of Agriculture and Food Science, University College Dublin, Belfield, Dublin 4, Ireland

[7]Department of Nutrition, Agriculture, and Food Systems, University of New Hampshire, Durham 03824

[8]Furst McNess Company, Freeport, IL 61032

[9]School of Agriculture, Policy and Development, University of Reading, Earley Gate, RG6 6AR, United Kingdom

[10]Animal Nutrition Group, Wageningen University and Research, 6700 AH Wageningen, the Netherlands

[11]UMR Herbivores, INRA, VetAgro Sup, Université Clermont Auvergne, 63122 Saint-Genès- Champanelle, France

[12]School of Biosciences, University of Nottingham, Loughborough, LE12 5RD, United Kingdom [13]Department of Large Animal Sciences, University of Copenhagen, 1870 Frederiksberg, Denmark

[14]Department of Animal Science, Aarhus University, Foulum, 8830 Tjele, Denmark

[15]Department of Agricultural Science for Northern Sweden, Swedish University of Agricultural Sciences, SE-901 87 Umeå, Sweden

[16]ETH Zurich, Institute of Agricultural Sciences, 8092 Zurich, Switzerland

[17]Institute of Nutritional Physiology, Leibniz Institute for Farm Animal Biology, 18196 Dummerstorf, Germany

[18]Agriculture Victoria, Ellinbank, Victoria 3821, Australia

[19]Ag Research, Palmerston North 4442, New Zealand

[20]Instituto de Investigaciones Agropecuarias, INIA Remehue, Osorno, Región de Los Lagos 5290000, Chile

[21]Animal Sciences Unit, Flanders Research Institute for Agriculture, Fisheries and Food, 9090 Melle, Belgium

[22]USDA-ARS US Dairy Forage Research Center, Madison, WI 53706

[23]Institute of Biological, Environmental and Rural Sciences, Aberystwyth University, Aberystwyth SY23 3EB, United Kingdom

[24]Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences, As 1432, Norway

[25]Estación Experimental del Zaidin, CSIC, 1, 18008 Granada, Spain

[26]Department of Animal Sciences, The Ohio State University, Columbus 43210

There are large uncertainties in national and global livestock enteric methane inventories, including animal numbers, feed dry matter intake (DMI) data, ingredient and chemical composition of animal diets, and methane emission factors. Globally, atmospheric mole fraction of methane has continuously increased since 2006 but there is no consensus about the major drivers for this increase and there is a considerable disagreement regarding the contribution of livestock to global methane emissions. Accurate prediction of methane emissions, for various animal categories and production systems, is important for both inventory and mitigation purposes. Complex prediction models have the disadvantage of requiring inputs that may not be uniformly available or may be inaccurate. Therefore, prediction models based on feed-related data, such as DMI, will likely have wider practical application. Meta-analyses of individual dairy and beef cattle data have shown that models based on DMI alone or DMI and limited feed- or animal-related inputs can

predict average methane emission with a similar accuracy as more complex empirical models. There is also uncertainty associated with enteric methane measurements. The most commonly used techniques for measuring enteric methane emissions are respiration chambers, the sulfur hexafluoride tracer technique, and the automated head chamber system (AHCS). Meta- analyses, however, have shown poor relationship between DMI and methane emission for the latter two techniques. In the case of AHCS, the relationship likely depends on the time of measurement relative to time of feeding and can be improved by matching diurnal DMI and methane emission patterns.

Keywords: enteric methane, uncertainty, dry matter intake, cattle.

[1]This study is part of the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI)'s GLOBAL NETWORK project (https://globalresearchalliance.org/research/livestock/collaborative-activities/global-research-project).

1.2 Methane (Poster)

Cattle ranked in terms of methane intensity have reduced methane output and heavier carcass weight

Paul E Smith[1], Stephen Conroy[2], Alan K Kelly[3], David A Kenny[4] and Sinéad M Waters[5]

[1]B.Agr.Sc, PhD Research Student, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

[2]PhD, Performance Test Centre Manager, Irish Cattle Breeding Federation, G€N€ IR€LAND Progeny Test Centre, Tully, Kildare Town,

County Kildare, Ireland

[3]PhD, Lecturer in Animal Science, UCD, School of Agriculture and Food Science, University College Dublin Belfield, Dublin 4, Ireland

[4]PhD, Principal Research Officer, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

[5]PhD, Principal Research Officer, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation

Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

Selecting cattle based on methane intensity (MI), methane output corrected for animal product produced, provides an opportunity to sustainably produce animal protein, without negatively effecting performance. The objective of this study was to investigate differences in animal performance of beef cattle ranked in terms MI. Thirty LIMX steers consuming a TMR of 10kg concentrates and 3kg of hay, underwent measurements of feed intake, feed conversion ratio (FCR) and methane output. Methane output was estimated over a 3 week period, using the GreenFeed System. Cattle were ranked in terms of MI with the 10 highest (H; n=10) and lowest (L; n=10) cattle in terms of MI selected for comparison. Statistical analysis was carried out in SAS using the PROC TTEST function. MI (g CH4/ kg carcass weight) was significantly lower in the L compared to H group (0.43 vs. 0.66; P 0<0.001) as was daily methane production (165.0 vs. 228.3g/ day; P< 0.001). No significant differences in FCR, DMI, ADG or methane measurement weight were detected between the groups. However, cattle with a lower MI produced a significantly greater carcass weight (347.4 vs. 380.7 kg; P<0.02) and had a greater kill out (%) (54.47 vs. 57.22%; P0<.01). Selecting cattle for improved MI therefore has potential to decrease methane output while maintaining, and potentially increasing, meat yield.

Index terms: bos taurus, enteric fermentation, animal breeding, beef production.

Commercial-scale evaluation of fed 3-NOP in reducing methane from cattle feedlots using micrometeorological methods

S. M. McGinn[1], T.K. Flesch[2], K.A. Beauchemin[1] ,A. Shreck[3] and M. Kindermann[4]*

[1]Agriculture and Agri-Food Canada, 5403 1 Avenue South, Lethbridge, Alberta,
Canada T1J 4B1
[2]University of Alberta, Department of Earth Sciences and Meteorology, Edmonton, Alberta, Canada
[3]Feedlot Health Management Services Ltd, Okotoks, Alberta, Canada T1S 2A2
[4]DSM Nutritional Products, Basel, Switzerland

It is highly desirable to use agricultural emission mitigation strategies on a whole-farm scale to ensure all aspects of management and production operations are included in the treatment response. Working at a commercial beef cattle feedlot in southern Alberta, Canada, we compared the cattle enteric methane emissions using the Concentration Ratio Method and an Inverse Dispersion Method for a control and treatment block of pens containing a total of 1500 cattle. There was clear reduction in methane emission reduction of 70% for cattle fed the compound 3-nitrooxypropanol (3- NOP) compared to cattle fed just the basal diet. Both micrometeorological methods measured an increase in the concentration ratio (a decrease in the emission rate) during study. There was also a diel fluctuation in methane emission that coincide with feeding in the early morning. The simplicity and sensitively of the Concentration Ratio Method is expected to have applications for evaluating other mitigation strategies at large commercial scales, such as the application of manure additives to pen floors to reduce odours and ammonia emissions.

Keywords: emissions, concentration, ruminant, techniques, inhibitor

Database construction to predict enteric methane emission from ruminants under different nutritional mitigation strategies

Mohammed Benaouda[1], Cécile Martin[2] and Maguy Eugène[3]

[1]Animal science, PhD, Postdoctoral fellowship, INRA, UMR1213 Herbivores, F-63122 Saint-Genès-Champanelle, France
[2]Animal Science, PhD, Senior Scientist, INRA, UMR1213 Herbivores, F-63122 Saint- Genès-Champanelle, France
[3]Animal science, PhD, Senior Scientist, INRA, UMR1213 Herbivores, F-63122 Saint-Genès- Champanelle, France

The objective of this work was the construction of individual database to estimate enteric methane (CH_4) emissions from ruminants considering the mitigating strategy used in the diet. Individual animal records of daily CH_4 emissions were collected (n=729) from 20 studies conducted at INRA, since 2003. The homogenization of data and analysis of outliers were performed and missing information of dietary chemical composition were completed using INRA feed tables (2017). The database contained CH_4 emissions data obtained with the SF_6 technique (80.5%) and respiration chambers (19.5%) on dairy cattle (n data; n studies= 373; 11), beef cattle (181; 4) and sheep (175; 5). According to the purpose of each study in the database, data were coded and classified into 5 CH_4 mitigating strategies: (**A**) starch supplementation, (**B**) enhancing forage quality, (**C**) lipid supplementation, (**D**) plant extract supplementation, and (**E**) other additives. The inclusion of lipid and starch in the diets ranged between 19.0 and 80.1 g ether extract/kg DM and between 25 and 472 g starch/kg DM, respectively. The CH_4 emissions averaged 305 and 203 g/d for dairy and beef cattle, respectively, and 23 g/d for sheep. The large ranges of dietary lipid and starch content showed in the meta-design will allow analyzing the variation of CH_4 emission under different levels of lipid and starch supplementations. However, few direct comparisons of the source of lipid or starch were made. Next step will consist in using this database to evaluate the performance of models on CH_4 emissions.

Index terms: Meta-design, prediction equation, methane, nutritional practices

Effects of an essential oils blend on productivity and methane emissions in dairy cows: meta-analysis

Alejandro Belanche[1], Beatrice Zweifel[2] and David R. Yañez-Ruiz[3]

[1]Research Fellow, EEZ-CSIC, Profesor Albareda 1, 18008, Granada, Spain
[2]Technical Director, Agolin SA, 1145 Bière, Switzerland
[3]Assistant Professor, EEZ-CSIC, Profesor Albareda 1, 18008, Granada, Spain

There is growing pressure to identify feed additives which increase productivity and decrease methane emissions without compromising animal health. Essential oils (EO) have shown positive effects on the ruminal fermentation *in vitro*, but there are few *in vivo* studies describing animal responses and results are often inconsistent. This study described the effects of supplementing a specific EO blend (Agolin® Ruminant) at 1g/d per cow in comparison to non-treated animals. A total of 20 *in vivo* studies and farm trials were identified and a meta-analysis was performed to determine the standardized effect size on milk yield, rumen fermentation and methane emissions. Results indicated that an adaptation period of at least 4 weeks of treatment is required. Whereas short- term studies showed minor and inconsistent effects of EO, long-term trials (≥ 4 weeks) revealed that EO supplementation increases milk yield (+3.8%, $P<0.001$), fat and protein corrected milk (+4.5%, $P<0.001$) and feed efficiency (+3.3%, $P<0.001$) without further changes in milk composition or feed intake. Long-term treatment also decreased methane production per day (-9.6%, $P<0.001$), per DM intake (-13.6, $P=0.001$) and per milk yield (-12.7%, $P=0.042$) without having negative effects on the body condition score, fertility or health. In conclusion, although the mode of action is still unclear, this study suggested that Agolin supplementation may promote a subtle modulation of the rumen fermentation and protozoal levels which favoured the efficiency of the cow. Despite the small number of studies considered, these findings show that Agolin represents an encouraging alternative to improve productivity in dairy cattle.

Index terms: Bos taurus, essential oils, meta-analysis, methane, milk yield

Enteric gas emissions and lactational performance of dairy cows fed 3-nitrooxypropanol: A meta-analysis

Audino Melgar Moreno[1], Nicola D. Walker[2], and Alexander N. Hristov[3]

[1]Graduate Student, Department of Animal Science, The Pennsylvania State University, University Park, PA 16802, United States

[2]DSM Nutritional Products, Switzerland

[3]Professor, Department of Animal Science, The Pennsylvania State University, University Park, PA 16802, United States

A meta-analysis was performed to examine the effect of the investigational product 3-nitrooxypropanol (3-NOP) on enteric gaseous emissions (methane, carbon dioxide, and hydrogen) and lactational performance of dairy cows. Data from four randomized complete block design experiments (a total of 185 cows; duration of 31 to 105 days) conducted at The Pennsylvania State University were used in the analysis. Cows received a control diet or a diet containing 3-NOP at 40 to 200 mg/kg feed dry matter. Enteric gas emissions were measured using the GreenFeed system. Addition of 3-NOP decreased ($P < 0.001$) daily methane emission [effect size (ES) ± SE: -101 ± 8.05 g/d], emission yield (-1.95 ± 0.198 g/kg dry matter intake), and emission intensity (-1.30 ± 0.179 g/kg energy corrected milk). Treatment increased hydrogen emission (+2.23 ± 0.211 g/d; $P < 0.001$) and had no effect on carbon dioxide emission ($P = 0.34$). Dry matter intake, milk yield, and cow body weight were not affected ($P \geq 0.72$) by 3-NOP (mean ± SE: 25.4 ± 1.01 kg/d, 42.8 ± 1.69 kg/d, and 631 ± 16.3 kg, respectively). Treatment increased milk fat and milk urea nitrogen concentrations (ES ± SE: +0.33 ± 0.167 % and +0.38 ± 0.166 mg/dL, respectively; $P \leq 0.05$) but had no other effects on milk components. In this meta- analysis, 3-NOP decreased daily enteric methane emission by 24% and both methane yield and intensity by 25% without affecting dry matter intake and milk yield and increased milk fat concentration in lactating dairy cows.

Keywords: dairy cattle, enteric methane, milk production, milk fat

Enteric methane emission from sheep fed diets including red macroalgae

Vibeke Lind[1], Martin Riis Weisbjerg[2], Grete M. Jørgensen[1] and Eduarda Molina-Alcaide[3]

[1]PhD, Norwegian Institute of Bioeconomy Research (NIBIO), PB 118, 1432 Ås, Norway

[2]Professor, Aarhus University, AU Foulum, Blichers Allé 20, 8830 Tjele, Denmark

[3]Professor, Estación Experimental del Zaidin (Consejo Superior de Investigaciones Cientificas), Profesor Albareda, 1, 18008 Granada, Spain

Edible seaweed biomass is a valuable alternative feed ingredient for livestock. The composition of seaweeds is highly variable, with large differences in proteins, minerals, lipids and carbohydrates. Species, season, harvesting year, habitat, and prevailing proximate environmental conditions account for this variation. Using seaweeds as a protein source for production animals is of interest. Studies suggest that some seaweed species may have bioactive compounds with antimethanogenic properties. To investigate the effect of the red seaweed *Porphyra ssp* on enteric methane produced by sheep an *in vivo* study was carried out with 24 Norwegian White ewes. The ewes were allocated into four groups receiving a control diet or one of three supplemented diets. All groups were fed grass silage *ad libitum*, crushed oat and mineral pellets; the three supplemented diets included a protein source where dried and powdered *Porphyra ssp*. was compared with white clover silage or pelleted soybean meal. The ewes were fed their respective diets for a two-week adaptation period and a 72-h experimental period during which methane was measured individually using open-circuit respiration chambers. Weight changes and methane production (L CH_4/kg DM intake) were analysed using the GLM procedure with diet as fixed effect. No differences in weight changes and methane production between diets were found. Diet did not affect weight changes and methane production but DM intake was higher ($P<0.001$) for diets including soybean and macroalgae than white clover. Feeding red macroalgae showed no reduction in enteric methane production compared to the control diet.

Keywords: *porphyra ssp*, protein, feed intake, methane

Evaluation of interval time and calculation method to quantify methane emissions measured by respiration chamber

Min Wang

CAS Key Laboratory for Agro-Ecological Processes in Subtropical Region, National Engineering Laboratory for Pollution Control and Waste Utilization in Livestock and Poultry Production, Institute of Subtropical Agriculture, The Chinese Academy of Sciences, Changsha, Hunan 410125, China

The present study was designed to evaluate the effects of interval time of measurement and calculation method on the quantification of enteric CH_4 emissions measured by respiration chamber. Methane concentrations were measured at every 0.5 min to obtain the 23-h kinetics of CH_4 emissions of ten growing Chinese Holstein dairy heifers. Two calculation methods include using mean value of measuring period (Mean method) and the nearest value of measurement just before chamber opening (Nearest method). The results showed that the increment of interval time decreased maximum rate of CH_4 emission and increased minimum rate of CH4 emission. Interval time of measurement caused a less 5% of difference in measuring CH_4 emissions. Although mean method had greater estimated daily CH_4 emission than nearest method, the difference was within 3%. In conclusion, both interval time of measurement and calculation method causes a less 5% of difference in measuring enteric CH_4 emissions.

Keywords: Methane emission, Respiratory chamber, Interval time, Calculation method

Evaluation of low-cost carbon dioxide and methane sensors to determine methane/carbon dioxide ratio in the breath of cows during milking

Tomoyuki Suzuki[1], Yuko Kamiya[1], Hisami Kobayashi[1], Itoko Nonaka[2], Taketo Obitsu[3] and Fuminori Terada[4]

[1]Central Region Agricultural Research Center, NARO, Nishinasuno, Tochigi 329-2793, Japan
[2]Institute of Livestock and Grassland Science, NARO, Tsukuba, Ibaraki 305-0901, Japan
[3]Graduate School of Integrated Sciences for Life, Hiroshima University, Higashihiroshima, Hiroshima 739-8511, Japan
[4]Graduate School of Agriculture Division of Biological Resource Sciences, Tohoku University, Sendai, Miyagi 980-8572, Japan

For the purpose of genetic selection, a method to determine methane (CH_4) and carbon dioxide (CO_2) concentration in the breath of cows during automatic milking and to estimate enteric CH_4 emission using CH_4/CO_2 ratio has been established. Of equipment comprised in gas collection apparatus, gas analyzer is the most expensive one. The objective is to evaluate low-cost gas sensors as an alternative to high-spec nondispersive infrared (NDIR) gas analyzer. Gas around feed bin in the automatic milking robot was collected with air-pump via air-filter and dryer. A part of collected gas was sent to test sensors of NDIR CO_2 sensor and semiconductor CH_4 sensor, and another part was sent to high-spec NDIR CO_2 and CH_4 analyzers as a reference. Gas collection was made with 91 visits of Holstein lactating cows during 6 days. Output voltage from CO_2 test sensor linearly correlated with reference CO_2 concentration, and was stable through a measurement period, while output from CH_4 test sensor curvilinearly related with reference CH_4 concentration. The calibration curve for CH_4 concentration was obtained every day from varying voltage outputs and reference CH_4 concentrations during one cattle visit. Average CO_2 and CH_4 concentration (Y) during one visit obtained from test sensor correlated with each reference gas (X); $Y=0.89X+0.02$ ($R^2=0.97$; n=91) for CO_2, and $Y=1.02X$ ($R^2=0.95$; n=91) for CH_4, respectively. Average CH_4/CO_2 ratio during one visit obtained from test sensors correlated with that from reference gases (X); $Y=1.01X$ ($R^2=0.84$).

Key words: Automatic milking system, Holstein cows, NDIR sensor, semiconductor sensor

Extreme concentrate level decrease enteric methane significantly, and more in Holstein than in Jersey cows.

Christian Friis Børsting[1], Anne Louise Frydendahl Hellwing[2] and Peter Lund[3]

[1]Christian Friis Børsting, Ph.D., senior scientist, Department of Animal Science, Aarhus University, AU Foulum, P.O. Box 50, DK 8830 Tjele

[2]Anne Louise Frydendahl Hellwing, Ph.D., scientist, Department of Animal Science, Aarhus University, AU Foulum, P.O. Box 50, DK 8830 Tjele

[3]Peter Lund, Ph.D, professor, Department of Animal Science, Aarhus University, AU Foulum, P.O. Box 50, DK 8830 Tjele

Corresponding author: Christian F. Børsting, E-mail:Christian.borsting@anis.au.dk

The aim of the study was to investigate the effect on methane emission when feeding three diets with increasing levels of concentrate to 12 Holstein and 12 Jersey lactating cows. Concentrate constituted 49, 70 or 91 % of dry matter intake (DMI), forage (grass-clover and maize silage 1:1, DM basis) constituted 50, 25 or 0 % of DMI, whereas the remaining 1, 5 or 9 % of DMI was barley straw. Concentrate consisted of sugar beet pulp, barley, rape seed meal, soy bean meal, dried distillers grain, NaOH treated wheat, molasses, minerals and vitamins. Diets were isoenergetic. Increasing level of concentrate gave a slight increase in crude protein and starch, and a slight decrease in NDF content in DM. Diets were thoroughly mixed after adding water to a DM content of 40 %. Methane emission was measured in respiration chambers during three days. The enteric methane emission was 565, 505 and 295 L/d for Holstein for the 49, 70 and 91 % concentrate diets, respectively. For Jersey the emission was 478, 450 and 422 L/d. Daily DMI was 22.5, 23.9 and 22.4 kg/d for Holstein, and 16.5, 18.9 and 19.0 kg/d for Jersey. Methane emission per kg DMI for the three diets was 25.3, 21.1 and 13.2 L/kg for Holstein and 29.0, 23.8 and 22.4 L/kg for Jersey. In conclusion, methane emission per kg DMI could be reduced by 48 % for Holstein when no forage and 91 % concentrate was fed, but only 23 % for Jersey.

Keywords: Cattle, greenhouse gasses, high concentrate diet, low forage diet

Feed efficiency and enteric methane emission of Nellore cattle[1]

Leandro Sannomiya Sakamoto[1], Luana Lelis Souza[2], Lorena Ferreira Benfica[3], Joslaine Noely dos Santos Gonçalves Cyrillo[4], Alexandre Berndt[5], Lucia Galvão de Albuquerque[6] and Maria Eugênia Zerlotti Mercadante[7]

[1]Animal Scientist, Post-doctoral Researcher at Institute of Animal Science, Beef Cattle Research Center, Sertãozinho, São Paulo, Brazil;

[2]Biologist, PhD Student at São Paulo State University (UNESP), School of Agricultural and Veterinarian Sciences, Jaboticabal, São Paulo, Brazil;

[3]Animal Scientist, MSc Student at Institute of Animal Science, Beef Cattle Research Center, Sertãozinho, São Paulo, Brazil;

[4]Animal Scientist, Researcher at Institute of Animal Science, Beef Cattle Research Center, Sertãozinho, São Paulo, Brazil.

[5]Agronomist Engineer, Researcher at Embrapa Southeast Livestock, Brazilian Agricultural Research Corporation, São Carlos, São Paulo, Brazil;

[6]Veterinarian, Professor at São Paulo State University (UNESP), School of Agricultural and Veterinarian Sciences, Jaboticabal, São Paulo, Brazil;

[7]Animal Scientist, Researcher at Institute of Animal Science, Beef Cattle Research Center, Sertãozinho, São Paulo, Brazil.

The aim of the study was to calculate the residual feed intake (RFI), average daily weight gain (ADG), dry matter intake (DMI) and metabolic weight (MW) and to estimate the correlation with enteric methane emission. The influence of animal class RFI on the enteric methane emission was also verified. Seventy- two Nellore cattle with mean weight of 273 ± 43.8 kg and age of 350 ± 26.2 days were evaluated. The animals remained in collective pens equipped with automated troughs (GrowSafe) for recording individual daily intake. The feed efficiency test had a duration of 84 days. Animals were weighed every 21 days. Animals were classified as lower RFI with mean of -0.697 ± 0.30 kg/day (n = 24), medium RFI with mean of -0.023 ± 0.15 kg/day (n = 25) and high RFI with mean of 0.752 ± 0.31 kg/day (n = 23). Enteric methane was measured by tracer gas technique sulfur hexafluoride. The results were analyzed using the GLM procedure and Pearson correlation coefficients were determined between variables. Average enteric methane emission was 199 ± 35.9 g/day, and showed low correlation with RFI (r = 0.069), differently from those found with ADG (0.671), DMI (0.610) and MW (0.634). The RFI classes did not influence the enteric methane emission (*P = 0.7035*). Enteric methane emission showed low correlation with RFI, and was not influenced by its classes. There isn't evidence that high-efficiency animals emit less enteric methane, even with lower dry matter intake and same performance than their inefficient counterpart.

Keywords: correlation, Nellore cattle, residual feed intake, SF_6 technique.

[1]Grant #2018/17313-5 and #2017/50339-5, São Paulo Research Foundation (FAPESP)

Feed intake level on enteric methane emission from growing dairy heifers

Tainá Silvestre[1], Luis Gustavo Ribeiro Pereira[2], Fernanda Samarini Machado[2], Thierry Ribeiro Tomich[2], Mariana Magalhães Campos[2] and Paulo Henrique Mazza Rodrigues[3]

[1]Undergraduate student of University of São Paulo, College of Veterinary Medicine and Animal Science, University of Sao Paulo, Pirassununga, Brazil.

[2]PhD of Federal University of Minas Gerais, Reseacher of Brazilian Agricultural Research Corporation, Embrapa Dairy Cattle, Juiz de Fora, Brazil.

[3]PhD of University of São Paulo, Professor of the College of Veterinary Medicine and Animal Science, University of Sao Paulo, Pirassununga, Brazil.

It was aimed to determinate methane emission using SF_6 tracer technique from growing dairy heifers fed at three different nutritional plans (NP). Thirty-six heifers, 12 Holstein, 12 Gyr and 12 F1 Holstein-Gyr, 10 months old, initial body weight 174.8±42.6 kg, 123.5±44.4 kg and 201.5±44.6 kg to Holstein, Gyr and F1 Holstein-Gyr respectively, were distributed in multiples latin squares in a 3x3 factorial arrangement (3 nutritional plans x 3 genotypes). Within each latin square, heifers were randomly distributed in 3 different nutritional plans (NP) predicted by NRC (2001), which were (1) 1.0x maintenance; (2) 1.5x maintenance and (3) 2.0x maintenance. Heifers were fed a diet consisting of 85.0% corn silage and 15.0% concentrate on dry matter basis. Dry matter intake and nutrients showed interaction ($p<0.05$) among genotype and nutritional plan. Gyr heirfers present greatest ($p<0.05$) crude protein digestibility than other heifers. Average daily gain (ADG) also had interaction between genotype and NP, which was lower to Gyr heifers. Methane emission in grams per day was influenced ($p<0.05$) by intake level and genotype. When heifers increased their intakes, CH_4 emission expressed in animal basis (g/animal/d) increased, but when expressed by unit of daily gain (g/kg of ADG) declined, and this was associated with a dilution on CH_4 production by live weight gain. This suggests that an important benefit of high feed intake level is a reduction on emission intensity as CH_4/product unit.

Index terms: genotype, milk, sustainability

Freezing and thawing permeation tubes does not alter their subsequent rate of SF_6 release

Peter J. Moate[1], Brigid E. Ribaux[2], Kate M. Rabl[3], Murray C. Hannah[4], Matthew H. Deighton[5] and S. Richard O. Williams[6]

[1]PhD, Senior Research Scientist, Agriculture Victoria Research, Ellinbank, Victoria 3821, Australia
[2]B. Sc., Technical Officer, Agriculture Victoria Research, Ellinbank, Victoria 3821, Australia
[3]Technical Officer, Agriculture Victoria Research, Ellinbank, Victoria 3821, Australia
[4]M. Sci., Senior Research Scientist, Agriculture Victoria Research, Ellinbank, Victoria 3821, Australia
[5]PhD, Technical Manager, Cropmark Seeds, Rolleston, 7677, New Zealand
[6]M. Eng. Sci., Senior Research Scientist, Agriculture Victoria Research, Ellinbank, Victoria 3821, Australia

Permeation tubes are used in the measurement of enteric methane emissions, but they cannot be manufactured with a narrow range of sulphur hexafluoride (SF_6) release rate, a key requirement of the SF_6 technique. One way to achieve a small range in release rate is to make a large batch of permeation tubes, order them by release rate, then select a subset for each experiment. The remainder are then stored at -80°C until required since there is no release of SF_6 at this temperature. The release rate of SF_6 from freshly made permeation tubes follow Michaelis-Menten kinetics, but it is not known if freezing then thawing permeation tubes has any effect on the subsequent pattern of SF_6 release rate. Twenty permeation tubes had their initial release rate measured over 3 weeks. Ten of the permeation tubes were stored at -80°C ('frozen'), with the remaining 10 tubes maintained at 39°C ('control') and their masses measured monthly for the next 3 years. After 365 days at -80°C, the frozen permeation tubes were returned to 39°C and their masses measured monthly for three years. The permeation tubes did not lose any mass while frozen. Excluding the period when permeation tubes were in the freezer ('frozen adjusted'), the release rate and patterns of SF_6 release were identical to those of control permeation tubes (Fig. 1). Individual permeation tubes can be stored at -80°C until required with no change in release rate or pattern of SF_6 release.

Terms for indexing / Index terms: sulphur hexafluoride, Michaelis-Menten kinetics

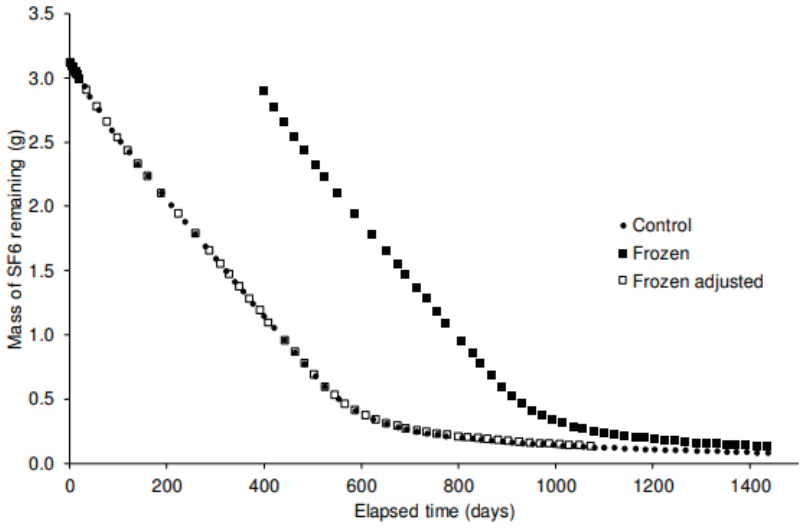

Fig. 1 Pattern of SF6 release from control and frozen permeation tubes.

Gaseous emissions in split sex fattening of heavy pigs

Elio Dinuccio, Davide Biagini, Jacopo Maffia and Carla Lazzaroni

Dipartimento di Scienze Agrarie, Forestali e Alimentari, Università di Torino, Largo Paolo Braccini 2, 10095 Grugliasco, Italy

Swine intensive rearing systems produce emissions of several air pollutants, such as greenhouse gases (GHG) and ammonia (NH_3). This work aims to evaluate the effect of split sex fattening on carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and NH_3 emissions in finishing pig farms from piggery and slurry storage. An experimental trial has been carried out in a commercial swine farm, by growing three groups of 500 pigs each, grouped according to gender: female (F), male castrated (M), and mixed (MF). The three groups were fed similar diet, fitted to different protein and energy requirement of each group. During the trial the emissions from housing facilities, as well as live and slaughtering animal performances were assessed. In addition, manure samples were collected during the rearing period to evaluate at a laboratory-scale NH_3 and GHG emission potential during the subsequent phase of slurry storage prior to land application. The results showed that split sex cannot be considered as a valid strategy for reducing gaseous emissions from pig houses, as MF showed always the lowest emission ($P<0.01$). Specifically, the average NH_3 and GHG emissions from MF resulted, respectively, 15.9% and 28.8% lower than M, and respectively 24.0% and 38.2% lower than F. Live performances and the overall productivity were not affected by split sex, whereas higher dressing percentage ($P<0.05$) and back fat depth ($P<0.01$) were found in MF. Laboratory- scale experiment revealed no significant ($P>0.05$) effect of split sex on NH_3 and GHG emis

Grassland nitrogen fertilization did not affect enteric methane emission from young Nellore bull

Ricardo Andrade Reis[1], Lutti Delevatti Maneck[1], Rhaony Gonçalves Leite[1], Débora Siniscalchi, Letícia Estéfani de Oliveira [1], Ana Cláudia Ruggieri[1] and Abmael da Silva Cardoso[1]

[1]Departamento de Zootecnia da Universidade Estadual Paulista "Júlio de Mesquita Filho", UNESP, Jaboticabal, São Paulo, Brazil

The synchronism between protein and energy in bovine diet can increase the efficiency of energy usage and may lead to a reduction in the enteric methane production that is a way to reduce H^+ concentrations in the rumen. Tropical grasses are poor in protein and nitrogen fertilizer can increase forage N content. We aimed to quantify enteric methane production from young Nellore bulls during the rearing phase in grassland fertilized with different N rates. Experimental design was completely randomized with four treatments: 0, 90, 180 and 270 kg N ha^{-1} and six replications. Enteric methane production was quantified using the technique of gas tracer (SF_6) and gas determination by gas chromatography. Nitrogen application did not affect daily CH_4 emissions, CH_4 per kg of DM ingested, CH_4 per kg of gain and methane conversion rate (Ym). Methane production average 167 g CH_4 $animal^{-1}$ day^{-1}, 28.6 g CH_4 kg^{-1} DM and the Ym was 8.74%. Our date is similar to that default for beef cattle reported in the 2006 IPCC guidelines for national inventories. Increases in N application rate do not increase enteric CH_4 production from young Nellore bull during the rearing phase in tropical pastures.

Keywords: pasture management, beef cattle, N pollution.

Acknowledgments: We thanks the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) for financial suporte (# 2015/16631-5) and the Coordenação de aperfeiçoamento pessoal de nível superior for the scholarships.

Methane emissions in sheep infected with parasitic nematodes and supplemented with *Acacia mearnsii*

Paulo de Mello Tavares Lima[1], Pierre Crouzoulon[2], Geneviève Zabré[3], Adama Kabore[4], Vincent Niderkorn[5], Hervé Hoste[6], Adibe Luiz Abdalla[7] and Helder Louvandini[8]

[1]Universidade de São Paulo, Centro de Energia Nuclear na Agricultura, Piracicaba, São Paulo, Brasil – PhD - Post-Doctoral Researcher

[2]Universidade de São Paulo, Centro de Energia Nuclear na Agricultura, Piracicaba, São Paulo, Brasil – MSc Student

[3]Laboratoire de Biologie et Santé Animales-DPA/INERA, Ouagadougou, Burkina Faso MSc - PhD Student

[4]Laboratoire de Biologie et Santé Animales-DPA/INERA, Ouagadougou, Burkina Faso PhD - Professor

[5]Université Clermont Auvergne, INRA, VetAgro Sup, UMR Herbivores, F-63122 Saint-Genès Champanelle, France – PhD – Scientific Researcher

[6]INRA, UMR, Chemin des Capelles, Toulouse, France – PhD – Senior Researcher

[7,8]Universidade de São Paulo, Centro de Energia Nuclear na Agricultura, Piracicaba, São Paulo, Brasil - PhD - Associate Professor

Our objective was to evaluate the effects of Acacia mearnsii bark extract (PAB) on methane (CH_4) production in sheep infected with Trichostrongylus colubriformis and Haemonchus contortus. Twenty 10 month-old Santa Inês lambs were used in a 50-day trial. Four treatment groups were formed: two control groups uninfected, one without PAB (C-) (n=4) and one with PAB (C+) (n=4); and two infected groups, one without PAB (I-) (n=6) and another receiving PAB (I+) (n= 6). Animals were kept in individual pens for 40 days, and received ad libitum chopped tifton 85 hay (Cynodon spp.) and 210 g/animal/day of concentrate (PAB supplementation: 15 g/animal/day – in concentrate). Animals were reared indoors to avoid helminthic infections (faecal egg count (FEC) was monthly controlled). At day 0, infected groups were artificially infected with L3 larvae of T. colubriformis (7500)and H. contortus (5000). After 28 days post- infection, establishment of infections was confirmed by FEC: I-: 1150 + 530.1 and I+: 567 + 544.6 eggs/gram of feces. After 40 days of trial (during which other parameters were evaluated - data not shown), CH_4 emissions in chambers were measured and variance analysis (proc GLM, SAS®) showed no PAB effects on methanogenesis ($p > 0.05$), however, both infected groups had higher CH4 emissions than the control groups: C-: 16.7 + 10.91; C+:23.7 + 12.88; I-: 43.1 + 6.37; I+: 40.6 + 6.02 (g CH_4/kg dry matter intake) ($p < 0.05$). The methanogenic effect of parasitic infections should be explored in studies addressing sustainability of animal production.

Keywords: Black wattle, Haemonchus contortus, Small chamber, Trichostrongylus colubriformis, Tannins

Methane mitigation trial from Vietnam local cattle production system

Koki Maeda[1], Nguyen Van Thu[2], Tomoyuki Suzuki[1, 3], Keita Yamada[4], Kushi Kudo[4, 5], Chie Hikita[6], Le Van Phong[2], Nguyen Minh Chon[2] and Naohiro Yoshida[4]*

[1]JIRCAS, Crop, Livestock & Environment Division, 1-1 Ohwashi, Tsukuba, Ibaraki 305-8686, Japan

[2]Faculty of Agriculture & Applied Biology, Can Tho University, Can Tho, Vietnam

[3] NARO, Institute of Livestock and Grassland Science, 768 Senbonmatsu, Nasu-shiobara, Tochigi 329-2793, Japan

[4]Department of Environmental Chemistry and Engineering, Tokyo Institute of Technology, 4259 Nagatsuta, Midori-ku, Yokohama 226-8502, Japan

[5]Faculty of Human Development and Environment, Kobe University, 3-11 Tsurukabuto, Nada- ku, Kobe 657-8501, Japan

[6]Idemitsu Koran, Co. Ltd, 2-1 Midorigahara, Tsukuba, Ibaraki 300-2646, Japan

*Corresponding author (k_maeda@affrc.go.jp), Tel; +81-29-838-6365

Methane emission from cattle production is a critical problem for global warming issue. Mitigation option for CH4 emission in south-east Asian countries is important since the demand of beef tend to increase in this region. We tested the effect of cashew nuts shell liquid (CNSL) feeding (8 g/100 kgBW) on CH4 emission from four Vietnam local cattle (Lai sind). Head box chamber system was used for CH4 measurement. Rumen fluid was sampled and microbial community shift with CNSL feeding was monitored by 16S rRNA gene amplicon sequencing. Results showed that a range of 20.2 to 23.4% of CH4 emission was mitigated through CNSL feeding ($P<0.05$), while no adverse effect was observed on feed intake or feed digestibility ($P>0.1$). Also, rumen fluid analysis showed that the propionate proportion in total VFA significantly increased (6.9 to 9.5%, $P<0.05$), while no significant effect was observed on acetate proportion (76.3 to 73.6%, $P>0.1$). Relative abundance of Methanobacteriales significantly decreased (3.1% to 1.4%, $P<0.05$), indicating that direct inhibiting effect of CNSL on methanogens. Relative abundance of orders Clostridiales and species Prevotella significantly increased ($P<0.05$), indicates the increase of hydrogen production activity and propionate production pathway activity. δ13C of CH4 ranged from -74.2 to -66.6‰. From the results above it was clearly proved that CNSL feeding can mitigate CH4 emission from local cattle production system of Vietnam. Although further understanding of mechanism behind is needed, CNSL feeding would be a promising way to mitigate CH4 emission from cattle production in SE Asia through expanding the local CNSL supply system.

Keywords: CH4, cattle rumen, cashew nuts shell liquid, 16S rRNA gene sequencing

Methane production from an extensive beef herd grazing natural veld over a complete production cycle.

Susanna M, Grobler[1] and Michiel M, Scholtz[1,2]

[1]Agricultural Research Council, Private Bag X05, Lynn East 0039, South Africa
[2]University of the Free State, P.O. Box 339, Bloemfontein 9300, South Africa

The need for accurate estimates of enteric methane production in ruminants in different production and grazing systems has been emphasized in a number of reports. Techniques monitoring methane at individual animal level under extensive conditions is crucial to better monitor methane mitigation alternatives while improving production efficiency. This study was aimed to measure methane production with a Laser Methane Detector under extensive beef production conditions. Twenty-six Bonsmara heifers were allocated to the project after weaning at the Agricultural Research Council Roodeplaat campus in Gauteng South Africa, which is described as a Savannah region. Heifers were extensively managed and mated naturally at 24 months over a three month breeding season (January 2018 – March 2018) and calved between October 2018 and December 2018. All calves were weaned July 2019. Enteric methane production was measured every three months for 10 consecutive days at dawn, until these heifers weaned their first calves to include a full production cycle. Due to the Laser Methane Detector measuring in parts per million per meter, results was reworked by means of a deterministic model to methane produced in grams per day. It can be concluded that significant less methane was produced during spring 2017 (76g/day) with average heifer weight of 283kg and summer 2018 (88g/day) with average heifer weight of 347kg due to higher grazing quality when rangeland was in a vegetative growth state. The highest methane production was obtained in autumn (123g/day) with average heifer weight of 397kg and winter (131g/day) with average heifer weight of 420kg.

Keywords: Enteric methane production, extensive beef cattle

Milk fatty acids can predict enteric methane emissions from dairy cows fed various diets[(1)]

Adeline Bougouin[1], Jayasooriya Ranga Niroshan Appuhamy[2], Anne Ferlay[3], Ermias Kebreab[4], Cécile Martin[5], Peter Moate[6], Chaouki Benchaar[7], Peter Lund[8] and Maguy Eugène[9]

[1]Animal science, PhD, Postdoctoral at INRA Clermont-Ferrand, France
[2]Animal science, PhD, Assistant Professor, Iowa State University, USA
[3] Animal science, PhD, Senior Scientist at INRA Clermont-Ferrand, France
[4]Animal Science, PhD, Professor at University of California, Davis, USA
[5]Animal science, PhD, Senior Scientist at INRA Clermont-Ferrand, France
[6]Veterinary Science, PhD. Senior Scientist at Agriculture Victoria Research, Ellinbank, Australia
[7]Animal Science, Ph.D. Senior Scientist, Agriculture and Agri-Food Canada, Quebec, Canada
[8]Animal Science, PhD, Professor at Aarhus University, Denmark
[9]Animal science, PhD, Senior Scientist at INRA Clermont-Ferrand, France

Proxies are needed to develop genetic selection of low methane (CH_4) emitting ruminants and to evaluate at large scale, CH_4 mitigating strategies on farm. Milk fatty acids (**MFA**) have been used as proxies to predict CH_4 emissions from dairy cows because of common rumen biochemical pathways between the two processes. The objectives of the study were (1) to construct a set of empirical models to predict CH_4 emissions using MFA records of individual lactating dairy cows (n =825) fed a wide range of diets, (2) to increase the representativeness of the models by including additional independent variables such as dietary chemical composition [organic matter (**OM**); neutral detergent fiber (**NDF**); crude protein (**CP**); starch; ether extract (**EE**)], milk yield and composition, and animal characteristics [days in milk (**DIM**) or body weight (**BW**)], and (3) to evaluate the performance of the developed models on two independent datasets (individual measurements and treatment means). Prediction equations based only on MFA [C10:0, *iso* C17:0 + *trans*-9 C16:1, *cis*-11 C18:1, and *trans*-11,*cis*-15 C18:2 for CH_4 production (g/d); *iso* C16:0, *cis*-11 C18:1, *trans*-10 C18:1, and *cis*-9,*cis*-12 C18:2 for CH_4 yield (g/kg of dry matter intake (**DMI**)); *iso* C16:0, *cis*-15 C18:1, and *trans*-10+*trans*-11 C18:1 for CH_4 intensity (g/kg of milk)] have root mean square error of 58.6 g/d, 2.8 g/kg DMI and 3.7 g/kg milk, respectively. The models including DMI, dietary nutrient contents (NDF, EE, starch), and BW had lower root mean square errors of 42.8 g/d, 2.5 g/kg DMI and 3.3 g/kg milk, respectively.

Index terms: cattle, methane equation, milk fatty acids

[(1)]This study is part of collaborative project led by INRA and funded by 11 institutes and private companies: Adisseo France SAS (Antony, France), Agrial (Caen, France), APIS-GENE (Paris, France), Deltavit (Janzé, France), DSM Nutritional Products AG (Kaiseraugst, Switzerland), Institut de l'Elevage (Paris, France), Lallemand (Blagnac, France), Moy Park Beef Orléans (Fleury-les-Aubrais, France), Neovia (Saint-Nolff, France), Techna France Nutrition (Couëron, France), Valorex (Combourtillé, France).

Mitigation of enteric methane using chestnut bark in Llamas (*Lama glama*) pastored in Andean grasslands

Francisco Enrique Franco[1], Juan Elmer Moscoso[2], Lucrecia Aguirre[1], Javier Ñaupari[1], Felipe Antonio San Martín[3], Enrique Ricardo Flores[1]

[1]Universidad Nacional Agraria La Molina

[2]Universidad Nacional de San Antonio Abad del Cusco

[3]Universidad Nacional Mayor de San Marcos

The objective of the present study was to measure the emission of enteric methane in Llamas and the use of tannins as a mitigation strategy. The study was carried out from August to September 2016 at the Experimental Center IVITA-Marangani-Cusco-Peru (4200 masl), 20 young female llamas were used, with an average live weight of 104.5 kg. They were divided into two treatments (Control and Tannin); Intake was calculated from excretion of organic matter and digestibility in feces, methane emissions were determined during seven continuous days, using the SF6 technique, while grazing in a native pasture with dominance of *Festuca rigida* and *Calamagrostis amoena*; Tannin group was provided chestnut tannin (Castanea sp.) with a dose of 11 g orally/day before grazing. The enteric methane emission for Control was 27.35 ± 10.47 g/day and for Tannin it was 19.32 ± 6.84 g/day ($t < 0.001$); showing the same tendency when the emission of CH_4 was compared according to the live weight of the animal that for Control was 0.24 ± 0.10 g / Kg PV / day and for Tannin it was 0.17 ± 0.07 g / Kg PV / day ($t < 0.001$); Intake for Control was 1494.03 g / day and for Tannin it was 1514.71 ($t > 0.05$) and the weight gain was similar ($t > 0.05$) for both groups (5.7 kg and 5.2 kg for Control and Tannin, respectively). It is concluded that the use of tannins in the present study reduced the emission of methane by approximately 30% without affecting intake.

Keywords: Tannins, dosification, intake, Castanea sp.

Non-linear effect of N fertilizers doses on CH_4 oxidation in tropical grassland

Ana Cláudia Ruggieri[1], Abmael da Silva Cardoso[1], Liziane de Figueiredo Brito[1], Elisamara Raposo[1], Débora Siniscalchi[1], Ricardo Andrade Reis[1]

[1]Departamento de Zootecnia da Universidade Estadual Paulista "Júlio de Mesquita Filho", UNESP, Jaboticabal, São Paulo, Brazil

Corresponding author. E-mail: ana.ruggieri@unesp.br

Recently was suggested that tropical grassland could be great sink of methane (CH_4). Approximately 16% of greenhouse gases emissions came from CH_4 production, which requires mitigation strategies. Thus, grassland nitrogen fertilization can increase CH_4 oxidation. Our goal in this research was to quantify the effect of N fertilization level on CH_4 production and oxidation. The treatments were 4 doses of N (0, 90, 180 and 270 kg N ha^{-1}) in completely randomized design with four replications. The nitrogen fertilization was split in 3 times during the growing season of marandu-grass managed at continuous stocking at 25 cm sward height and put-and-take methodology. Gaseous production was quantified using the static closed methodology and CH_4 quantification by gas chromatography. Nitrogen fertilization induced CH_4 oxidation. In the background treatment CH_4 emissions was, 79.7 µg CH_4 m^{-2} h^{-1}, while in the treatments the oxidation averaged: -50.5, -60.6 and -45.1 µg CH_4 m^{-2} h^{-1} for 90, 180 and 270 kg N ha^{-1}, respectively. Methane oxidation was affected by N doses ($P<0.001$) and presented a non-linear response. A relative low N dose can be used as strategy to mitigate CH_4 emissions in tropical grassland. Our study confirms that tropical grassland can be a sink of CH_4 production.

Keywords: CH_4 mitigation, nitrogen fertilization, grassland management, CH_4 oxidation.

Acknowledgments: We thanks the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) for financial suporte (# 2015/16631-5) and the Coordenação de aperfeiçoamento pessoal de nível superior for the scholarships.

Nutritional evaluation and ruminal parameters in sheep fed the tropical legume *Stizolobium aterrimum*

Paulo de Mello Tavares Lima[1], Guilherme Dias Moreira[2], Ana Maria Krüger[3], Flávia Maria de Andrade Gimenes[4], Luciana Gerdes[5], Adibe Luiz Abdalla[6] and Helder Louvandini[7]

[1]Universidade de São Paulo, Centro de Energia Nuclear na Agricultura, Piracicaba, São Paulo, Brasil - PhD - Post-Doctoral Researcher

[2]Universidade de Brasília, Faculdade de Agronomia e Medicina Veterinária, Brasilia, Distrito Federal, Brasil - PhD

[3]Universidade de São Paulo, Centro de Energia Nuclear na Agricultura, Piracicaba, São Paulo, Brasil - MSc. - PhD Student

[4,5]Instituto de Zootecnia, APTA, SAA-SP, Nova Odessa, São Paulo, Brasil - PhD - Scientific Researcher

[6,7]Universidade de São Paulo, Centro de Energia Nuclear na Agricultura, Piracicaba, São Paulo, Brasil - PhD - Associate Professor

Based on the hypothesis that condensed tannins (CT) commonly found in legumes may affect ruminal fermentation, we aimed to evaluate the effects of the legume *Stizolobium aterrimum* (mucuna-preta - MUC) (5.6 g/kg dry matter) on total gas, methane (CH_4) production and fermentation parameters in lambs, by using both, in vitro and in vivo assays. Initially, ground (1 mm) MUC hay samples (0.5 g) were incubated with or without polyethylene glycol (PEG) in an in vitro semi-automatic system. Increased total gas, ammonia nitrogen and lower pH were observed in samples incubated with PEG ($p < 0.05$). After, during 24 days (d) of experimental period (18 d to adaptation and 6 d to collections), in vivo CH_4 emissions and fermentation parameters from Santa Inês lambs ($n = 18$; 24 months-old; 47 ±7.8 kg) fed on this legume were measured by using chambers system. Diets were: chopped Panicum maximum cv. Aruana hay (CON), CON supplemented with MUC (MWO) or CON supplemented with MUC plus PEG (MWP). No effects on CH_4 emissions were observed ($p > 0.05$) but reduced production of short- chain fatty acids (SCFA) and propionate were observed for CON and both groups fed MUC showed reduced acetate:propionate (A:P) ratio while animals fed MWP had reduced protozoa count ($p < 0.05$). Based on the results, CT from MUC showed to be capable of reducing in vitro degradability of substrates, while in vivo, it did not affect CH_4 production, but quality of fermentation end-products (i.e. A:P ratio) was improved when feeding this legume.

Keywords: Forages, In vitro gas production, Mucuna-preta, Polyethylene glycol, Small chambers.

Perspective on the Methane Production of Primary Beef Production Systems in South Africa

Nelly T. Chabalala[1,2], Michiel M. Scholtz[1,3] and Susanna M. Grobler[1]

[1]Agricultural Research Council-Animal Production, Private Bag X2 Irene, 0062, South Africa

[2]School of Agriculture and Live Sciences, UNISA, Florida, 1709, South Africa

[3]Department of Animal, Wildlife and Grassland Sciences, University of the Free State, P.O. Box 339, Bloemfontein, 9300, South Africa.

Livestock is important to mankind since most of the world's vegetation biomass is rich in fibre. Only ruminants can convert this high fibre vegetation into high quality protein sources (e.g. meat and milk) for human consumption. Despite this important role, they are specifically targeted and singled out as producers of large quantities of GHG that contribute to climate change. A simulation study was conducted to estimate the methane footprint of primary beef production, using the national average weights for beef cattle, grazing extensively in South Africa. The principle of Large Stock Units (LSU) were used as a reference, with the guideline that a LSU produce 94kg of methane per year in South Africa. Thus, a LSU produce approximately 260g (0.26kg) of methane per day. Both a weaner calf production system and an 18 month ox production system were simulated. Furthermore, weaning percentages of 60% and 80% were simulated and a 20% replacement rate was assumed. Using the simulations described, it was estimated that the methane footprint of a weaner calf of 220kg was 248kg of methane at a weaning percentage of 60% and it decreases to 196kg at a weaning percentage of 80%. In an ox production system (marketing at 18 months of age), the methane footprint of a 350kg ox was 332kg and 280kg of methane for weaning percentage of 60% and 80% respectively. The effects of production system, weaning percentage and replacement rate all influence the methane production of beef.

Keywords: Greenhouse gas, Large Stock Units**,** Weaning percentage, replacement rate

Prediction of enteric methane emissions from cattle raised in tropical conditions

Rafael S. Ribeiro[1], João P.P. Rodrigues[2], Rogério M. Maurício[4], Ana L.C. C. Borges[5], Ricardo R. Silva[5], Telma T. Berchielli[6], Sebastião C. Valadares Filho[7], Fernanda S. Machado[3], Mariana M. Campos[3], Alexandre L. Ferreira[3], Roberto G. Júnior[8], José A. G. Azevêdo[9], Rafael D. Santos[10], Thierry R. Tomich[3]e Luiz G.R. Pereira[3]

[1]PhD student, Federal University of São João del Rei (UFSJ), Minas Gerais, Brazil
[2]Adjunct professor, Federal University of South and Southeast of Para (UNIFESSPA), Para, Brazil
[3]Researcher, Brazilian Agricultural Research Corporation (Embrapa Dairy Cattle), Minas Gerais, Brazil
[4]Adjunct professor, Federal University of São João del Rei (UFSJ), Minas Gerais, Brazil
[5]Adjunct professor, Federal University of Minas Gerais (UFMG), Minas Gerais, Brazil
[6]Adjunct professor, Paulista State University "Julio de Mesquita Filho" (Unesp), São Paulo, Brazil
[7]Adjunct professor, Federal University of Viçosa (UFV), Minas Gerais, Brazil
[8]Researcher, Brazilian Agricultural Research Corporation (Embrapa Cerrados), Federal District, Brazil
[9]Adjunct professor, State University of Santa Cruz, Bahia, Brazil
[10]Researcher, Brazilian Agricultural Research Corporation (Embrapa Semi-Arid), Pernambuco, Brazil

A dataset containing diet composition, intake, digestibility and CH_4 emissions (717 observations, 153 treatments means, 34 studies) obtained in Brazil was used to: *i*) evaluate 41 equations available in the literature; *ii)* develop equations to predict yield (%GEI) and production (Mj/d) of CH_4. Methane measurements were obtained by open- circuit respirometric chambers (n=430), SF_6 technique (n=200), or GreenFeed® system (n=87). For general (n=717) and lactating cows (n=284) datasets, the best fit equation showed a significant mean bias (-0.59MJ/d and -0.62MJ/d, respectively). For growing cattle and non-lactating cows dataset (n=433) the equation that best fit did not present significant mean slope bias. The IPCC Tier 2 method resulted in an over prediction of 0.55, 0.62 and 0.50MJ/d of CH_4 for general, lactating cows, and growing cattle and non- lactating cows datasets, respectively. None of the equations from literature precisely predicted CH_4. Multiple regression equations were developed using mixed models and the best-fit equations were: general dataset, CH_4(Mj/d)=– 3.7(±1.56)+0.7(±0.08)×DMI+0.01(±0.002)×BW–0.03(±0.01)×EE+0.005(±0.002)×GE_{cd} [$RMSE_{\%obs}$=12.62; R^2=0.92] and CH_4(%GEI)=28.9(±11.32)–1.8(±0.48)×DMI+0.07(±0.01)×BW–0.29(±0.12)×EE+0.04(±0.01)×GE_{cd} [$RMSE_{\%obs}$=10.65; R^2=0.77]; lactating cows, CH_4(Mj/d)=3.1(±1.69) +0.05(±0.007)×GEI(Mcal) [$RMSE_{\%obs}$=12.58; R^2=0.69] and CH_4(%GEI)=38.03(±21.15)+5.02(±2.67)×DMI–0.23(0.08)×DMI^2 [$RMSE_{\%obs}$=12.43; R^2=0.26]; Growing cattle and non-lactating cows, CH_4(Mj/d)=–3.6(±1.32)+2.0(±0.27)×DMI–0.05(±0.02)×DMI^2–0.18(±0.04)×DMI%BW–0.04(±0.01)×EE +0.007(±0.002)×GE_{cd} [$RMSE_{\%obs}$=9.11; R^2=0.93] and CH_4(%GEI)=43.2(±8.29)–1.6(±0.45)×DMI–0.3(±0.10)×EE +0.05(±0.01)×GE_{cd} [$RMSE_{\%obs}$=10.32; R^2=0.82]. The equations developed in the present study can be useful for proper estimation of the CH_4 emissions in Brazil, as well as to provide a better understanding of the dietary and animal characteristics that influence the yield and production of enteric CH_4 in tropical feeding systems.

Keywords: Beef, Dairy, Greenhouse gas, Livestock

Acknowledgment: Embrapa, Pecus/RumenGases, CNPq, CAPES, FAPEMIG and INCT/Ciência Animal

Relationship between rumen archaea diversity and methane production in three breed composition and nutritional plans of dairy heifers[1]

Ellen de Almeida Moreira[2], Shirley Motta de Souza[3], Carlos Alberto Alves Oliveira Filho[4], Alexandre Lima Ferreira[6], Mariana Magalhães Campos[6], Fernanda Samarini Machado[6], Thierry Ribeiro Tomich[6], André Luis Alves Neves[6] and Luiz Gustavo Ribeiro Pereira[6]

[1]Part of the doctoral thesis of the first author, RumenGases Research Project, INCT - Ciência Animal

[2]Biomedical, Doctor, Universidade Estadual de Santa Cruz, Ilhéus, Bahia, Brazil

[3]Zootechnist, Doctor, Instituto Federal do Sul de Minas, Machado, Minas Gerais, Brazil

[4]Zootechnist, Doctor, Universidade Estadual do Sudoeste da Bahia, Itapetinga, Bahia, Brazil

[6]Veterinarian, Doctor, Embrapa Dairy Cattle, Juiz de Fora, Minas Gerais, Brazil

The aim of this study was to evaluate the effect of breed composition and nutritional plans on the archaeal community and the correlation of the archaeal population with CH_4 emissions, animal performance and fermentative variables. Data were derived from twenty-seven heifers of different breeds (9 Gyr, 9 Holstein x Gyr and 9 Holstein) that were randomly allocated to three nutritional plans: intake of 11, 14 and 19 g/kg body weight (90 days trial). Diets consisted of corn silage and concentrate (70.7% and 29.3% dry matter basis). The production and yield of enteric CH_4 were measured by open-circuit respiration chambers for two consecutive 24-h periods. The phylogenetic diversity of the ruminal archaeal community was assessed by sequencing the V6-V8 region of the 16S rRNA gene. Breeds composition influenced the relative abundances of the genera *Methanobrevibacter* and *Methanosphaera*, and the species *Methanobrevibacter acididurans. Methanosphaera* was more abundant in Holstein, while *Methanobrevibacter* and *M. acididurans* were more abundant in Gyr. The regularized canonical correlation analysis showed positive correlation between *M. acididurans* and acetate: propionate ratio, and a negative correlation was observed between *Methanosphaera ISO3-F5* and acetate: propionate ratio. The results of this study support the hypothesis that there is a contribution of host genetics to the composition of the ruminal microbiome, and no correlation was confirmed between the diversity of the archaea community and CH_4 emissions, however, it was possible to observe a strong correlation between the diversity of the archaea community and the acetate: propionate ratio.

Keywords: rumen microbiome, dairy heifer, zebu cattle.

Relative quantification of methanogenic bacteria from *q*PCR assays in bovine treated with natural additive.

Luis Eduardo Ferreira[1]; André Pastori D'Aurea[1]; Lauriston Bertelli Fernandes[1]; Ana Lucia Fachin[2]; Suzelei de Castro França[2]

[1]Premix® Company, Ribeirão Preto, SP, Brazil.

[2]University of Ribeirão Preto (UNAERP), Ribeirão Preto, SP, Brazil

The aim of this work was quantify the population of the methanogenic bacteria by the quantitative PCR assay (qPCR), from the ruminal liquid sample collected from bovines treated with additive natural. This additive is compound by mix of aminoacids, probiotics, essential fatty acid (omega 3 and omega 6), organic minerals and surfactants. The experiment were realized using 4 animals donor of ruminal liquid under pasture during the transition from drought to rainy season, receiving daily 5 g of additive Fator P® and negative control. After of the 15 days of the adaptation of ruminal microbiota, the samples were collected in five times (0, 2, 8, 16 and 24 hours) after the treatment, and in the end of experiment, was prepared the pool of each time of each treatments. The DNA were extracted using the kit QIAamp® DNA (Qiagem 51504) followed by qPCR reaction in triplicate of each time of each treatments, previous standardized in four concentrations (100nM, 200nM, 300nM e 400nM), using primers sequence of methanogenic bacteria as described in the literature. The mean of results of the duplicate of the five times of each treatment, showed the reduce of 64,8% (p=0,0009) in population of total methanogenic bacteria for the animals treated with the additive natural. The resulted showed the importance of presence of the additive for modulation of ruminal flora in improving the use of diet of animals, and in reduction of the enteric methane gas emissions from bovine breeding.

Keywords: Methanogenic, Ruminal Metabolism, Additives, Bovine Breeding, Molecular Biology.

Repeatability of CH_4 measurements by the SF_6 tracer gas technique in Nellore steers in feedlot system[1]

Leandro Sannomiya Sakamoto[1], Luana Lelis Souza[2], Elaine Magnani[3], Ana Fabrícia Braga Magalhães[4], Alexandre Berndt[5], Lucia Galvão de Albuquerque[6] and Maria Eugênia Zerlotti Mercadante[7]

[1]Animal Scientist, Post-doctoral Researcher at Institute of Animal Science, Beef Cattle Research Center, Sertãozinho, São Paulo, Brazil;

[2]Biologist, PhD Student at São Paulo State University (UNESP), School of Agricultural and Veterinarian Sciences, Jaboticabal, São Paulo, Brazil;

[3]Animal Scientist, Researcher at Institute of Animal Science, Beef Cattle Research Center, Sertãozinho, São Paulo, Brazil.

[4]Animal Scientist, Post-doctoral Researcher at Institute of Animal Science, Beef Cattle Research Center, Sertãozinho, São Paulo, Brazil;

[5]Agronomist Engineer, Researcher at Embrapa Southeast Livestock, Brazilian Agricultural Research Corporation, São Carlos, São Paulo, Brazil;

[6]Veterinarian, Professor at São Paulo State University (UNESP), School of Agricultural and Veterinarian Sciences, Jaboticabal, São Paulo, Brazil;

[7]Animal Scientist, Researcher at Institute of Animal Science, Beef Cattle Research Center, Sertãozinho, São Paulo, Brazil.

The aim of this study was to verify the repeatability and the mean values of 3, 4 and 5 days of measurement of enteric methane (CH_4, g/day) in Nellore steers using the tracer gas sulfur hexafluoride (SF_6). CH_4 emissions were evaluated using collection cylinders on the back of 70 male Nellore bulls in feedlot system. Permeation tubes were calibrated (average daily emission of 3.132 ± 0.25 mg/day) and supplied to the animals. The initial vacuum of the cylinders was around -13.600 psi and the capillary tubes were calibrated to absorb 50 ± 3% of the sample inside the cylinder in 24 hours. During five consecutive days, the cylinders were changed for another every day at the same time, totaling five samples per animal. The repeatability of dry matter intake (DMI) during the collection days was 0.49. DMI and CH_4 variance components were estimated using MIXED procedure and the CH_4 means were compared using Tukey test ($P < 0.05$). Repeatability of CH_4 measurement were 0.78, 0.80 and 0.82 for 5, 4 and 3 days, respectively. The average of CH_4 emission obtained in 5, 4 and 3 days did not differ (199.5, 198.6 and 196.0 g/day). The results showed high repeatability for CH_4 measurement using this technique. More research using a larger number of animals should be performed to assure the reliability in measuring the emission of enteric methane in 4 or 3 days of collection through the SF_6 tracer gas technique.

Keywords: enteric methane, cattle, cylinder, sulfur hexafluoride.

[1]Grant #2018/17313-5 and #2017/50339-5, São Paulo Research Foundation (FAPESP)

Ruminal fluid metabolomics associated with diet and environmental impact of Nelore cattle: initial results

Jessica Moraes Malheiros[1], Banny Silva Barbosa Correia[2], Caroline Ceribeli[2], Daniel Rodrigues Cardoso[2], Luiz Alberto Colnago[3], Gerson Barreto Mourão[4], Luiz Lehmann Coutinho[4], Julio Cesar Pascale Palhares[1], Alexandre Berndt[1] and Luciana Correia de Almeida Regitano[1]

[1]Embrapa Southeast Livestock, São Carlos, São Paulo, Brazil.

[2]Institute of Chemistry, University of São Paulo/USP, São Carlos, São Paulo, Brazil.

[3]Embrapa Instrumentation, São Carlos, São Paulo, Brazil.

[4]Department of Animal Science, University of São Paulo/ESALQ, Piracicaba, São Paulo, Brazil.

[Ψ]CNPq fellowship

The objective of this study was to apply metabolomics tool (untargeted metabolite analysis) to improve our understanding of how feeding aim to reduces greenhouse gas emissions of bovine. A population of 52 Nelore animals was submitted to different nutritional interventions (conventional n = 26 and by-product-based diet n = 26) for 105 days in collective pens equipped with automated feeding (GrowSafe®), where methane emissions were measured. After slaughter, ruminal fluid samples were collected and submitted to metabolomics analysis performed by nuclear magnetic resonance spectroscopy (^{1}H NMR) in a 14 T Bruker Avance III spectrometer. Principal component analysis (PCA), Partial least squares discriminant analysis (PLS-DA) and Variable importance in the projection (VIP score) were conducted by MetaboAnalyst 4.0 software to identify differentially expressed metabolites ($p<0.05$) between the nutritional interventions. The by-product-based diet affected the rumen fermentation and decreased methane production compared to conventional nutrition. PLS-DA revealed the formation of two clusters of metabolic profiles for ruminal fluid samples and were correlated to the two different feeding systems. Comparative analysis based on VIP score values led to the identification of differentially expressed metabolites, of which the top 15 metabolites presented VIP score > 1.8 and the compounds belonging to the by-product-based diet showed higher intensity, when compared to conventional diet. Thus, the results of this study demonstrated that ^{1}H NMR metabolomics combined with multivariate analysis may be capable of distinguishing the rumen fluid derived from animals on different feeding systems and may help to understand the relation between feeding and methane production.

Index terms: *Bos indicus*, bovine metabolome, metabolites, nuclear magnetic resonance

Acknowledgments: Sao Paulo Research Foundation (FAPESP; grant number: 2017/26537-1) and National Council for Scientific and Technological Development (CNPq; grant number: 428153/2018-6) for financial support.

Ruminal metabolism and methane emission in a dual-flow continuous culture system fed different protein levels.

María Paz Tieri[1], Eduardo Alberto Comerón[2], José Gere[3], Francisco Stefañuk[4], Delfina Montiel[5], Gustavo Depetris[5], María Ceron Cucchi[6], Abimael Ortiz[7] and Horacio Leandro Gonda[8]

[1]Agr. Eng., PhD student, Department of Animal Production, National Institute of Agricultural Technology, Rafaela, Santa Fe, Argentina.

[2]Agr. Eng., PhD, Department of Animal Production, National Institute of Agricultural Technology, Rafaela, Santa Fe, Argentina.

[3]B. Environ. Technol. PhD. CONICET. Engineering Research and Development Unit - National Technological University. Ciudad Autónoma de Buenos Aires, Argentina.

[4]Med. Vet. MSc. Animal Production ,Deparment, National Institute of Agricultural Technology, Balcarce, Buenos Aires, Argentina.

[5]Med. Vet. MSc. Animal Production Deparment, National Institute of Agricultural Technology, Balcarce, Buenos Aires, Argentina.

[6]Med. Vet. PhD. Institute of Veterinary Pathobiology, National Institute of Agricultural Technology, Buenos Aires, Argentina.

[7]Med. Vet. PhD Student. CONICET. Institute of Veterinary Pathobiology, National Institute of Agricultural Technology, Buenos Aires, Argentina.

[8]Agr. Eng., PhD, Associate Professor, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden.

The objective of this study was to evaluate the effects of increased dietary CP levels on ruminal nutrient digestibility, ruminal fermentation, N metabolism, microbial efficiency and methane emission in dairy cattle diets using a dual-flow continuous culture system. Three fermenters (1,550 ± 32 mL) were used in a 3 x 3 Latin square design with periods lasting 10 d each (7 d for adaptation and 3 d for sampling). Experimental diets were composed, on dry matter basis, of 26.6% lucerne hay, 30.8% maize silage and 42.6% concentrate based on maize grain (MG) and soybean meal (SBM). Proportions of MG and SBM were such to result in diets with 13, 16 and 19% crude protein contents. Fermenters were fed 90 g/d and solid and liquid dilution rates were adjusted to 5 and 10%/h, respectively. Data were analyzed using the MIXED procedure in SAS with $\alpha = 0.05$. Apparent and true digestibility's, total volatile fatty acids (VFA) concentration and molar proportions of acetate, propionate and butyrare were not affected ($P>0.05$) by increasing dietary CP. NH_3-N concentration and total flows of N, NH_3-N and dietary undegraded protein increased linearly ($P<0.01$) in response to increasing dietary CP, while efficiency of bacterial N synthesis decreased linearly ($P<0.01$). Methane production and microbial population (total and methanogenic) were not affected by treatments. At the lower CP levels, a low level of NH_3-N in the rumen may have a slightly improved ruminal function. Therefore, diets with 13% and 16% of CP may be the best strategy for improving N utilization in the rumen, without affecting methane output.

Keywords: ruminants, nitrogen metabolism, methane emission, rumen microorganisms.

Ruminal Methanogen Community Changes in Response to the Rumen Development and the Addition of Rhubarb

Zuo Wang[1], min Wang[2], Zhiliang Tan[2], Robert John Forster[3], Jianhua He[1]

[1]Hunan Agricultural University
[2]Institute of Subtropical Agriculture, The Chinese Academy of Sciences
[3]Lethbridge Research and Development Centre

This study was performed to investigate the initial colonization of metabolically active methanogens and subsequent changes in four fractions: the rumen solid-phase (RS), liquid-phase (RL), protozoa-associated (RP), and epithelium-associated (RE) from 1 to 60 d after birth, and manipulate methanogen community by early weaning on 40 d and supplementing rhubarb from 40 to 60 d in black goats. The RNA-based real-time quantitative PCR and 16S rRNA amplicon sequencing were employed to indicate the metabolically active methanogens. Results showed that active methanogens colonized in RL and RE on 1 d after birth. RP and RE contained the highest and lowest density of methanogens, respectively. *Methanobrevibacter*, Candidatus *Methanomethylophilus*, and *Methanosphaera* were the top three genera. The methanogen communities before weaning differed from those post weaning and the structure of the methanogen community in RE was distinct from those in the other three fractions. The discrepancies in the distribution of methanogens across four fractions, and various fluctuations in abundances among four fractions according to age were observed. The addition of rhubarb significantly ($P < 0.05$) reduced the abundances of *Methanimicrococcus* spp. in four fractions on 50 d, but did not change the methanogen community composition on 60 d.

Keywords: Microbial programming, 16S rRNA amplicon sequencing, Rumen solid, Rumen liquid, Rumen protozoa, Rumen epithelium

Ruminal microbiota change and methane emission in cattle receiving nitrate in diet using the SF6 tracer technique.

Abimael Ortiz[1], Gustavo Depetris[2], Francisco José Stefañuk.[3], José Ignacio Gere[4], Ricardo Bualó[5], Silvio Cravero[6], Claudia Faverin[7], Gisela Marcoppido[8], Cesar Pinares-Patiño[9], María Esperanza Ceron Cucchi[10]

[1]Med. Vet. PhD Student. CONICET. Institute of Veterinary Pathobiology, NationalInstitute of Agricultural Technology, Buenos Aires, Argentina.

[2]Med. Vet. MSc. Animal Production Department, National Institute of Agricultural Technology, Balcarce, Buenos Aires, Argentina.

[3]Med. Vet. MSc. Animal Production Department, National Institute of AgriculturalTechnology, Balcarce, Buenos Aires, Argentina.

[4]B. Environ. Technol. PhD. CONICET. Engineering Research and Development Unit -National Technological University. Ciudad Autónoma de Buenos Aires, Argentina.

[5]Ag. Eng. MSc. Animal Production, Institute of Veterinary Pathobiology, National Instituteof Agricultural Technology, Buenos Aires, Argentina.

[6]Biochem. PhD. Institute of Biotechnology, National Institute of Agricultural Technology,Buenos Aires, Argentina.

[7]B. Biol. PhD. Animal Production Department, National Institute of Agricultural Technology, Balcarce, Buenos Aires, Argentina.

[8]Med. Vet. PhD. CONICET. Institute of Veterinary Pathobiology, National Institute ofAgricultural Technology, Buenos Aires, Argentina.

[9]Ag. Eng. PhD. The Agribusiness Development Group New Zeland.

[10]Med. Vet. PhD. Institute of Veterinary Pathobiology, National Institute of Agricultural Technology, Buenos Aires, Argentina.

The aim of this study was to evaluate the impact of nitrate inclusion in the diet on methane emission and ruminal microbiota. Eighteen Holstein heifers and steer (214±13.5 kg live weight) were allocated to two dietary treatments (isonitrogenated and isoenergetic). Control diet (CD) was corn, urea and soybean mix (80%) and grass hay (20%); nitrate diet (ND) was the CD (98.7%) plus 1.3% calcium nitrate. The trial included a 30-d adaptation to the diet, followed by 7-d feed intake measurement, 5-d measurement of methane emission and a 3-d period of sampling of ruminal contents. The ND decreased the total methane emissions (178 vs 242 g/d, P=0.009) and per unit of dry matter intake (24 vs 31g/kg; P=0.050). Monitoring of ruminal microbiota (Log10 copies/g) in the ND revealed that total bacteria, *Rumicoccusalbus* and *Ruminococcusflavefaciens* were reduced (P<0.05) in pre-feeding (11.5 vs 11.9; 6.6 vs 7.8 and 7.4 vs 9.1, respectively), while for methanogens no differences were found (8.5 vs 8.5). Conversely, *F. succinogenes* was higher in the ND than CD (7.2 vs 6.4; P<0.05). At 4 and 8 h post-feeding the methanogens were reduced in ND (8.1 vs 8.4; 7.9 vs 8.3, respectively; P<0.05), while total bacteria, *albus* and *R. flavefaciens* were maintained in a lower concentration. However, *F. succinogenes* remained in a higher concentration in ND than CD. The inclusion of nitrate reduced absolute methane emissions by 27% without affecting feed intake, and it could be related to the reduction in methanogen populations.

Keywords: SF6 tracer technique, Dairy cattle, methanogens.

Selection for lower methane emission in dairy cattle

Jan Lassen[1] and Gareth Frank Difford[2]

[1]Viking Genetics, Ebeltoftvej 16 8960 Randers SØ Denmark
[2]NOFIMA, Oslovejen 1, Ås, Norway

Over the last decade concerted research thrust has been directed at methane mitigation strategies. Many animal science disciplines have been involved including: nutrition and physiology, microbiology, genetic management and engineering. There is a fundamental need for research within the area of methane mitigation strategies and indeed research across disciplines is needed. Different approaches to obtain data needed for genetic analysis have been performed and results all come to the same conclusion. Methane emission is under some genetic control (h^2=0.2) but by far more controlled by other effects in the surrounding environment. Genetic selection for a trait has the potential to make changes because the effect is cumulative and lasting. The effect is persistent over days and the inherited effect is cumulative from generation to generation. Often discussions are related to how methane should be placed in a breeding goal. Selection never will be put on methane alone. It will always be part of the existing total merit index and given a proper weight to ensure balanced breeding. Therefore beginning to select for decreased methane emission will not lead to cows that will not digest roughage or cows that select concentrate in their diet, because this would have enormous consequences for many other traits in the existing total merit index and therefore bulls that produce such offspring will not be selected as superior bulls. No significant correlations has been estimated so selection for reduced methane emission will likely have minimal consequences on other traits.

Strategies for enteric methane mitigation in ruminants fed low-quality tropical forages

Ku-Vera, J.C.[1], Castelán-Ortega, O.A.[2], Galindo-Maldonado, F.A[3]., Arango, J.[4], Chirinda, N.[4],Molina, L.T.[5], Flores-Santiago, E.J.[1], Jiménez-Ocampo, R.[6,1], Piñeiro-Vázquez, A.T.[7], Canul-Solís, J.R.[8], Montoya-Flores, M.D.[9], Molina-Botero, I.C.[1], Arceo-Castillo, J.I.[10], Elshereef, A.[1], Albores-Moreno, S.[1], Briceño-Poot, E.G.[1], Escobar-Restrepo, C.S.[1], Hernández-Pineda, G.S.[1], Zavala-Escalante, L.M.[1], Valencia-Salazar, S.S.[11], Ramírez-Cancino, L.[1], Quintana-Owen, P.[12], Aguilar-Pérez, C.F.[1], Ayala-Burgos, A.J.[1], Ramírez-Avilés, L.[1] and Solorio-Sánchez, F.J.[1]*

[1]Ruminant nutritionist, PhD. lecturer-researcher, Laboratory of Climate Change and Livestock Production (LACCLIGA), Department of Animal Nutrition, Faculty of Veterinary Medicine and Animal Science, University of Yucatan (UADY), Carretera Merida-Xmatkuil km 15.5, C.P. 97100, Merida, Yucatan, Mexico. *corresponding author: kvera@correo.uady.mx

[2]Ruminant nutritionist, PhD. lecturer-researcher, Laboratory of Livestock, Environment and Renewable Energies, Faculty of Veterinary Medicine and Animal Science, University of State of Mexico (UAEM), Instituto Literario 100, C.P. 50000, Toluca, Estado de Mexico, Mexico.

[3]Ethologist, PhD. lecturer-researcher, Department of Ethology, Wildlife and Laboratory Animals, Faculty of Veterinary Medicine and Animal Science, National University of Mexico (UNAM), Ciudad Universitaria, 04510 Mexico City, Mexico.

[4]PhD, research coordinators, International Center for Tropical Agriculture (CIAT), km 17, Recta Cali-Palmira, Palmira, Valle del Cauca, Colombia.

[5]PhD, researcher, Molina Center for Energy and the Environment, La Jolla, California, United States of America

[6]Ruminant nutritionist, MSc. PhD student, National Institute of Research in Forestry, Agriculture and Livestock-INIFAP, Experimental Field Valle del Guadiana. C.P. 34170 Durango, Durango, Mexico.

[7]Ruminant nutritionist, PhD, lecturer-researcher, National Technologic of Mexico/ I.T. Conkal, Avenida Tecnologico s/n, C.P. 97345, Conkal, Yucatan, Mexico.

[8]Ruminant nutritionist, PhD, lecturer-researcher Postgraduate Studies and Research Division, National Technologic of Mexico/Technologic Institute of Tizimin, Yucatan, Avenida Cupul km 2.5, Tizimin, Yucatan C.P. 97700, Mexico

[9]Ruminant nutritionist, PhD, researcher National Center for Disciplinary Research in Physiology and Animal Breeding-INIFAP, km 1 Carretera a Colon, C.P. 76280 Ajuchitlan, Queretaro, Mexico

[10]Mechanical engineer, MSc. PhD student Department of Applied Physics, Center for Research and Advanced Studies of the National Polytechnic Institute (CINVESTAV-IPN), Carretera Antigua a Progreso km 6, Colonia Cordemex, C.P. 97310, Merida, Yucatan, Mexico.

[11]Ruminant nutritionist, MSc student College of the Southern Border (ECOSUR), Livestock and Environment, Carretera Panamericana - Periferico Sur, C.P. 29290, San Cristobal de las Casas, Chiapas, Mexico

[12]Materials scientist, PhD, Department of Applied Physics, Center for Research and Advanced Studies of the National Polytechnic Institute (CINVESTAV-IPN), Carretera Antigua a Progreso km 6, Colonia Cordemex, C.P. 97310, Merida, Yucatan, Mexico.

Methane is a greenhouse gas which is produced and eructated to the atmosphere in large volumes by ruminants grazing tropical forages. Tropical grasses have been claimed to give rise to higher emissions of methane than temperate grasses when fed to ruminants. Fourteen experiments were performed in open-circuit respiration chambers and head-boxes with crossbred cattle and hair sheep respectively, to assess the mitigation potential of foliages and pods of tropical and temperate plants, as well as nitrates and oils in practical rations. On the basis of 125 individual determinations of methane carried out in respiration chambers, it can be asserted that the average methane yield for cattle fed (>70% ration DM) low-quality tropical grasses is 17.1 g CH_4/kg DMI. When foliages and ground pods of tropical trees and shrubs were incorporated into the ration of cattle and sheep, methane yield (g CH_4/kg DMI) was decreased in the general range of 15 to 25%, depending on plant species and level of inclusion. Incorporation of nitrates and oils in the ration also decreased methane yield. It is concluded that condensed tannins and saponins, as well

as starch contained in foliages and pods of tropical and temperate trees and shrubs can be fed to cattle and sheep to mitigate enteric methane emissions under practical feeding conditions with smallholders. Strategies of enteric methane mitigation in ruminants fed low-quality tropical forages in Latin America and the Caribbean can effectively increase productivity while decreasing methane emissions per unit of product (meat/milk), thus reducing the contribution of livestock to greenhouse gas emissions and therefore to climate change.

Keywords: Tropical grasses, legumes, rumen fermentation, methane production, greenhouse gases

The recovery rate of methane, carbon dioxide and hydrogen at different flow levels in respiration chambers.

Anne Louise Frydendahl Hellwing[1], Martin Riis Weisbjerg[2] and Peter Lund[3]

[1]Animal Science, Ph.D., Scientist, Department of Animal Science, AU Foulum, Aarhus University, Denmark
[2]Animal Science, Ph.D., Professor, Department of Animal Science, AU Foulum, Aarhus University, Denmark
[3]Animal Science, Ph.D., Professor, Department of Animal Science, AU Foulum, Aarhus University, Denmark.

During recent years, there has been an increased focus on the quality of data generated from systems measuring the enteric methane emissions, as data e.g. are used for country specific methane emissions inventories. The aim of this study was to investigate the recoveries of methane (CH4), carbon dioxide (CO2) and hydrogen (H2) at four different air flowrates for the respiration chambers at Aarhus University. The system has four identical chambers, with adjustable airflow. The air flowrates tested were 755±15, 1523±30, 1910±30 and 3074±27 liters per minute (45, 65, 75 and 100% of maximum flow). For each test CO2 recovery was measured in all chambers, CH4 recovery in two chambers and H2 recovery in one chamber. At each air flowrate four repetitions were performed. The data was analysed with PROC GLM in SAS with airflow, gas, chamber and two-way interactions as fixed effects. The recovery was affected by gas, airflow and interaction between chamber and airflow. For the main effect gas recoveries were 98.7, 98.4 and 95.0 for CH4, CO2 and H2. The recovery of H2 was significantly lower than of CH4 and CO2. For the main effect airflow the recoveries were 95.1, 98.3, 99.3 and 96.8% at 45, 65, 75 and 100% of max airflow. The recoveries were similar at 65 and 75% of max airflow. Within each air flowrate H2 always had the lowest recovery, and CH4 were highest except for air flowrate 75%. In conclusion, it is important to use gas and flowrate specific recoveries.

Index terms: chambers, test, quality

Towards the application of 3-nitrooxypropanol in pastoral farming systems

Stefan Muetzel[1], Katherine Lowe[2], Peter H. Janssen[3], David Pacheco[4], Nathan Bird[5], Nicola Walker[6], Olivia Vidoni[7], Loni Schweikert[8], Laure Clasadonte[9] and Maik Kindermann[10]

[1]Dr. Sc. Agr, Senior Scientist, Animal Nutrition & Physiology, AgResearch Ltd., Palmerston North, New Zealand

[2]BSc., Research Associate, Animal Nutrition & Physiology, AgResearch Ltd., Palmerston North, New Zealand

[3]DPhil., Principal Scientist, Rumen Microbiology, AgResearch Ltd., Palmerston North, New Zealand

[4]PhD., Principal Scientist - Science Team Leader, Animal Nutrition & Physiology AgResearch Ltd., Palmerston North, New Zealand

[5]PhD., Regional Director, Asia, DSM and Mohua Consulting, Australia.

[6]Dr., Principal Scientist, DNP Innovation Animal Nutrition and Health, DSM Nutritional Products, Kaiseraugst, Switzerland

[7]Dr., Senior Scientist, DNP Innovation R&D Formulation, DSM Nutritional Products, Kaiseraugst, Switzerland

[8]Dr., Principal Scientist, DNP Innovation R&D Formulation, DSM Nutritional Products, Kaiseraugst, Switzerland

[9]Feed Technology and Formulation Manager, DNP Innovation Animal Nutrition and Health, DSM Nutritional Products, Kaiseraugst, Switzerland

[10]Dr., Innovation Project Manager, DNP Innovation Animal Nutrition and Health, DSM Nutritional Products, Kaiseraugst, Switzerland

The investigational product 3-nitrooxypropanol (3-NOP) is an effective methane inhibitor that has been extensively evaluated mixed into rations in non-pastoral dairy and beef systems. The effects of 3-NOP when used in fresh-pasture rations were evaluated in three studies with cattle in respiration chambers (n=4 per treatment). In trial 1, compared to controls, there was a 52% reduction ($P < 0.01$) in methane yield when 3-NOP (2.5 g/d per cow) was mixed into fresh cut pasture fed in two daily allocations. Methane yield was decreased by 39% ($P = 0.03$) when 3-NOP was mixed in a supplement offered twice daily immediately before allowing access to fresh-cut pasture meals. In trial 2, no significant effect of 3-NOP was detected when 3-NOP was dosed at 2.5 g/d per cow in a supplement during milking but access to pasture was withheld for 1 h to simulate the delay in time from milking to grazing ($P = 0.20$). Feed intake was not affected by 3-NOP In both trials and 3-NOP had no effect on milk production in Trial 2. These results indicate that the time between 3-NOP administration and access to feed needs to be shortened or its longevity in the rumen extended. In trial 3, new slow release formulations of 3-NOP were tested and showed potential to extend the time that 3-NOP is active in the rumen, based on gas emission profiles from cows. Further studies are planned to refine promising formulations and to establish their methane reduction potential for pasture fed cattle.

Index Terms: methane mitigation, dairy cattle, temperate pastures, pastoral systems

Variability in the relationship between enteric methane emission and dry matter intake in dairy cows

Alexander N. Hristov[1] and Audino Melgar Moreno[2]

[1]Professor, Department of Animal Science, The Pennsylvania State University, University Park, PA 16802, United States
[2]Graduate Student, Department of Animal Science, The Pennsylvania State University, University Park, PA 16802, United States

We examined the relationship of enteric methane emission, measured using the GreenFeed system (GF), and dry matter intake (DMI) in a 15-week experiment with lactating dairy cows receiving a control diet or a diet containing the investigational product 3- nitrooxypropanol (3-NOP at 60 mg/kg feed DM). Daily methane emission and DMI were clustered into 12 time-slots of 2 h each. Methane emission and DMI were the lowest 2-h before feeding and highest within 6 h after feeding. The overall (24 h) relationship between methane emission and DMI was poor (R^2 = 0.01). The relationship for the control (but not 3-NOP) cows was improved (R^2 = 0.31; P < 0.001) when DMI was allocated to time-slots and was strongest (R^2 = 0.53; P < 0.001) 8-10 h after feeding. Analysis of the 3-NOP emission data showed marked differences in the mitigation effect of this proven methane inhibitor with time (overall 27%). There was a lack of effect in the 2-h time-slot before feeding, the mitigation effect was highest (45%) immediately after feeding, persisted at around 32-39% within 10 h after feeding, and decreased to 13%, 4-h before feeding. These trends were clearly related to DMI (i.e., 3-NOP intake). This analysis showed that the relationship of enteric methane emission, measured using GF, and DMI in dairy cows depends on the time of measurement relative to time of feeding and can be as high as determined in respiration chambers. The methane mitigation effect of 3-NOP is highest immediately after feeding and lowest before feeding.

Keywords: cattle, measurement technique, 3-nitrooxypropanol

LivestockPlus: Supporting low emissions development in the Latin American cattle sector.

Jacobo Arango[1], Idupulapati Rao[2], Todd Rosenstock[3], Jeimar Tapasco[4], Jennifer Twyman[5], Rolando Barahona[6], Cristobal Villanueva[7], Mauricio Chacón[8], Nelson Vivas[9] and Ngonidzashe Chirinda[10].

[1]PhD Plant science, Environmental biologist, International Center for Tropical Agriculture (CIAT), Km 17 Recta Cali – Palmira, Colombia

[2]PhD Plant physiology, Emeritus scientist, International Center for Tropical Agriculture (CIAT), Km 17 Recta Cali – Palmira, Colombia

[3]PhD Agroecology, Environmental scientist, World Agroforestry Centre (ICRAF), UN Avenue, Nairobi 00100, Kenya

[4]PhD Economy, Environmental economist, International Center for Tropical Agriculture (CIAT), Km 17 Recta Cali – Palmira, Colombia

[5]PhD Food and resource economics, Social scientist, International Center for Tropical Agriculture (CIAT), Km 17 Recta Cali – Palmira, Colombia

[6]PhD Agricultural sciences, Associate professor, National University of Colombia, Cl 59A No. 63-20 Medellín, Colombia

[7]MSc Agricultural sciences, Silvopastoral researcher, Tropical Agricultural Research and Higher Education Center (CATIE), Turrialba, Cartago 30501, Costa Rica

[8]BEng Agricultural engineering, National Manager of Livestock, Ministry of Agriculture and Livestock, Av.12 Cl 68 San José, Costa Rica

[9]PhD Agricultural sciences, Associate professor, University of Cauca, Cl 5 No. 4-70 Popayán, Colombia

[10]PhD Agroecology and sustainable agriculture, Soil scientist, International Center for Tropical Agriculture (CIAT), Km 17 Recta Cali – Palmira, Colombia.

After three years of successful operation, the LivestockPlus project enabled the development and the first steps for implementation of Nationally Appropriate Mitigation Actions (NAMAs) for the cattle sector in Costa Rica and Colombia. It provided technical support and generated critical information and guidelines allowing the identification of options by quantifying changes in fluxes of greenhouse gases, soil carbon stocks, and the productivity of cattle-based systems. This initiative helped to determine technical options for low emissions pasture development in Latin America, and how these can be scaled up using NAMAs and other environmental policies in Colombia and Costa Rica. Efforts are now expanded beyond these two countries across the region as applicable. The project facilitated synergies that enabled overcoming barriers to the adoption of improved management practices and, consequently, the achievement of low emission development by: (i) Fostering partnerships among relevant stakeholders; (ii) Identifying and evaluating best-fit mitigation options; (iii) Evaluating measurement reporting and verification (MRV) systems for the cattle sector in the target countries. Concrete examples will be shown on testing different forage-based diets *in vitro* and *in vivo* for their potential to reduce enteric methane emissions, potential of improved grasses to reduce soil nitrification and nitrous oxide emissions, the influence of improved forages in carbon stock accumulation in soil, Life Cycle Analysis of livestock farms with different production systems, definition of MRV guidelines for silvopastoral systems, as well as improvement of GHG national inventories by the validation of methane predicting models.

Index terms: Nationally Appropriate Mitigation Actions, Nationally Determined Contributions, Colombia, Costa Rica, Mitigation of climate change.

1.3 Modelling (Oral)

A disaggregated analysis of global N_2O emissions from livestock supply chains

Aimable Uwizeye[1,2], Juliana C. Lopes[1], Imke J.M. de Boer[2], Carolyn I. Opio[1], Rogier Schulte[3], Alessandra Falcucci[1], Giuseppe Tempio[1], Felix Teillard[1], Monica Rulli[1], Giuseppina Cinardi[1], Flavia Casu[1], Henning Steinfeld[1], and Pierre J. Gerber[2,4]*

[1]Food and Agriculture Organization of the United Nations, Animal Production and Health Division, Viale delle Terme di Caracalla, 00153 Rome, Italy

[2]Animal Production Systems Group, Wageningen University & Research, PO Box 338, 6700 AH, Wageningen, the Netherlands

[3]Farming Systems Ecology, Wageningen University, P.O. Box 430, Wageningen 6700 AK, The Netherlands

[4]The World Bank, 1818 H Street, NW Washington, DC 20433 USA.

* Corresponding author: Juliana.lopes@fao.org

The disruption of the nitrogen (N) cycle pose a threat to the environment and human life. Hence, analyzing N flows and losses from livestock is essential to understand the sector's contribution to the transgression of the planetary boundaries, in particular, climate change. Our study assessed the contribution of global livestock supply chains to anthropogenic N losses and flows on different spatial scales, using an updated version of the Global Livestock Environmental Assessment Model (GLEAM), which analyzed N inputs, N outputs, N loss by compounds and N recycled along the chain. The results show that global livestock N_2O emissions are about 815 Tg CO_2 eq. y^{-1}. In terms of N losses, N_2O emissions are equivalent to 1.7 Tg N y-1 and account for 3% of the total N losses from the livestock sector. Feed production is the largest source of N_2O emissions, accounting for a 75%, while the remaining 25% is from manure management. Whereas N_2O is an important greenhouse gas, climate change discussions should also consider the impacts of other forms of N. The current study provides a detailed disaggregated analysis of the magnitude, sources and pathways of N and insights on how to manage N_2O emissions in the context of a wider N cycle that can support evidence-based decisions to shape the future of livestock sector.

Keywords: livestock, animal, nitrous oxide, nitrogen, climate change, GLEAM

Evaluation of mathematical models to predict methane emissions from ruminants under different dietary mitigation strategies (1)

Mohammed Benaouda[1], Cécile Martin[2], Xinran Li[3], Ermias Kebreab[4], Alexander N. Hristov[5], Zhongtang Yu[6], David R. Yáñez-Ruiz[7], Christopher K. Reynolds[8], Les A. Crompton[9], Jan Dijkstra[10], André Bannink[11], Angela Schwarm[12], Michael Kreuzer[13], Mark McGee[14], Peter Lund[15], Anne L. F. Hellwing[16], Martin R. Weisbjerg[17], Peter J. Moate[18], Ali R. Bayat[19], Kevin J. Shingfield[20], Nico Peiren[21] and Maguy Eugène[22]

[1]Animal science, PhD, Postdoctoral fellowship, INRA, UMR1213 Herbivores, F-63122 Saint- Genès-Champanelle, France

[2]Animal Science, PhD, Senior Scientist, INRA, UMR1213 Herbivores, F-63122 Saint-Genès- Champanelle, France

[3]Animal science, PhD, Postdoctoral fellowship, INRA, UMR1213 Herbivores, F-63122 Saint- Genès-Champanelle, France

[4]Animal Science, Ph. D., Professor, University of California, Davis, Davis, CA 95616 USA

[5]Animal Science, Ph.D., Professor, Department of Animal Science, The Pennsylvania State University, USA

[6]Microbiology, Ph. D., Professor, Department of Animal Sciences, The Ohio State University, USA

[7]Estacion Experimental del Zaidin, CSIC, Granada, Spain

[8]Animal Science, PhD, Professor, Centre for Dairy Research, School of Agriculture, Policy and Development, University of Reading, UK

[9]Animal Science, PhD., Senior Fellow, School of Agriculture, Policy and Development, University of Reading, UK

[10]Animal Science, PhD, Associate Professor, Animal Nutrition Group, Wageningen University & Research, Wageningen, the Netherlands

[11]Animal science, PhD, Senior scientist, Wageningen Livestock Research, Wageningen University & Research, the Netherlands

[12]Animal Science, PhD, Associate Professor, Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences, Ås, Norway

[13]Agricultural science, Dr. Dr. habil., Professor, Institute of Agricultural Sciences, ETH Zurich, Switzerland

[14]Animal Science, Ph.D., Principal Researcher, Teagasc, Grange, Ireland

[15]Animal Science, Ph.D., Professor, Department of Animal Science, AU Foulum, Aarhus University, Denmark

[16]Animal Science, Ph.D., Scientist, Department of Animal Science, AU Foulum, Aarhus University, Denmark

[17]Animal Science, Ph.D., Professor, Department of Animal Science, AU Foulum, Aarhus University, Denmark

[18]Veterinary Science, PhD, Scientist, Agriculture Victoria Research, Australia

[19]Animal Science, Ph.D., Senior Researcher, Natural Resources Institute Finland (Luke), Finland

[20]Animal Science, Ph.D., Professor, Natural Resources Institute Finland (Luke), Finland. (deceased)

[21]Biology, PhD, Senior Researcher, Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Melle, Belgium

[22]Animal science, PhD, Senior Scientist, UMR1213 Herbivores, F-63122 Saint-Genès-Champanelle, France

This study evaluated the ability of published models to predict enteric methane (CH_4) emissions from dairy cattle, beef cattle, sheep and dairy goat, using a large database (3183 individual animal data). Models for each animal subcategory and CH_4 dietary mitigating strategies of lipid or starch supplementation and of diet quality (described by organic matter digestibility and neutral-detergent fiber digestibility) were assessed. Models were ranked according to root mean square prediction error (RMSPE; % of observed mean) to standard deviation of observed values ratio (RSR) and RMSPE, using all data within each animal subcategory. For dairy cattle, CH_4 emissions (g/day) were predicted with the smallest RSR using the model based on feeding level [dry matter intake (DMI)/body weight (BW)], digestibility of feed gross energy (dGE) and dietary ether extract (EE) content (RSR=0.66, RMSPE=15.6%). For beef cattle, the smallest RSR was obtained using GE intake, BW, forage and EE content (RSR=0.83, RMSPE=27.2%). For sheep and goat, there were limited published models; the smallest RSR was observed for a sheep model based on digestible energy intake (RSR = 0.61, RMSPE = 19.2%). IPCC Tier 2 models (1997; 2006) had low predictive ability for variation in dietary

EE content, neutral detergent fiber content and organic matter digestibility (RMSPE 14.3-30.5% and 23.0-40.5% for dairy and beef cattle, respectively). No model predicted CH_4 emissions accurately under all dietary mitigation strategies. Some models gave satisfactory predictions and for improved prediction, models should include feed intake, digestibility and information on dietary chemical composition.

Index terms: Prediction equation, enteric methane, livestock, nutritional practices.

(1)This study is part of the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI)'s "GLOBAL NETWORK" project and the "Feeding and Nutrition Network" (http://animalscience.psu.edu/fnn) of the Livestock Research Group within the Global Research Alliance for Agricultural Greenhouse Gases (www.globalresearchalliance.org).

Prediction of enteric methane can be improved by using the NorFor feed evaluation system for dairy cows.

Anne Louise Frydendahl Hellwing[1], Nicolaj Ingemann Nielsen[2], Martin Riis Weisbjerg[3] and Peter Lund[4]

[1]Animal Science, Ph.D., Scientist, Department of Animal Science, AU Foulum, Aarhus University, Denmark.
[2]Animal Science, Ph.D., Senior Specialist, Livestock Innovation, SEGES, Denmark.
[3]Animal Science, Ph.D., Professor, Department of Animal Science, AU Foulum, Aarhus University, Denmark.
[4]Animal Science, Ph.D., Professor, Department of Animal Science, AU Foulum, Aarhus University, Denmark.

NorFor is a semi-mechanistic, static and science-based feed evaluation system that predicts nutrients supply and requirements for cattle. The aim of the study was to investigate whether variables in the NorFor feed evaluation system could be used to predict the enteric methane emissions. A dataset was compiled from 11 studies, comprising 43 diets and 243 observations. Chemical composition of feedstuffs, live weight and dry matter intake (DMI) of individual cows were used in the NorFor model to estimate 134 variables describing nutrient intake, flows and digestion. The highest correlation was found between methane (L/d) and intake of fill units (0.77). Fill units describes the fill of feedstuffs and forms the basis for the feed intake system in NorFor. The fill value is fixed for concentrate, but for roughage it depends on organic matter (OM) digestibility and neutral detergent fibre (NDF) concentration. The correlations between methane and recorded DMI and NorFor estimated rumen digested OM and total digested OM were 0.74, 0.73 and 0.70, respectively. A prediction model for methane (L/d) was formulated using an automatic selection tool (PROC GLMselect in SAS). The following variables were selected; intake of fill units (no unit), intake of indigestible NDF from concentrate (g/day), rumen passage rate of roughage (%/h) and NDF in concentrate (%/h), sum of rumen degraded starch and sugar (g/day), and digestibility of crude fat (%). Methane emissions predicted were improved using a model based on NorFor estimates with a correlation of 0.89 between predicted and measured.

Index terms: dry matter intake, fill units, rumen passage

Variability in greenhouse gas emissions intensity of farm-scale suckler cow beef production systems

Stine Samsonstuen[1], Bente Aspeholen Åby[2] and Laila Aass[3]*

[1]Ph.D., Norwegian University of Life Sciences, Department of Animal and Aquacultural Sciences, Box 5003, 1432 Ås, Norway.

[2]Dr. Scient. (Ph.D.), Researcher, Norwegian University of Life Sciences, Department of Animal and Aquacultural Sciences, Box 5003, 1432 Ås, Norway.

[3]Dr. Scient. (Ph.D.), Senior Researcher, Norwegian University of Life Sciences, Department of Animal and Aquacultural Sciences, Box 5003, 1432 Ås, Norway.

*Corresponding author at: Department of Animal Sciences, Norwegian University of Life Sciences, P.O. Box 5003 NO-1432 Ås, Norway. E-mail address: stine.samsonstuen@nmbu.no (S.Samsonstuen).

The variability in greenhouse gas emission intensities were estimated from 27 beef farms in Norway with Angus, Hereford, and Charolais cattle, using the whole-farm model HolosNorBeef. HolosNorBeef is an empirical model based on the HolosNor model and the methodology of the Intergovernmental Panel on Climate Change with modifications to Norwegian conditions. HolosNorBeef considers direct emissions of methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) from on-farm livestock production and indirect N_2O and CO_2 emissions associated with inputs used on the farm. The corresponding soil carbon (C) emissions are estimated using the implemented Introductory Carbon Balance Model (ICBM). The farms were distributed across Norway with varying climate, natural resource base, feeding and management practices. Estimated emission intensities ranged from 20.9 to 44.2 CO_2 equivalents (eq) (kg carcass)$^{-1}$ when C-balance was included. Enteric CH_4 was the largest contributing source of GHG accounting for 50% of the total emissions on average dependent on animal requirement and diet composition. Variation in the estimated soil C emissions contributed the most to variation (average 6 %) of total emissions between individual farms. Differences in GHG intensity among farms were reduced when soil C balance was excluded, giving emission intensities from 20.5 to 30.3 CO_2 eq (kg carcass)$^{-1}$. High C losses from soils with high initial soil C content suggest that modelling of C balance in soils with high initial C contents might be encumbered with methodical deficiencies.

Keywords: whole-farm, modelling, methane, soil carbon, resource base

1.3 Modelling (Poster)

Environmental footprinting of upland lamb production

Hollie Rachael Riddell[1], Dave Chadwick[2], David Styles[3] and Bob Rees[4]

[1]PhD student, School of Natural Sciences, Bangor University, Bangor, Wales, UK

[2]Professor of Sustainable Land Use Systems, Environment Centre Wales, School of Natural Sciences, Bangor University, Bangor, Wales, UK

[3]Lecturer in Life Cycle Assessment, School of Natural Sciences, Bangor University, Bangor, Wales, UK

[4]Professor of Agriculture and Climate Change, Head of Carbon Management Centre Scotland's Rural College (SRUC), Peter Wilson Building, Kings Buildings, West Mains Road, Edinburgh, Scotland, UK

The environmental impacts of agricultural systems, particularly those associated with livestock production, are receiving increasing attention worldwide. This study will explore the emissions (nitrous oxide (N2O) from urine/dung and enteric methane (CH4)) and other environmental impacts associated with lamb production in UK upland areas. Measured and modelled data will be used to determine improved emission factors for upland systems, allowing development of a subsequent environmental footprint using Life Cycle Assessment (LCA) approaches. The study will also explore upland management scenarios including mitigation options and environmental trade-offs between land uses. Methodologies include measuring ruminant methane emissions (using a GreenFeed system), initially in cut and carry experiments for grass harvested from pastures at different altitudes (commencing summer 2019), followed by field grazing trials. Mobile soil gas measurement systems will be used to measure N2O emissions from sheep urine/dung. LCA techniques will be applied to determine the environmental footprint of lamb production and draw comparisons between upland and lowland systems. We expect differences between the systems due to environmental context and management differences. Lower urine N2O emissions factors are expected for upland vs. lowland pastures, however ruminant CH4 emission may be higher due to poorer pasture quality. Overall, the environmental impacts of upland systems may compare favourably against lowland systems, particularly when wider ecosystem services delivered by extensive livestock management in upland areas are considered. This work is intended to support policy decision making for the future of these nationally significant areas and aid in improving the environmental sustainability of the sheep industry.

Index Terms: ruminants, agriculture, life cycle assessment, climate change, upland management

Life Cycle Assessment of small, medium and large dairy cattle farms in Colombia[(1)]

Ricardo González Quintero[1], Rolando Barahona-Rosales[2], Ngonidzashe Chirinda[3], Jacobo Arango[4], Heiber Alexander Pantevez[5], Diana María Bolívar-Vergara[6] and María Solange Sánchez-Pinzón[7]

[1]MSc, PhD student, Facultad de Ciencias Agrarias, Universidad de Antioquia, Carrera 75 # 65-87 bloque 47, office 231, Medellín, Colombia. International Center for Tropical Agriculture (CIAT), Km 17 recta Cali – Palmira, Valle del Cauca, Colombia

[2]MSc, PhD, Full professor, National University of Colombia – Medellín Campus

[3]PhD, Research Scientist, International Center for Tropical Agriculture (CIAT), Km 17 recta Cali – Palmira, Valle del Cauca, Colombia

[4]PhD, Research Scientist, International Center for Tropical Agriculture (CIAT), Km 17 recta Cali – Palmira, Valle del Cauca, Colombia

[5]BSc, MSc student. Professional in Monitoring and Evaluation, Sustainable Cattle Ranching Project, Federación Colombiana de Ganaderos (FEDEGAN), Calle 37 # 14- 31, Bogotá, Colombia

[6]MSc, PhD, Full professor, National University of Colombia – Medellín Campus

[7]PhD, Environmental Leader Chocolate Bussiness, Compañía Nacional de Chocolates

In Colombia, cattle production is responsible for 31% of greenhouse gas (GHG) emissions from the agricultural sector. Dairy farms account for 15% of the Colombian cattle herd. Life Cycle Assessment (LCA) of GHG emissions from these farms are not common, and when performed, are based on a small number of farms. LCA is important because the identification of appropriate GHG mitigation actions requires larger data sets. This study quantified the carbon footprints (CF) on 192 dairy farms in Colombia by using LCA methodology. Farms were classified according to their herd size: small (0-30 animals; n=94), medium (31-50; n=32), large (>50; n=66). Emissions were estimated using the GHG emission factors reported in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, and locally estimated emission factors. A “cradle to farm gate” system boundary was established, and a physical allocation method proposed by the International Dairy Federation, was used to distribute GHG emissions between co-products. The functional units were 1 kg fat and protein corrected milk (FPCM) and 1 kg live weight gain (LWG). The CF (kg CO_2-eq kg^{-1}FPCM/LWG) for medium (1.6 FPCM and 13.8 LWG) and large farmers (1.6 FPCM and 13.1 LWG) were the lowest among the categories. The medium and large farm categories were characterized by implementing better pasture and herd management practices, by the highest milk productivity (3240.8 and 3645.6 kgFPCM $Cow^{-1}Year^{-1}$) and stocking rate (4.5 AU ha^{-1};4.4 AU ha^{-1}). It is possible to improve the environmental performance of farms by increasing productivity and adopting better agricultural practices.

Keywords: carbon footprint (CF), global warming potential (GWP), greenhouse gases (GHG), livestock production systems.

(1)Carried out with support from CGIAR Fund Donors and through bilateral funding agreements and COLCIENCIAS Doctoral Study Program in Colombia (call 727 of 2015).

Predicted performance of Afrikaner, Bonsmara and Nguni dams and top-crosses sired by Angus and Simmental

Georgette M. Pyoos[1,2], Michiel M. Scholtz[1,2], Michael D. MacNeil[4], Anette Theunissen[3] and Frederick W.C. Neser[2]

[1]Agricultural Research Council, Animal Production, Private Bag X 02, Irene, 0062, South Africa.

[2]University of the Free state, Department of Animal, Wildlife and Grassland Sciences, PO Box 339, Bloemfontein, South Africa.

[3]Northern Cape Department of Agricultural, Land Reform and Rural Development, Private Bag X9, Jan Kempdorp 8550, South Africa.

[4]Delta G, 145 Ice Cave Road, Miles City, MT 59301, USA. pyoosg@arc.agric.za

Crossbreeding systems allow for use of favourable effects of heterosis and the opportunity to use breeds whose additive effects offset each other's weaknesses. This study predicts levels of cow-calf production that's achieved through top-cross, two-breed rotation, and terminal sire crossbreeding systems. The data originated from cows that were from the Vaalharts Research Station. Calves, sired by Afrikaner (AF), Bonsmara (BN), Nguni (NG), Angus and Simmental bulls and out of AF, BN, and NG dams, were weaned from 2015 to 2017. Predicted performance of the various crossbreeding systems followed standard regression theory. Overall, the straightbred system was least efficient, followed by the criss- cross system (+2%) and the terminal sire system that utilized Simmental (+4%), with the terminal sire system utilizing Angus being on average most efficient (+8%). The severe drought and extreme heat of the 2015/2016 summer season had a marked effect on the pre- weaning performance of the calves (preceding year ADG = 879 ± 27 g/d., 2015/2016 ADG = 687 ± 28 g/d, following year ADG = 770 ± 28 g/d). The Nguni calves birth weights were less and also grew slower from birth to weaning than Bonsmara calves. As a consequence, Bonsmara calves were heavier at weaning than either Afrikaner or Nguni calves. Calves sire by Afrikaner bulls were less affected by the year effects than the Bonsmara, Nguni, Angus and Simmentaler sired calves. Despite the relatively small magnitude of observed genetic effects, advantages of crossbreeding that captures substantial heterosis effects became evident.

Keywords: Crossbreeding, Vaalharts, heat, top-cross, pre-weaning

Variability in ammonia emissions from an open-lot dairy

Richard H. Grant[1], Matthew T. Boehm[2] and G. Robert Hagevoort[3]

[1]Forest Meteorology, PhD, Professor, Department of Agronomy, Purdue University, West Lafayette, Indiana, USA

[2]Meteorology, PhD, Post-Doctoral Researcher, Department of Agronomy, Purdue University, West Lafayette, Indiana, USA

[3]Animal Sciences, PhD, Extension Dairy Specialist, Extension Animal Sciences and Natural Resources Department, New Mexico State University, Clovis, New Mexico, USA

Manure on dairies is the second largest agricultural source of ammonia (NH_3) emissions in the USA. Ammonia emissions were measured for multiple weeks at a time for most seasons over two years at an open-lot dairy using a backward Lagrangian Stochastic model in combination with long-path gas concentration and turbulence measurements. Background concentrations (Cbg) were estimated: emissions decreased with increasing Cbg. Mean daytime emissions were twice that of nighttime emissions. Half-hourly emissions variability was best explained by air temperature, with wind speed and saturation vapor density deficit explaining only 2-5% more of the variability. Daily emissions variability was best explained by the saturation vapor density deficit with air temperature and wind speed contributing 5% more each to the explained variability. The mean annual daily NH_3 emissions at the farm was estimated at 82 g NH_3 d^{-1} per animal with mean emission during the summer of 124 g NH_3 d^{-1} per animal.

Terms for indexing: *Bos taurus,* saturation vapor density, backward Lagrangian modeling, dry environment

Session 2

Farm level low carbon initiatives, measuring and modelling GHG

2.1 Mitigation (Oral)

A molecular pattern recognition receptor signalling compound (Biozest) presents an economically advantageous emissions reduction solution

Nathan Balasingham[1] and Usha Amaranathan[2]

[1]Horticultural Science, M Hort Sc. (Hon1), Chief Technical Officer, Zest Biotech Ltd, Auckland, New Zealand.
[2]Environmental Science, M Appl Sci (Hon), Chief Operating Officer, Zest Biotech Ltd, Auckland, New Zealand

A biogenic compound trademarked Biozest enables pasture to synthesise more simple sugars and bioactive molecules; phenylpropanoids. Phenylpropanoids help pasture overcome pest, disease and environmental stress to increase pasture quality and yield. When consumed by ruminants phenylpropanoids can protect proteins from rapid degradation and improve the conversion efficiency of pasture protein to milk and meat. The effect of the compound on both pasture and ruminant efficiency was evaluated via split block trials followed by full-scale, full life-cycle on-farm trials. Aspects measured include pasture resilience and productivity, livestock productivity (milk production, live-weight) and urea excretion. Biozest was found to improve pasture resilience, quality and yield (by over 100%). The higher content of phenylpropanoids in Biozest treated pasture form conjugates with pasture protein. This resulted in reduced urea excretion (20–48%) and increased milk and meat production (30%). Methane production is expected to be reduced because phenylpropanoid/protein conjugates cannot be deamminated to ammonia and methane; instead they are converted to milk or meat. During carbohydrate digestion, the higher content of simple sugars in treated pasture (brix increased by 18%) is expected to favour production of propionate rather than methane, acetate and butyrate. Urea excretion is reduced so it follows that nitrous oxide production from urine and dung patches will be reduced. Future work may include quantification of nitrous oxide and methane emissions reductions. However, the productivity and urea benefits of Biozest have been clearly established via this series of trials proving the compound to be an economically smart and climate-smart choice.

An early life methane inhibitor treatment reduced methane emissions in dairy calves

Sarah Jade Meale[1,2], Cristina Saro[1], Cecile Martin[1], Milka Popova[1], Aurélien Bernard[1], David R. Yáñez-Ruiz[3], Hamid Boudra[1], Stephane Duval[4], and Diego P. Morgavi[1]

[1]UMR1213 Herbivores, INRA, VetAgro Sup, Clermont Université, Université de Lyon, 63122 Saint Genès-Champanelle, France

[2]School of Agriculture and Food Sciences, The University of Queensland, Gatton Campus 4343, QLD, Australia

[3]Estación Experimental del Zaidían (CSIC), Profesor Albareda 1, 18008, Granada, Spain

[4]DSM Nutritional Products, Research Centre for Animal Nutrition and Health, BP 170, F- 68305 Saint-Louis Cedex, France

Recent evidence suggests that changes in colonization of the rumen prior to weaning may influence the rumen microbiome and modify phenotypes later in life. The influence of dietary manipulation from birth on growth, methane production, and gastrointestinal microbial ecology in dairy calves was investigated. At birth, 18 female Holstein and Montbéliarde calves were randomly assigned to either the investigational product, 3-Nitrooxypropanol (3- NOP; 3 mg/ kg BW, n=10) or control (CONT, n=8). Treatment was administered daily from birth until three weeks post-weaning (week 14). Samples of rumen fluid were collected at weeks 11, 14, 23, and 60 of life. Enteric methane emissions from the calves were measured using GreenFeed systems (week 11-23 and week 56-60 of life). BW, ADG and individual VFA were similar across groups throughout the trial. Treated calves showed a persistent reduction (11.6%, P= .03) in methane emissions (g CH4/d) throughout the post-weaning period, despite treatment ceasing three weeks post-weaning. CONT calves aged 60 weeks showed greater archaeal richness than 3-NOP calves. Correspondingly, beta-diversity differed (P≤0.036) between CONT and 3-NOP calves in week 60. No clear trends emerged in microbes' relative abundance as a result of 3-NOP treatment. However, patterns of co-occurrence of ruminal archaea, bacteria and anaerobic fungi indicated a more inter-dependant relationship in 3-NOP calves. Despite only minimal modifications to the microbiota composition, the reductive effect of the treatment on methane production persisted following cessation of the treatment period, perhaps indicating that microbial activity or a host response was programmed by the treatment.

Keywords: Bovine, Microbial, Rumen, 3-nitrooxypropanol

Combining brewers' grains with rapeseed meal in dairy cows reduces feed carbon footprint and methane emissions

Dorien Van Wesemael[1], Leen Vandaele[2], Sophie Huysveld[3], Sam De Campeneere[4], Veerle Fievez[5] and Nico Peiren[6]

[1]Bioscience Engineering, MSc, PhD student, Animal Sciences Unit, Flanders Research Institute for Agriculture, Fisheries and Food, Belgium

[2]Veterinary Science, PhD, Research Group Leader Cattle Husbandry, Animal Sciences Unit, Flanders Research Institute for Agriculture, Fisheries and Food, Belgium

[3]Bioscience Engineering, PhD, Researcher, Department of Sustainable Organic Chemistry and Technology, Research Group EnVOC, Ghent University, Belgium

[4]Applied Biological Sciences, PhD, Scientific Director, Animal Sciences Unit, Flanders Research Institute for Agriculture, Fisheries and Food, Belgium

[5]Applied Biological Sciences, PhD, Full Professor, Department of Animal Sciences and Aquatic Ecology, Laboratory for Animal Nutrition and Animal Product Quality, Ghent University, Belgium

[6]Biology, PhD, Senior Researcher, Animal Sciences Unit, Flanders Research Institute for Agriculture, Fisheries and Food, Belgium

Enteric methane mitigation in ruminants is necessary to tackle climate change. Replacing soybean meal (SBM) by a combination of brewers' grains (BG) and rapeseed meal (RSM) might improve the carbon footprint of the diet. Furthermore, a preliminary trial showed the enteric methane (CH_4) mitigation potential of such a diet. In a 15 week trial with three groups of 10 high-productive cows, the impact on CH_4, milk production and carbon footprint of BG alone and in combination with RSM (BG-RSM) was compared with a reference diet (REF). The first two weeks all cows received REF (62% maize silage, 38% grass silage and SBM). In week 3 BG and BG-RSM switched to 53% maize silage, 32% grass silage, 15% BG, less SBM for BG and no SBM but RSM for BG-RSM. Throughout the trial, CH_4 was measured with a GreenFeed unit. Dry matter intake increased with 7% for both BG-RSM and BG, milk production was not affected. BG-RSM significantly reduced CH_4 compared to REF: 14% for CH_4/kg DMI; 10% for CH_4/kg FPCM. BG alone did not affect CH_4 parameters. Including BG alone or with RSM in the diet reduced the feed carbon footprint by 13% and 43% respectively compared with REF. Together BG and BG-RSM showed a reduction in total carbon footprint (feed and CH_4) of 9% and 33%, respectively. Replacing SBM by alternative protein sources in smart combinations allows to reduce the carbon footprint of dairy production systems at feed and enteric CH_4 level.

Index terms: Bos taurus, protein source, methane mitigation, feeding strategy

Desmanthus: A tropical legume for mitigating methane emissions in Northern Australian beef cattle

Bénédicte Suybeng[1], Edward Charmley[2], Christopher P. Gardiner[3], Bunmi S. Malau-Aduli[4] and Aduli E.O. Malau-Aduli[5]

[1]Master of Agricultural Science, PhD student, Animal Genetics and Nutrition, Veterinary Sciences Discipline, College of Public Health, Medical and Veterinary Sciences, Division of Tropical Health and Medicine, James Cook University, Townsville, Queensland 4811, Australia

[2]PhD from The Grassland Research Institute, Group Leader and Principal Research Scientist, CSIRO Agriculture and Food, Private Mail Bag Aitkenvale, Australian Tropical Sciences and Innovation Precinct, James Cook University, Townsville, Queensland 4811, Australia

[3]Master of Tropical Agriculture, Lecturer in Livestock Production Systems, Animal Genetics and Nutrition, Veterinary Sciences Discipline, College of Public Health, Medical and Veterinary Sciences, Division of Tropical Health and Medicine, James Cook University, Townsville, Queensland 4811, Australia

[4]PhD in Animal Reproductive Physiology, Associate Professor in Medical Education, Academic Lead, Assessment and Evaluation and Associate Dean Teaching & Learning, College of Medicine and Dentistry, Division of Tropical Health and Medicine, James Cook University, Townsville, Queensland 4811, Australia

[5]PhD in Animal Quantitative and Molecular Genetics, Associate Professor in Animal Genetics and Nutrition, Animal Genetics and Nutrition, Veterinary Sciences Discipline, College of Public Health, Medical and Veterinary Sciences, Division of Tropical Health and Medicine, James Cook University, Townsville, Queensland 4811, Australia

The aim of this study was to examine enteric CH_4 emissions in beef cattle in response to incremental supplementation with 2 species of Desmanthus (*D. leptophyllus* and *D. bicornutus*) – a tropically adapted legume for grazing in the drier parts of Northern Australia. Seven Droughtmaster steers were allocated to each of the 2 legume cultivars. The animals were fed basal Rhodes Grass (*Chloris gayana*) plus fresh Desmanthus at 0, 12, 24, 36 and 48% of DM in each period. Every period lasted 21 days and CH_4 production was measured by open-circuit gas exchange in the last 2 days of every period. Results showed no differences in CH_4 emissions between Desmanthus cultivars. Yet, a significant decrease in CH_4 emissions with increasing level of Desmanthus ($p=0.014$) was observed. The reduction followed a linear pattern and could be predicted ($R^2=0.76$) with the equation: CH_4 emissions (g/kg DMI)=18.46– 0.037xDes. level (%). The study showed that Desmanthus can reduce *in vivo* CH_4 emissions from cattle.

Terms for indexing: *Chloris gayana, Desmanthus leptophyllus, Desmanthus bicornutus.*

Economic analysis of silvopastoral systems eligible for the Carbon Neutral Brazilian Beef protocol [(1)]

Mariana de Aragão Pereira[1], Roberto Giolo de Almeida[2], Rodrigo da Costa Gomes[1], Valdemir Antônio Laura[2], Vanderley Porfírio-da-Silva[3] and Fabiana Villa Alves[1]

[1]Animal Scientist, D.Sc., Researcher, Embrapa Beef Cattle, Campo Grande-MS
[2]Agronomist, D.Sc., Researcher, Embrapa Beef Cattle, Campo Grande-MS
[3]Agronomist, D.Sc., Researcher, Embrapa Forestry, Colombo-PR.

Economic analyses of two silvopastoral systems eligible for the Carbon Neutral Brazilian Beef (CNBB) protocol and one typical monoculture sown pasture (PM) were undertaken. Experiments were established in the Brazilian Savanna (Quartzarenic Neossol) in 2015. The trees (Eucalyptus urograndis) arrangements were 28x2 m (single lines) with 178 trees/ha (SP-178) and 28x2x3 m (triple lines) with 441 trees/ha (SP-441). Charcoal and timber production estimates were 16.5 and 65.9 m^3, respectively, for SP-178, and 62.6 and 75.1 m^3 for SP-441. Rearing Nellore steers were fattened on Urochloa brizantha (BRS Piatã) between rows. Fertilization with 20-00-20 occurred every four years (cycles), resulting in decreasing beef production throughout cycles, with an annual average of 241, 223 and 291 kg of live weight for SP-178, SP-441 and PM, respectively. Investment analysis based on a 12-year cash-flow was undertaken, using 2018 average prices, experimental and estimated data. SP-441 was economically better than SP-178, which, in turn, was better than PM. The net present value (US$) and the payback period (years) were 1,062 and 11.3, 1,126 and 11.3, and 632 and 5.7 for SP-178, SP-441 and PM, respectively. CO2eq estimated balance was positive for SPs systems, but negative for PM, with accumulated CO2eq sequestrations by the trunk of 6.5 and 2.8 t ha^{-1} $year^{-1}$ for SP-441 and SP-178, respectively, over four years. Combined economic-environmental analysis suggests both SP systems are eligible for CNBB. SP-441 showed higher potential for CNBB than SP-178, but the latter might be more appealing for beef farmers and should be further investigated.

Index Terms: economic viability; Eucalyptus urograndis; integrated farming systems; low carbon livestock

[(1)]This research is funded by Embrapa (SEG) and Grupo Mutum.

Emissions and carbon sequestration in silvopastoral cattle systems

Roberto Giolo de Almeida[1], Emizael M. Almeida[2], Rodrigo da Costa Gomes[3], Fabiana Villa Alves[3], Valdemir Antônio Laura[1], Vanderley Porfírio-da-Silva[4], Genilson F. Costa[5] and Davi José Bungenstab[6]

[1]Agronomist, D.Sc., Researcher, Embrapa Beef Cattle, Campo Grande-MS
[2]Animal Scientist, M.Sc., Doctorate student in Animal Science, UFMS, Campo Grande-MS
[3]Animal Scientist, D.Sc., Researcher, Embrapa Beef Cattle, Campo Grande-MS
[4]Agronomist, D.Sc., Researcher, Embrapa Forestry
[5]Animal Scientist, Master student in Animal Science, UEMS, Aquidauana-MS
[6]DVM, D.Sc. Researcher, Embrapa Beef Cattle, Campo Grande-MS.

Goal was to evaluate enteric methane emissions and carbon sequestration under silvopastoral systems (SP), compared to monoculture sown pastures (PM) aiming enhanced sustainability. The trial was established in December 2015 at a Quatzarenic Neossol in the Savanna biome, Brazil, using Urochloa brizantha cv. BRS Piatã and Eucalyptus urograndis (clone I144). Evaluations took place in 2017-2018. Nellore steers grazed for 463 days (growing and finishing), following the Carbon Neutral Brazilian Beef (CNBB) protocol. Experimental design was random blocks with five treatments (PM, SP with 178, 238, 357 and 441 trees/ha) and two replicates. Growing animals were fed protein-energy supplement at 0.2% live weight (LW) raised to 1.2% LW for finishing. Dry matter intake (DMI), was predicted through the equation: DMI (kg/day) =-1.912+0.900×DMIs+0.094×$LW^{0.75}$+1.070×ADG-1.395×ADG^2. Where: DMIs = supplement intake (kg/day), LW (kg), ADG = average daily weight gain (kg/day). Enteric methane (CH_4) emission was calculated through: CH_4 (kg/day) = -0.1011+0.02062×DMI+0.001648×NDF. Where: NDF = neutral detergent fiber (%). There was effect of system for CO_2eq emissions (kg/ha), associated to stocking rates (animal-unit, AU/ha). PM showed highest values (3,357 and 1.86), followed by SP-357 (2,784 and 1.55) and SP-178 (2,561 and 1.42). Lowest values were found in SP-238 and SSP-441, with average 2,288 and 1.27. CO_2eq sequestration by trees (in the trunk) for SP-441, SP-178, SP-238 and SP-357 was: 13.9, 18.8, 32.5, and 28.5 ton/ha, respectively. CO_2eq balance for SP systems was positive. However, when estimating timber-based sequestration, only SP-238 and SP-357 are able to neutralize all CO_2eq generated by livestock for CNBB production.

Index Terms: Carbon Neutral Brazilian Beef, eucalyptus, stocking rate, timber.

Engineered biocarbon does not decrease enteric methane emissions, however it does alter the rumen microbiome

Stephanie Amelia Terry[1], Gabriel Ribeiro[2], Robert Gruninger[3], Alex Chaves[4], Karen Beauchemin[5], Erasmus Okine[6], and Tim McAllister[7]

[1]Bachelor of Animal and Veterinary Bioscience, University of Sydney, Australia; PhD Candidate, University of Sydney, Sydney, Australia

[2]PhD Animal Nutrition, Universidade Federal de Minas Gerais, Brazil; Assistant Professor, Faculty of Veterinary Medicine, University of Calgary

[3]PhD Biochemistry, University of Lethbridge, Canada; Principal Research Scientist, Agri-Food and Agriculture, Lethbridge, Canada

[4]PhD Animal Science, Massey University, New Zealand; Professor, University of Sydney, Sydney, Australia

[5]PhD Ruminant Nutrition, University of Guelph, Canada; Principal Research Scientist, Agri- Food and Agriculture, Lethbridge, Canada

[6]PhD Nutrition and Digestive Physiology, University of Alberta, Canada; Vice-President (Research), University of Lethbridge, Lethbridge, Canada

[7]PhD Ruminant Nutrition and Microbiology, University of Guelph, Canada; Principal Research Scientist, Agri-Food and Agriculture, Lethbridge, Canada

The objective of this study was to examine the effect of engineered biocarbon (EB) on rumen fermentation, apparent total tract digestibility, methane emissions, and the rumen microbiome of beef heifers. The experiment was a replicated 4 × 4 Latin square using 8 ruminally cannulated heifers (565 ± 35 kg initial BW). The basal diet contained 60% barley silage, 35% barley grain and 5% mineral supplement with EB added at 0%, 0.5%, 1.0%, or 2.0% (DM basis). Samples for profiling of the microbiome in rumen liquid, solids and feces were collected on d 15 before feeding. Rumen samples for fermentation characterization were taken at 0, 3, 6, and 12 h post feeding. Total collection of urine and feces was conducted from d 18 to 22. Heifers were housed in open-circuit respiratory chambers on d 26 to 28 to estimate CH_4 emissions. Dry matter intake was similar across treatments (P = 0.21). NH_3-N concentration and protozoa counts responded quadratically (P = 0.01) to EB. Minimum pH was increased (P = 0.04), and variation of pH was decreased (P = 0.03) by 2.0% EB. Total tract digestibility, N balance and methane production were not affected ($P \geq 0.17$) by EB. EB decreased the relative abundance of *Fibrobacter* (P = 0.05) and *Tenericutes* (P = 0.01), and increased the relative abundance of *Spirochaetaes* (P = 0.01), *Verrucomicrobia* (P = 0.02), and *Elusimicrobia* (P = 0.02). Results suggest that at the examined concentrations, EB was ineffective at decreasing enteric CH_4 emissions; however, it altered the rumen microbiome.

Index terms: biochar, enteric

Greenhouse gas emissions and profitability of dairy systems aimed at reducing nitrate leaching

Pierre C Beukes[1], Alvaro J Romera[1], Kathryn Hutchinson[2], Tony J van der Weerden[3], Cecile de Klein[3] and Robyn A Dynes[4]

[1]DairyNZ Ltd, Private Bag 3221, Hamilton 3240, New Zealand
[2]AgResearch, Grasslands Research Centre, Palmerston North 4410, New Zealand
[3]AgResearch, Invermay Agricultural Centre, Mosgiel 9053, New Zealand
[4]AgResearch, Lincoln Research Centre, Lincoln 7674, New Zealand

Dairy systems are being developed in New Zealand (NZ) that can maintain or increase profitability while reducing environmental impacts. Using research 'farmlets' in three regions over at least three years, we assessed the impacts of 'low nitrate leaching' systems on total greenhouse gas (GHG) emissions, milk production and profitability. Annual average GHG emissions were calculated based on the NZ inventory methodology and included off-platform feeding and imported supplements. Milk production was determined from daily volumes and weekly milk compositions, while known physical inputs and outputs were used with actual milk prices and actual or regional average costs for estimating profitability. In the Waikato, the 'low nitrate leaching' system reduced GHG emissions by 2.2 t CO_2-eq/ha (16%). However, averaged over five farming seasons, milk production was reduced by 50 kg milksolids (MS)/ha (4%) and profitability by NZ$280/ha (13%). In Canterbury, the 'low nitrate leaching' system reduced GHG by 5 t CO_2-eq/ha (24%) with milk production (542 kg MS/ha, 24%) and profit ($358/ha, 9%) also lower. In Otago, 'low nitrate leaching' systems (one with a barn and one that optimised feeding) reduced GHG emissions by between 0.3 and 1.1 t CO_2-eq/ha (3-9%). Decreases in production were small (2-3%). However, the profitability of the system that included the barn was significantly lower (NZ$600/ha), mainly due to capital and maintenance costs. In summary, 'low nitrate leaching' systems reduced N leaching by 22-45%. These lower-input, lower-stocked dairy systems reduced GHG emissions by between 3 and 24% at an average cost of approximately NZ$100/t CO_2.

Index terms: milk production, stocking rate, mitigation cost

High by-product inclusion rate to pasture diets reduces methane production and alters the rumen microbiome

Paul E Smith[1], John Heffernan[2], Sinéad M Waters[3], Tommy M Boland[4], David A Kenny[5] and Alan K Kelly[6]

[1]B.Agr.Sc, PhD Research Student, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

[2]MSc.Agr, UCD, School of Agriculture and Food Science, University College Dublin Belfield, Dublin 4, Ireland

[3]PhD, Principal Research Officer, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

[4]PhD, Associate Professor of Ruminant Nutrition, UCD, School of Agriculture and Food Science, University College Dublin Belfield, Dublin 4, Ireland

[5]PhD, Principal Research Officer, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

[6]PhD, Lecturer in Animal Science, UCD, School of Agriculture and Food Science, University College Dublin Belfield, Dublin 4, Ireland

The objective of this study was to investigate the effects of By Product (BP) inclusion rate to pasture diet on methane production, fermentation pattern and rumen microbiome composition using the rumen stimulation technique (RUSITEC). *In vitro* diets consisted of 50:50 perennial ryegrass (DM=21.6%, CP=25.01%, GE=16.97 MJ/ kg DM) and one of two concentrates, differing in their proportion of BP (BP35=35% BP DM=90.5%, CP=16.85%, GE= 16.92 MJ/ kg DM; BP95=95% BP DM=92.1%, CP=16.73%, GE=17.73 MJ/ kg DM).. Sixteen vessels (n=8/treatment) were incubated over 14 days and inoculated with 500ml of rumen fluid, obtained from rumen cannulated heifers consuming a 50:50 diet of grass silage and concentrates, and 350ml of artificial saliva. Fluid samples were collected on day 13 for microbial analysis. Rumen microbial DNA was extracted with 16S rRNA amplicon libraries generated and sequenced on the Illumina MiSeq. Sequences were analysed with DADA2 with sample functional pathway analysis predicted using CowPI. BP35 had a greater dry and organic matter digestibility (P<0.0001) coinciding with an increased production of methane (P<0.0001). At the phylum level, an increased relative abundance of Firmicutes and Proteobacteria in the BP35 (63.45 vs. 58.16%; adj P <0.01) and BP95 (0.96 vs. 2.01%; adj P <0.01) groups was observed. Methane metabolism predicted pathways tended to mirror methane output, with a greater proportion of reads associated with methane metabolism (adj P=0.197) in the low BP group. The formulation of high BP based concentrate diets therefore has the potential to alter the rumen microbiome in favour of a reduction in methanogenesis.

Index terms: enteric fermentation, rumen microbiome, in vitro

Improved cow-calf efficiency is the key to reduce the carbon footprint of beef production

Michiel M, Scholtz[1,2], Motshabi C. Mokolobate[1], Frans J Jordaan[1] and Frederick W.C. Neser[2]

[1]Agricultural Research Council-Animal Production, Private Bag X2 Irene, 0062, South Africa

[2]Department of Animal, Wildlife and Grassland Sciences, University of the Free State, P.O. Box 339, Bloemfontein, 9300, South Africa

An effective way to reduce the carbon footprint from beef production is to increase the production per animal unit. Increased productivity generates less greenhouse gas (GHG) emission per unit of product. In beef cattle, the parent-offspring production cycle is responsible for approximately 72% of the energy consumed from conception to slaughter. In this study cow-calf efficiency is defined as (weaning rate [deducted from inter-calving period] x 205 day calf weaning weight) / cow Large Stock Unit (LSU)); the component traits being calf weaning weight, cow weight (from which LSU is estimated) and inter-calving period. In South Africa, the enteric methane emission factor (MEFenteric) of a LSU is 94 kg methane/year for beef cattle. It was estimated that the MEFenteric of the indigenous Afrikaner, Bonsmara, Drakensberger and Nguni breeds decreased by 12.0%, 6.6%, 9.3% and 6.8% respectively, because of an increase in cow-efficiency over a period of 33 years. The challenge is to define breeding objectives that will improve cow-calf efficiency and not just increase production. A possible breeding objective is kg of calf weaned per Large Stock Unit mated (cow-calf efficiency). However, a ratio has challenges. It is thus proposed to evaluate the total contribution of the following on the "methane budget/balance" of the cow-calf production system; longevity of a cow, fertility (number of calves born over a lifetime), size of her calves, feed efficiency and maintenance cost of the cow. This can then be combined in a selection index for a cow-calf "methane budget/balance".

Kewords: Breeding objective**,** enteric methane, indigenous breeds, methane budget

Improving the dairy farm efficiency with a milk low carbon action plan

Catherine Brocas[1], Agnès Lejard[3], Jean-Baptiste Dolle[2]

[1]Project manager, Institut de l'Elevage, Monvoisin - 35652 Le Rheu cedex, France

[2]Environment Head department, Institut de l'Elevage, 54-56 avenue Roger Salengro - BP 80039 - 62051 St Laurent Blangy, France

[3]Project Manager, France Conseil Elevage, 42 Rue de Chateaudun, 75009 Paris

The French Livestock Institute (Institut de l'Elevage), in association with key players in the French dairy sector i.e. dairy advisory enterprises and French dairy board, has launched the LIFE CARBON DAIRY project with the main objective to reduce the milk carbon footprint at dairy farm level by 20% over 10 years. A national Life Cycle Assessment tool named CAP'2ER® was developed to measure the milk carbon footprint. We characterized and calculated the carbon footprint of 4,150 dairy farms and performed multivariate analysis to access the contribution of production parameters to the carbon footprint. The average carbon footprint is 1 kg CO2e per liter Fat and Protein Corrected Milk. The top-performing farms have carbon footprints 18% lower than the average. Practices with the largest impact are milk yield, age at first calving, quantity of concentrate, N-fertilizer used and fuel consumed. The results also show that the farms can improve economic performance while also reducing carbon footprint. The top- performing group's gross margin was 30€/1000 l higher than the bottom-performing carbon footprint group. In parallel, a sample of 366 farms carried out two CAP'2ER® and gross margin analysis during the project. The farms which decrease the most their carbon footprint within three years (-21%) reduce the variable costs by 27€/1000 l as the average decrease by 17€/1000 l. These results encourage now the dairy sector to implement the Low Carbon Dairy Farm initiative at a national level for the 60 000 dairy producers with the objective to engaged all of them in 2028.

Terms for indexing: milk production, global warming potential, greenhouse gases, life cycle assessment, farm efficiency

Life Beef Carbon: Commitment of beef farms from 4 European countries to reduce carbon footprint.

Sara Carè[1], Josselin Andurand[2], Donal O'Brien[3], Jonathan Herron[4], Giacomo Pirlo[5], Luciano Migliorati[6], Matilde Moro[7], Paula Martinez[8] and Jean-Baptiste Dollé[9]

[1]Agronomist, PhD, scientist of Council for Agricultural Research and Economics, Lodi Italy.

[2]Agronomist, Master and Engineer, Project manager of Environment Department, Idele – French Livestock Institute, Le Rheu, France;

[3]Agricultural scientist, BSc and PhD, Irish farm assessments co-ordinator at Livestock Systems Department, Animal and Grassland Research and Innovation Centre, Teagasc, Cork, Ireland;

[4]Agricultural scientist, BSc, Irish life cycle assessment/farm systems modelling at Livestock Systems Department, Animal and Grassland Research and Innovation Centre, Teagasc, Cork, Ireland;

[5]Agronomist, Degree in Agronomy, senior scientist of Council for Agricultural Research and Economics, Lodi Italy;
[6]Agronomist, Degree in Agronomy, scientist of Council for Agricultural Research and Economics, Lodi Italy

[7]Veterinary, Master and Degree, general manager of ASOPROVAC, Madrid, Spain;

[8]Agronomical engineer, Master and Degree, technical manager of ASOPROVAC, Madrid, Spain;

[9]Agronomist, Master and Engineer, head of Environment Department, Idele – French Livestock Institute , St Laurent Blangy, France;

Public concerns regarding climate change is pressuring the beef sector to find strategies to reduce greenhouse gas (GHG) emissions. The sector is responding to this challenge through the EU founded "LIFFE BEEF CARBON" project coordinated by IDELE. LIFE BEEF CARBON's goal is to reduce GHG emissions by 15% within 10 years across 172 volunteer beef farms in France, Ireland, Italy and Spain. Three tools are utilized to estimate emissions: CAP'2ER® for France and Italy, Carbon Audit for Ireland and Bovid-CO_2 for Spain. The system boundaries attempt to include all beef farming processes. The functional unit is 1 kg of Live Weight Gain (LWG). On the various beef production systems, (suckler to weanling 6-8 months, suckler to store, suckler to finish, and fattening, the carbon footprint ranges from 5 to 25 kg CO_2/kg LWG, corresponding to fattening and suckler to weanling at 6 months systems, respectively. The mitigation strategies implemented by farmers are: i. improving animal welfare to increase growth, enhance reproductive performance and health; ii. reducing enteric methane emissions through feeding techniques; iii. using chemical fertilisers and manure efficiently; developing anaerobic digestion; v. preserving grassland; vi. planting hedgerows/trees and minimizing tillage. Three years after applying mitigation practices, the lowest reduction (7%) was observed in the fattening systems in France and Italy and the greatest reductions were obtained in Irish and Spanish suckler to store and suckler to weanling production systems (15%). These results exclude carbon sequestration. Farms combing more than one strategy have obtained the best results.

Keywords: carbon footprint, beef production, mitigation strategies

Low emission, sustainable beef cattle production on mixed Brachiaria-grass/forage-peanut pastures

José Marques Pereira[1], Claudia de Paula Rezende[2], Augusto Magno Ferreira Borges[3], Bruno Grossi Costa Homen[4], Daniel Rume Casagrande[5], Thasia Martins Macedo[6], Bruno José Rodrigues Alves[7], Selenobaldo Alexinaldo Cabral de Sant'Anna[8], Segundo Urquiaga[9] and Robert Michael Boddey[10]*

[1]Director, Animal Husbandry Division, (PhD - Federal University of Viçosa, MG), CEPLAC/CEPEC, Km 22 da Rodovia Ilhéus – Itabuna, Itabuna, BA, Brazil

[2]Director, (PhD, Federal University of Lavras) Animal Husbandry Experimental Station of the Extreme South of Bahia (CEPLAC-ESSUL), Km 757, BR 101, Itabela, BA, Brazil

[3]Technical assistant (BSc Econ, Bahia State Unuiversity, Santa Cruz - UESC), CEPLAC/CEPEC, Km 22 da Rodovia Ilhéus – Itabuna, Itabuna, BA, Brazil

[4]PhD student, Department of Animal Sciences, Lavras Federal of University, Lavras, MG, Brazil.

[5]Professor (PhD, UNESP, Jaboticabal, SP), Department of Animal Sciences, Lavras Federal of University, Lavras, MG, Brazil.

[6]Pos-doctoral student (PhD, Universidade Federal de Minas Gerais), Escola de Veterinária, Av. Antônio Carlos 6627, Campus Pampulha da Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil.

[7]Research scientist, (PhD - Federal Rural University of Rio de Janeiro), Embrapa- Agrobiologia, Km 7, BR 465, Seropédica, RJ, Brazil.

[8]Professor (PhD - Federal Rural University of Rio de Janeiro), Centro Universitário CESMAC, Environmental Systems Analysis, Maceió, AL, Brazil.

[9]Research scientist, (PhD – Escola Superior de Agricultura Luiz de Queiroz, Piracicaba, SP), Embrapa-Agrobiologia, Km 7, BR 465, Seropédica, RJ, Brazil.

[10]Research scientist (PhD - University of the West Indies, Trinidad e Tobago), Embrapa- Agrobiologia, Km 7, BR 465, Seropédica, RJ, Brazil.

Mixed grass/legume pastures are an alternative for increased beef cattle production in warm-season climates. The objective of this study was to evaluate the productivity of beef cattle grazing a mixed pasture of *Brachiaria brizantha* cv. Marandu and forage peanut (*Arachis pintoi*) or Marandu monoculture pasture under rotational stocking. Five trials, total duration of nine years, were conducted in northeastern Brazil, where two types of pasture were assessed: Mixed pasture of Marandu and forage peanut, and monoculture of Marandu with 120 kg ha^{-1} yr^{-1} of nitrogen. The stocking rate was adjusted to maintain forage allowance at 4 % of body weight day^{-1} of forage mass. Sward structure (forage, grass and legume mass) and animal performance (average daily gain, stocking rate and area gain) were measured. A block design was used with four replicates, and the warm and cool seasons within each trial were considered using repeated measurements over time. In the warm season the forage mass in the mixed pastures was 17% greater (P = 0.049). The stocking rate, average daily gain and area gain were 16.4, 20.0 and 28.7% greater in the mixed pasture than in the grass monoculture in the warm season (P = 0.056, P<0.001 and P<0.001, respectively). Average daily gain showed a positive linear relationship with botanical composition (P<0.001). The mixed pasture of forage peanut with Marandu sustained significantly greater beef cattle production compared to the grass monoculture fertilized with 120 kg N ha^{-1}, the avoided emission for fertilizer manufacture alone amounted to ~500 kg CO_2 ha^{-1}.

Keywords: *Arachis pintoi*, Beef cattle, *Brachiaria*, Mixed pasture, Nitrogen fertilization, Tropical legume

Methane emission from dairy cows in cultivated and native pastures in High Andes of Peru

Víctor Alvarado[1], Jorge Medrano[1], José Haro[2], Joaquín Castro Montoya[3], Uta Dickhoefer[3], Carlos Gómez[1]

[1]Universidad Nacional Agraria La Molina, Av. La Molina s/n, La Molina, Lima, Perú.

[2]Consultant, Instituto Interamericano de Cooperación para la Agricultura. Av. La Molina 1581, La Molina, Lima, Perú.

[3]University of Hohenheim, Animal Nutrition and Rangeland Management in the Tropics and Subtropics, Stuttgart, Germany.

The objective of the study was to determine the enteric methane emissions from lactating cows under grazing conditions in prevalent high Andean systems of Peru based on cultivated (CULP) or native (NATP) pastures during two seasons of the year. In CULP, brown Swiss cattle pastured alfalfa/oats with supplementation of with 1 kg concentrate daily per cow. Conversely, in NATP, crossbred cows pastured to native pastures without supplementation. The sulfur hexafluoride (SF_6) tracer technique was used to measure CH_4 emissions. In CULP, CH_4 emission was higher ($P<0.001$) in the rainy season (322 g/d) than the dry season (274 g/d), but, in NATP this trend was opposite (213 vs. 257 g/d) ($P<0.01$). In PCUL, CH_4 emission per unit of intake was lower ($P <0.001$) in the rainy season (24.3 g/kg DMI) than in the dry season (28.2 g/kg DMI), but in PNAT the results were similar ($P = 0.18$) between seasons (23.2 vs. 25.0 g/kg DMI). The intensity of emission in CULP was lower ($P <0.01$) in rainy than in dry season (24.6 and 27.5 g/kg ECM). In NATP, the intensity of emission was also lower ($P < 0.001$) in rainy (68.9 g/kg ECM) than in dry season (131.2 g/kg ECM). Emission intensity differences between systems were remarkable, being greater in the NATP both in rainy and dry season.

Keywords: lactating cows, grazing, sulfur hexafluoride.

Nitrous oxide emission intensity from grazed pastures of *Brachiaria brizantha* in monoculture or mixed with *Desmodium ovalifolium*[(1)]

Camila Almeida dos Santos[1], Rafael Cassador Monteiro[1], Claudia de Paula Rezende[2], José Marques Pereira[2], Robert Michael Boddey[3], Claudia Pozzi Jantalia[3], Segundo Urquiaga[3] and Bruno José Rodrigues Alves[3]

[1]Doctorate fellow at the Soil Science Department, UFRRJ, Seropédica, 23890-000, Rio de Janeiro, Brazil.

[2]PhD, Researcher at Animal Husbandry Experimental Station - CEPLAC, Itabela, Bahia, Brazil.

[3]PhD, Researcher at Embrapa Agrobiologia, Seropédica, 23891-000, Rio de Janeiro, Brazil.

Mixed grass/legume pasture systems can be a mitigation strategy for N_2O emissions. Hence, this study aimed at evaluating animal performance and monitoring N_2O emissions from cattle excreta, fertilizers and plant residues of tropical pastures of *Brachiaria brizantha* cv Marandu either mixed with *Desmodium ovalifolium* or fertilized with 150 kg N ha^{-1} $year^{-1}$ during three years. Using static-closed chambers gas measurements, the estimated N_2O emission factors (EFs) for each year as an average of pasture types were, respectively, 0.337%; 0.579% and 0.275% for urine, year 2 being greater than year 3 (Fisher l.s.d test, p = 0.05). The N-fertilized pasture presented a mean EF of three years for urine of 0.345%, which was not different from the EF of 0.449% for the mixed pasture. An EF of 0.051% was calculated for feces from fertilized pasture and 0.030% from the mixed pasture. These were means of the three years, without statistical differences for years and pasture type. Soil N_2O emissions induced by urea were also below 1% with no detectable effect of pasture litter on the background emission of this gas. The mixed pasture presented greater live weight gains (LWG) and also higher stocking rates (Fisher l.s.d test, p = 0.05). In a 16-month period the LWG was 1.7 kg ha^{-1} day^{-1} (0.51 kg AU^{-1} day^{-1}) and 2.01 kg ha^{-1} day^{-1} (0.56 kg AU^{-1} day^{-1}) for the N- fertilized and mixed pastures, respectively. Therefore, mixed grass/legume pasture presented itself as a strategy for increasing productivity, with reduced emission intensity of N_2O.

Keywords: Pasture, N_2O, forage legume

[(1)]This research was financed by PROCISUR/FONTAGRO, the Rio State Research Foundation (FAPERJ), the National Science and Technology Research Council (CNPq) and Embrapa.

Persistency of the 3-nitrooxypropanol effect on methane and hydrogen emissions in postpartum Holstein-Friesian dairy cows

Sanne van Gastelen[1], Jan Dijkstra[2], Gisabeth Binnendijk[3], Stéphane M. Duval[4], Jeroen M. L. Heck[5], Maik Kindermann[6], Tamme Zandstra[7], and André Bannink[8]*

[1]Dr., researcher, Wageningen Livestock Research, Wageningen University & Research, Wageningen, the Netherlands

[2]Dr., associate professor, Animal Nutrition Group, Wageningen University & Research, Wageningen, the Netherlands

[3]*Ing*., research assistant, Wageningen Livestock Research, Wageningen University & Research, Wageningen, the Netherlands

[4]Dr., centre head, Research centre DNP Innovation Animal Nutrition & Health, DSM Nutritional Products, Basel, Switzerland

[5]Dr., senior scientist, FrieslandCampina, Amersfoort, the Netherlands.

[6]Dr., innovation project manager, Research centre DNP Innovation Animal Nutrition & Health, DSM Nutritional Products, Basel, Switzerland

[7]*Ing*., research and education officer, Animal Nutrition Group, Wageningen University & Research, Wageningen, the Netherlands

[8]Dr., senior researcher, Wageningen Livestock Research, Wageningen University & Research, Wageningen, the Netherlands

*Corresponding author: sanne.vangastelen@wur.nl

The aim of this study was to determine the methane mitigation potential of 3-nitrooxypropanol (3-NOP) and its persistency when fed to dairy cows in early lactation. Sixteen Holstein-Friesian cows (parity 2.3

± 0.48, average ± SD) were blocked in pairs and randomly allocated to 1 of 2 dietary treatments; a diet including 52 mg 3-NOP/kg DM (3-NOP) and a diet including a placebo at the same concentration (control). Diets consisted of 35% grass silage, 25% corn silage, and 40% concentrates (on DM basis). Cows received the diets from 3d post-calving up to 115 days in milk. Every 4 weeks, the cows were housed in climate respiration chambers for 5 consecutive days to measure production characteristics and gas emissions. Data were subjected to repeated measures ANOVA using the MIXED procedure in SAS with dietary treatment, days in lactation, and their interaction as fixed effect and block and cow as random effects. The results indicate that dietary 3-NOP supplementation did not affect DM intake, milk yield, and fat-and protein-corrected milk. These characteristics, as well as hydrogen and methane emission, changed over time ($P < 0.038$) following the expected pattern of advancing days in lactation. On average, feeding 3-NOP persistently increased ($P < 0.001$) hydrogen emissions 11-fold and decreased ($P < 0.014$) methane emission by 16% (e.g., 21.0 vs. 17.7 g methane /kg DM intake for 3-NOP and control diet, respectively). In conclusion, feeding 3-NOP persistently decreases methane emission in early lactation Holstein-Friesian cows without affecting animal production characteristics.

Terms for indexing: Methane mitigation; feed additive; gas emissions; production performance.

Sprouting barley grain reduces the methane yield of cattle fed barley-based rations

Katherine Anne Smith[1] and Roger Stephen Hegarty[2]

[1]B.Agr. Sc, (Hons 1; Univ. Qld), PhD candidate, Univ. New England, Armidale NSW 2351 Australia

[2]B.Agr. Sc, (Hons 1; Univ. Qld), PhD (Univ. New England), Prof. Animal Nutrition, Univ. New England, Armidale NSW 2351 Australia

Sprouting barley prior to feeding is promoted as a means of increasing feed supply. In this study, the quantity of DM remaining after allowing barley to sprout for 5d was only 90.4% of that present before sprouting commenced. Sprouting for 5d reduced the starch content from 62.6% to 11.6% of DM and increased protein and fat contents of DM, relative to the unsprouted grain. Ten Aberdeen Angus heifers (348 ± 16.1 kg), were allocated into two diet treatments (n = 5) in a completely randomised design lasting 42 d. Treatments were 5.97 kg/d of DM, offered as either 5-day sprouted barley fodder (25 kg as fed) plus 2 kg wheaten chaff as fed, or an equal total quantity of DM fed as 6.8 kg of commercial mix feedlot finisher (75% barley), based on the same barley. Cattle fed the sprouted barley-based diet instead of feedlot finisher exhibited a higher total VFA concentration and lower ruminal pH, ammonia and protozoal population density than cattle fed the feedlot ration. The sprouted barley-based ration also supported a significantly lower daily methane production (124 v 175 g CH_4/d; P=0.001) and a lower methane yield (16.0 v 21.2 g CH_4/kg DM intake; P=0.004) than did the feedlot ration. This study confirms that sprouting for 5d reduces the quantities of DM and of starch in barley, and that cattle fed a ration based on sprouted barley have a lower methane yield than cattle fed a feedlot ration based on the same barley.

Terms for indexing: hordeum vulgare, sprouts, rumen fermentation, greenhouse gas

Supplementing the diet of dairy cows with fat or tannin reduces methane yield

S. Richard O. Williams[1], Murray C. Hannah[2], Richard J. Eckard[3], William J. Wales[4], and Peter J. Moate[5]

[1]M. Eng. Sci., Senior Research Scientist, Agriculture Victoria Research, Ellinbank, Victoria 3821, Australia
[2]M. Sci., Senior Research Scientist, Agriculture Victoria Research, Ellinbank, Victoria 3821, Australia
[3]PhD, Professor, University of Melbourne, Parkville, Victoria 3052
[4]PhD, Senior Research Scientist, Agriculture Victoria Research, Ellinbank, Victoria 3821, Australia
[5]PhD, Senior Research Scientist, Agriculture Victoria Research, Ellinbank, Victoria 3821, Australia

Addition of fat to the diets of ruminants is known to result in a reduction in enteric methane yield. Tannins have also been used to reduce methane yield but with mixed success. The effect of feeding fat in combination with tannin is unknown. Eight ruminally-cannulated Holstein cows were offered a basal diet of 6.0 kg DM concentrate and 20 kg DM of lucerne (*Medicago sativa*) hay with one of four dietary supplements in a double Latin-square, full crossover sequence. The supplements, 800 ml/d of water (CON), 800 g/d of cottonseed oil (FAT), 400 g/d of tannin (TAN) extracted from black wattyl (*Acacia mearnsii*), and FAT plus TAN (FPT), were administered via ruminal cannula. Methane was measured using open-circuit respiration chambers. Intakes of basal diets were not different between treatments but cows fed FAT or FPT had greater total DMI due to the addition of these ingredients to the diets. Milk yield of cows fed FAT, TAN or FPT were not different to those from cows fed CON (33.3 kg/d). However, cows fed FAT or FPT produced more milk (34.9 kg/d) than cows fed TAN (31.1 kg/d). There were no differences between treatments in energy corrected milk. Compared to cows fed CON, methane yield of cows fed FAT was reduced by 14%, TAN by 11% and those fed FPT by 20%. We conclude that both fat and tannin reduce methane, and that this reduction is mostly additive when fat and tannin are fed together.

Index terms: ruminants, methane yield, *Acacia mearnsii*, cottonseed oil, respiration chambers

Sustained Decrease in Enteric Methane Production by Beef Cattle in a Commercial Feedlot fed a Forage-based Backgrounding Diet Supplemented with Increasing Doses of 3- Nitrooxypropanol

Aklilu W. Alemu[1], Calvin W. Booker[2], Adam Shreck[2], Sean M. McGinn[1], Scot N. Williams[3], Maik Kindermann[3] and Karen A. Beauchemin[1]

[1]Agriculture and Agri-Food Canada, Lethbridge Research and Development Centre, Lethbridge, AB, Canada

[2]Feedlot Health and Management Services, Okotoks, AB, Canada.

[3]DSM Nutritional Products, Animal Nutrition and Health, Kaiseraugst, Switzerland

Effects of the investigational inhibitor 3-nitrooxypropanol (3-NOP) on dry matter intake (DMI) and enteric methane (CH_4) production of beef cattle fed a backgrounding grower diet were evaluated in a commercial feedlot. Fifty crossbred steers (body weight = 328 ± 29 kg) were assigned in a completely randomized design to one of two treatment pens (n = 25/treatment): control and 3-NOP. The treatment pen received increasing doses of 3-NOP to adapt to the final level: 150 (low), 175 (medium) and 200 (high, final dose) mg/kg dry matter (DM), with each dose fed for 28 days. 3-NOP was mixed daily into the high-forage diet (70% corn or barley silage, DM basis). DMI of individual animals was monitored with the GrowSafe system and CH_4 was measured using the GreenFeed system. Over the 84 d study, compared with control (11.4 kg/d), DMI was decreased by 6.3% ($P = 0.008$) with 3-NOP supplementation, and this reduction was similar among the 3-NOP doses (5.8 to 6.4% decrease). On average, addition of 3-NOP lowered ($P \leq 0.002$) CH_4 emissions (g/d) by 26% and yield (g CH_4/kg DMI) by 19%. Compared with control, the greatest decrease in CH_4 yield occurred with the medium dose (-23%), followed by high (-19%) and low (-15%) doses. In conclusion, regardless of dose, supplementation of 3- NOP lowered enteric CH_4 production from commercial feedlot cattle fed a forage-based diet, with the decrease maintained over the entire study. A concurrent large pen study at the same feedlot will evaluate the effects of 3-NOP on animal performance.

Keywords: Beef steers, Commercial feedlot, GreenFeed, Methane.

What are the system changes required to reduce environmental impacts of Tanzanian livestock farms?

Şeyda Özkan Gülzari[1], Roel Helmes[2], Angello J Mwilawa[3] and Theun Vellinga[4]

[1]PhD, Researcher, Wageningen Livestock Research, Wageningen University & Research, PO Box 338, 6700 AH Wageningen, The Netherlands

[2]MSc, Researcher, Wageningen Economic Research, Wageningen University & Research, PO Box 338, 6700 AH Wageningen, The Netherlands

[3]PhD, Directorate for Research Training and Extension; Ministry of Livestock and Fisheries; Nyerere Road, NBC Building, PO Box 2870, 40487 Dodoma, Tanzania

[4]PhD, Researcher, Wageningen Livestock Research, Wageningen University & Research, PO Box 338, 6700 AH Wageningen, The Netherlands

The Global Livestock Environmental Assessment Model (GLEAM) was used to evaluate the impacts of improved management strategies on greenhouse gas emissions from mixed dairy, pastoralist and backyard chicken farms in Tanzania. Emissions intensity i.e. emissions produced per unit of product are reported as a final output in kilogram carbon dioxide equivalents (kg CO2e). The intervention options for each production system consist of a combination of improvements in genetics, feeding, milk production, herd structure and animal health and mortality, which were compared with a baseline. The emissions intensities in improved cases reduced from 60.4 kg to 40.4 kg CO2e/kg live weight in pastoralist systems; from 8.1 kg to 7.2 kg CO2e/kg for eggs and from 12.2 kg to 11 kg CO2e/kg live weight for backyard chicken; and from 24 kg to 17 kg CO2e/kg milk, and from 78 kg to 29 kg CO2e /kg live weight in mixed dairy production systems. Note that a 10-fold increase in annual milk yield from 240 kg to 2400 kg/cow and simultaneous replacement of grazed grass with fresh cut grass would in fact result in emission intensities as low as 3 kg CO2e/kg milk. In the latter scenario for dairy systems, ammonia volatilised and nitrate leached almost halve compared to the baseline. The mitigation measures proposed here align with the intended interventions to reduce greenhouse gas emissions in Tanzania. The sector development programs are expected to facilitate the implementation; however, adapting alternative feeds and herd structure in Tanzania face potential institutional, infrastructural and societal challenges.

Terms for indexing: Africa, greenhouse gas, livestock, production efficiency

2.1 Mitigation (Poster)

3-nitrooxypropanoal mitigates enteric methane with a minimal impact on the feedprint

Dorien Van Wesemael[1], Leen Vandaele[2], Sophie Huysveld[3], Ulla Letinois[4], Sam De Campeneere[5], Veerle Fievez[6], Maik Kindermann[7]and Nico Peiren[8]

[1]Bioscience Engineering, MSc, PhD student, Animal Sciences Unit, Flanders Research Institute for Agriculture, Fisheries and Food, Belgium

[2]Veterinary Science, PhD, Research Group Leader Cattle Husbandry, Animal Sciences Unit, Flanders Research Institute for Agriculture, Fisheries and Food, Belgium

[3]Bioscience Engineering, PhD, Researcher, Department of Sustainable Organic Chemistry and Technology, Research Group EnVOC, Ghent University, Belgium

[4]Chemistry; PhD, Senior Scientist, DSM Nutritional Products, Switzerland

[5]Applied Biological Sciences, PhD, Scientific Director, Animal Sciences Unit, Flanders Research Institute for Agriculture, Fisheries and Food, Belgium

[6]Applied Biological Sciences, PhD, Full Professor, Department of Animal Sciences and Aquatic Ecology, Laboratory for Animal Nutrition and Animal Product Quality, Ghent University, Belgium

[7]Chemistry, PhD, Innovation Project Director, Innovation Animal Nutrition & Health, DSM Nutritional Products, Switzerland

[8]Biology, PhD, Senior Researcher, Animal Sciences Unit, Flanders Research Institute for Agriculture, Fisheries and Food, Belgium

The investigational product 3-nitrooypropanol (3-NOP) showed clear reductions in enteric methane emissions in cattle in studies worldwide. However, a mitigation strategy will only be effective in abating the global warming if there is a net reduction in greenhouse gas emissions. In this study the net abatement potential of 3-NOP in dairy cattle was assessed by performing a life cycle assessment (data 2016). There were three treatments: REF (no 3-NOP), NOP_{bas} (3-NOP mixed in with the basal diet, the roughage) and NOP_{conc} (3-NOP incorporated in a pelleted balanced compound feed). The system boundaries were: the life cycle of the feed and the feed additive from the "cradle", i.e. resource extraction from the natural environment, to the production of milk at the farm. The measured enteric CH_4 emissions in CO_2 equivalents were added to the carbon footprint of the consumed feed to calculate a combined carbon footprint. The functional unit was defined as 1 kg fat-and-protein-corrected milk (FPCM). The combined carbon footprint of REF was 1.14 kg of CO_2-eq./kg of FPCM, compared to 1.06 for NOP_{bas} (P=0.15) and 1.04 for NOP_{conc} (P=0.02). The enteric methane production was 23 and 21% lower for NOP_{bas} (P=<0.01) and NOP_{conc} (P=<0.01), respectively, whereas the contribution of 3-NOP in the combined carbon footprint of NOP_{bas} and NOP_{conc} was only 0.32% and 0.34%, respectively. Feed supplementation with 3-NOP is definitely a successful strategy for abating impact of dairy on climate, even when pre-farm emissions for feed and 3-NOP are taken into account.

Index terms: *Bos taurus,* feed additive, methane mitigation, carbon footprint

Carbon capture by silvopastoral arrangements under contrasting stocking rates in the northern coast of Colombia

Luis Giraldo[1], Tatiana Montoya[2], Mariana Ángel[2], Mateo Castañeda[2], David Mendoza[2], Ana Pérez[3] and Alexandra Torres[4]

[1]Zoot. PhD. Profesor Asociado Universidad Nacional de Colombia sede Medellín

[2]Estudiante de pregrado Universidad Nacional de Colombia sede Medellín

[3]DVM-PhD

[4]Química MS Universidad Nacional de Colombia sede Medellín

Use of silvopastoral systems (SS) for cattle production has proven to be useful to increase productivity and generate ecosystem services, including carbon fixation through soil and vegetation, as tools to mitigate climate change pressures from the cattle sector and guide it towards environmental sustainability. Evaluate the carbon capture potential of cattle SS under two different stocking rates (SR) in the town of San Sebastian de Buena Vista, northern coast of Colombia. The SS was composed of timber trees *Eucalyptus tereticornis* planted in stripes (6m) with 3 lines of trees each (2mx2m), associated with *Megathyrsus maximus* in 30m wide pasture stripes, alternating pasture and tree stripes. Treatments were: T1=High SR(3,5UA/Ha), T2=Low SR(2,0UA/Ha), with 1UA=150Kg live weight. Average SR for the area is 1UA/Ha. Both treatments were managed under 6 paddocks (7 days occupation and 42 days rest) for 2 years of paddock rotation, adjusting SR through "Put and take" method. A full random block design was used with 6 replicates (Animals) per treatment. The soil carbon stock was similar ($P>0.05$) between treatments (T1=65,98 vs. T2=68,08 TCO_2/Ha). Pasture carbon stock (aerial + radicular portions) was higher ($P<0.05$) for T2=12,80 than T1=12,09 TCO_2/Ha. The carbon captured by the trees (aerial + radicular portions) was the same ($P>0.05$) for both treatments (T1=78,71; T2=81.07 TCO_2/Ha). The carbon stock summation of the different silvopastoral system compartments was similar for both treatments ($P>0.05$) with T1=156,75 vs T2=161,95 TCO_2/Ha. Use of contrasting stocking rates had no significant effect on the carbon capture capacity of the production systems evaluated.

Keywords: Carbon immobilization, Trees, pastures, *Eucalyptus tereticornis, Megathyrsus maximus,* silvopastoralism, bovine

Effect of starch substitution by rapeseed oil on enteric methane emission and performance in dairy cows fed grass-silage based diets(1)

Cécile Martin[1], Anne Ferlay[2], Mohammed Benaouda[3] and Maguy Eugène[4]

[1]Animal science, PhD, Senior Scientist, INRA, UMR1213 Herbivores, F-63122 Saint-Genès-Champanelle, France

[2]Animal science, PhD, Senior Scientist, INRA, UMR1213 Herbivores, F-63122 Saint-Genès-Champanelle, France

[3]Animal science, PhD, Postdoctoral fellowship, INRA, UMR1213 Herbivores, F-63122 Saint-Genès-Champanelle, France

[4]Animal science, PhD, Senior Scientist, INRA, UMR1213 Herbivores, F-63122 Saint-Genès-Champanelle, France

This work aimed to study the effect of energy source supplementation on methane emission and performance in dairy cows fed grass-silage based diets. Eight multiparous lactating Holstein cows were used in a replicated 4 x 4 Latin square design with 4 periods of 28 days. Animals were limited fed (95% ad libitum) with 4 grass silage based diets supplemented with 4 concentrates in which starch was gradually substituted by increasing amounts of rapeseed oil (1.5, 3.0 and 4.5% on a dry matter basis). Diets were formulated to be iso-energy and iso-protein to meet individual energy and protein requirements for production. Methane emissions were measured (days 23 to 27) when animals were in open-circuit respiration chambers. Daily intake, milk production and composition were also recorded. Intakes of gross energy and fiber were similar among diets, starch intakes decreased linearly ($P < 0.0001$) and ether extract intake increased linearly ($P < 0.001$) with increasing rapeseed oil amounts. Methane emissions (g/d), yield (g/kg dry matter intake) and intensity (g/kg milk) decreased linearly ($P < 0.01$) when starch was replaced by rapeseed oil in the diets. Milk production and composition differ among diets ($P < 0.001$). The linear decrease in milk fat yield with increasing amounts of oil suggests a milk fat depression with changes in milk fatty acids profile. Starch substitution by rapeseed oil decreased both enteric methane emission and performance in dairy cows fed grass-silage based diets.

Index terms: methanogenesis, mitigation feeding strategy, energy source, milk cow

(1)This study is part of the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI)'s "GLOBAL NETWORK" project and the "Feeding and Nutrition Network" (http://animalscience.psu.edu/fnn) of the Livestock Research Group within the Global Research Alliance Agricultural Greenhouse Gases (www.globalresearchalliance.org).

Effects of energy and tannin supplementation on N_2O emission and emission factor from sheep's excreta

Mariana Nunes de Souza[1], Maurício Civiero[1,2] and Henrique Mendonça Nunes Ribeiro-Filho[3]

[1]PhD Student at the University of Santa Catarina State – UDESC, Lages, SC, Brazil
[2]Professor at the University of Vale do Iguaçu, União da Vitória – UNIGUAÇU, PR, Brasil.
[3]Professor at the University of Santa Catarina State – UDESC, Lages, SC, Brazil.

Abstract - Livestock is one of the main activities responsible for greenhouse gases emission, such as nitrous oxide (N2O). The aim of the study was to evaluate the N2O flow and emission factor (EF) from feces and urine of sheep receiving corn ground and tannin extract supplementation. The animals were fed with ryegrass (*Lolium multiflorum* Lam.) haylage *ad libitum* and three different daily supplementation : 60 g of soybean meal (S; control); 140 g of cracked corn grain + 60 g soybean meal (SC); 140 g of cracked corn grain + 60 g soybean meal + 40 g kg^{-1} of concentrated feed of *Acacia mearnsii* tannin extract (SCT). Feces (100 g) and urine (140 ml) collected from animals of the respective treatments were applied to the soil, besides a control treatment without excreta application. The feces of all treatments had similar flux and emission of N2O and did not differ from the control. However, the N2O flow of the urine samples from diets with corn grain were reduced ($P < 0.05$) compared to that ones from the animals supplemented with soybean meal only. The EF for feces was similar among treatments with a mean of 0.18%. The average of EF from urine samples was 4%, moreover the EF from the SM treatment showed a tendency ($P = 0.089$) of reduction in 60% compared to the S treatment. Corn grain supplementation may be a tool to mitigate N2O emissions in sheep, whereas the inclusion of *Acacia mearnsii* tannin extract has not been effective.

Terms For Indexing: *Acacia mearnsii, Lolium multiflorum* Lam., *Ovis aries,* ruminants, emission factor, mitigation.

Enteric emission from beef cattle supplemented with Yerba mate extract[1]

Rafaela Vincenzi[1], Richard Roberto Lobo[1], Yuli Andrea Peña Bermúdez[1], Caroline Matos da Silva[2], Vanderlei Benetel Junior[2], Paulo de Méo Filho[3], Leandro Sannomiya Sakamoto[4], Alexandre Berndt[5] and Ives Claudio da Silva Bueno[6]

[1]Animal Scientist, Master Student in the Animal Science Program, College of Animal Science and Food Engendering, University of São Paulo, Pirassununga, São Paulo, Brazil;

[2]Animal Science Undergraduate Student, College of Animal Science and Food Engineering, University of São Paulo, Pirassununga, São Paulo, Brazil;

[3]Animal Scientist, PhD Student, College of Animal Science and Food Engineering, University of São Paulo, Pirassununga, São Paulo, Brazil;

[4]Animal Scientist, Post-doctoral Researcher at Institute of Animal Science, Beef Cattle Research Center, Sertãozinho, São Paulo, Brazil;

[5]Agronomist Engineer, Researcher at Embrapa Southeast Livestock, Brazilian Agricultural Research Corporation, São Carlos, São Paulo, Brazil;

[6]Agronomist Engineer, Associate Professor at College of Animal Science and Food Engineering, University of São Paulo, Pirassununga, São Paulo, Brazil.

The objective of this study was to evaluate enteric methane emission from Nellore cattle with levels of inclusion of Yerba mate (*Ilex paraguariensis* St. Hilaire) extract in feed. Eight castrated male Nellore steers, rumen cannulated, were fed four experimental diet (0, 0.5, 1 and 2% of inclusion of Yerba mate extract); all the diets were composed with 10.4% crude protein and 65.9% total digestible nutrients. The experimental design was a double Latin square 4x4. Each period was composed by 14 days of adaptation and 5 days of methane collection by the tracer gas technique sulfur hexafluoride (SF_6). Data were analyzed using the MIXED procedure of SAS software and a regression test was developed for P value < 0.05. For treatment 0, 0.5, 1 and 2% (respective values in the parenthesis), methane emitted daily (230, 238, 238 and 237 g/d), methane per dry matter intake (30.8, 31, 30.8 and 30.6 g/kg DM.d), methane per daily weight gain (215.4, 409.1, 239.8 and 219.3 g/kg gain.d), methane per body weight (497, 509, 514 and 505 g/kg BW.d), and methane conversion factor (9.6, 9.6, 9.5, and 9.5%) did not show difference (P > 0.05). This results may not have been significant due to the short adaptation time or low inclusion of the additive. The results show that Yerba mate extract on these levels of inclusion is not a good addictive to modulate methanogenesis, however more researches are required.

Keywords: Nellore cattle, methane, feed addictive.

[1]Grant #2018/10308-6, São Paulo Research Foundation (FAPESP)

Enteric methane emissions from beef cattle in N-fertilized grass or grass-legume pastures in North Florida

Liza Garcia[1], Jose Carlos Dubeux Jr.[2], Nicolas DiLorenzo[3], Lynn E. Sollenberger[4], Joao Vendramini[5], Erick Santos[6], David Jaramillo[7], and Martin Ruiz-Moreno[8]

[1]PhD candidate and graduate research assistant, University of Florida, North Florida Research and Education Center, 3925 Highway 71, Marianna, FL 32446

[2]PhD, Associate Professor University of Florida, North Florida Research and Education Center, 3925 Highway 71, Marianna, FL 32446

[3]PhD, Associate Professor University of Florida, North Florida Research and Education Center, 3925 Highway 71, Marianna, FL 32446

[4]PhD, Distinguished Professor - Forage Agronomy, Graduate Coordinator, University of Florida, Main Campus, Gainesville, FL

[5]PhD, Associate Professor Forage specialist, University of Florida, Range Cattle Research & Education Center, 3401 Experiment Station, Ona, FL 33865

[6]PhD candidate and graduate research assistant, University of Florida, North Florida Research and Education Center, 3925 Highway 71, Marianna, FL 32446

[7]PhD candidate and graduate research assistant, University of Florida, North Florida Research and Education Center, 3925 Highway 71, Marianna, FL 32446

[8]PhD Biological scientist, University of Florida, North Florida Research and Education Center, 3925 Highway 71, Marianna, FL 32446

Enteric methane emissions were assessed in grazing steers for three years (2016-2018). Treatments were allocated in a RCBD and consisted of: 1) N-fertilized (112 kg N ha^{-1}) bahiagrass (*Paspalum notatum* F.) pastures during the warm-season, overseeded with a mixture of cereal rye (*Secale cereale*, L.) and oat (Avena sativa, L.) + 112 kg N ha^{-1} during the cool-season (Grass+N); 2) Rhizoma peanut (*Arachis glabrata* B.) and bahiagrass pastures during the warm-season, overseeded with similar rye-oat mixture fertilized with 34 kg N ha^{-1} plus a mixture of clovers during the cool season (Grass+CL+RP); 3) unfertilized bahiagrass pastures during the warm-season, overseeded with similar rye-oat Grass+clover mixture + 34 kg N ha^{-1} during the cool-season (Grass+clover). The SF_6 tracer technique was used to measure enteric CH_4 emissions and the marker dilution technique with Cr_2O_3 and TiO_2 as indigestible external markers was used to determine dry matter intake (DMI). Enteric CH_4 emissions in g $steer^{-1}$ d^{-1}, g $BW^{-(0.75)}$, g ha^{-1} d^{-1}, or g kg of DMI^{-1}, did not differ among treatments ($P > 0.05$) in either warm or cool season. Emission intensity in g of CH_4 kg of ADG^{-1} had a season × treatment interaction ($P < 0.01$), averaging 177, 140, and 123 in the cool season, and 397, 448, and 225 in the warm season for Grass+N, Grass+clover, and Grass+CL+RP treatments, respectively. In conclusion, increased quality of forages grazed in the cool season contributed to decrease CH_4 emissions intensity in grazing systems relative to that in the warm season.

Keywords: enteric methane, beef cattle, fertilized grass, legumes.

Enteric Methane Production of Beef Steers Consuming Molasses, Cottonseed Meal, and Alkali Treated Bahiagrass Hay

Francine M. Ciriaco[1], Darren D. Henry[3], Gonzalo Barreneche[4], Ana Carolina G. Luna[5], and Nicolas DiLorenzo[2]

[1]Texas Tech University, Ph.D., Post Doc. Research Associate, Department of Animal and Food Sciences, Lubbock, TX, USA 79409

[2]University of Florida Ph.D., Associate Professor, North Florida Research and Education Center, Marianna, FL, USA 32446

[3]Texas Tech University, Ph.D., Assistant Professor, Department of Animal and Food Sciences, Lubbock, TX, USA 79409

[4]University of Florida, B.S., Intern, North Florida Research and Education Center, Marianna, FL 32446

[5]University of Florida, B.S., Intern, North Florida Research and Education Center, Marianna, FL 32446

An experiment was conducted to evaluate the effects of bahiagrass (*Paspalum notatum*) hay treated with calcium oxide (CaO) on enteric methane production of beef steers supplemented with molasses and cottonseed meal. Twenty growing *Bos taurus* and *Bos indicus* steers (314 ± 37 kg of BW) were used in a generalized randomized block design. On day -1 and 0, steers were weighed and the average weight of both days was considered the initial BW. On day 0, steers were stratified by breed and BW, blocked by initial BW (heavy and light) and randomly assigned to one of two treatments: 1) bahiagrass hay as is (DH; *n*=10) or 2) bahiagrass hay treated with 5% CaO (DM basis) + water (to 50% DM; CAO; *n*=10). Steers were provided, individually, cottonseed meal and molasses at 0.3% of BW and 0.454 kg/steer/d, respectively. Steers were housed in four pens (108 m^2 each; 5 steers/pen) in a feed efficiency facility where individual intake of hay was measured via GrowSafe. Enteric CH_4 production was measured using the SF_6 tracer technique. Data were analyzed using steer as the experimental unit. The model included the fixed effects of treatment and the random effects of breed and block. No differences between treatments were observed on total CH_4 production (g/d; P = 0.535) or grams of CH_4 produced per kilogram of OM intake (P = 0.694), OM digested (P = 0.168), and metabolic BW (P = 0.717). Bahiagrass hay treated with CaO did not alter enteric CH_4 emissions in beef steers.

Index terms: *Bos taurus*, calcium oxide, green house gas, low quality forage

Evaluation of Methane Emissions from Lambs Offered Fresh Grass Based Diets

Yiguang Zhao, Aurélie Aubry and T. Yan

Agri-Food and Biosciences Institute, Hillsborough, Co. Down, BT26 6DR, United Kingdom

The present study aimed to evaluate the effect of feeding good quality grass on enteric methane (CH4) emissions of sheep. Forty-eight lowland lambs were used in a 2 breeds (Highlander vs. Texel) × 3 sexes (female vs. intact male vs. wether) × 2 diets (fresh grass vs. fresh grass plus 0.5 kg/d pelleted concentrate) factorial design study with a single period (23 days). Animals were 5 months old and weighing 36 ± 5.0 kg at the commencement of the study. The CH4 emissions were measured using respiration chambers. Lambs offered concentrate diets had greater DM intake and CH4 production (g/d) than those given fresh grass only, but diets had no effect CH4/DM intake or CH4 energy/GE intake (6.4% vs. 6.3%). Texels produced more CH4/DM intake than Highlanders, while sex had no effect on CH4/DM intake. The results indicate that high quality fresh grass may play a similar role to concentrates in mitigating CH4 emissions of sheep.

Keywords: fresh grass, methane, respiration chamber, sheep

Factors Affecting on Enteric Methane Emission from Dairy Cattle integrated with Paddy Rice Farming

Kalaya Boonyanuwat[1], Anusorn Thinowong[2] and Kannika Panpui[1]

[1]Biodiversity Research and Development Sector. Bureau of Animal Husbandry and Genetic Improvement. Department of Livestock Development. Meang District. Pathumthani Province. 12000. Thailand.

[2]Sakon Nakorn Livestock Research and Breeding Center. Bureau of Animal Husbandry and Genetic Improvement. Department of Livestock Development. Meang District. Sakon Nakorn Province. 47000. Thailand.

In 2018, in Sakon Nakhon province there were 4,524 dairy cows, 193 dairy farmers. They were integrated dairy cattle and paddy rice farming systems. The objective was to study the effect of farm size and feeding management on enteric methane emission from dairy cattle integrated with paddy rice farming in Sakon Nakhon Province. There were 2 parts of data, 1) primary data and 2) secondary data. Data were analyzed by least square analysis. There were 2 farm sizes, 1) small dairy farm (1-20 cows) and 2) medium dairy farm (21-100 cows). Milking cows from small and medium farms had an average enteric methane emission of 0.65 and 0.80 kg per head per day, respectively (P <0.01). The basic feeding were 21 %CP concentrate and rice straw. There were 3 levels of feed managements, 1) no supplement, 2) with 1 supplement source, and 3) with more than 1 supplement source. The milking cows of feed management level 1, 2 and 3 had average enteric methane emission 0.90, 0.74 and 0.56 kg per head per day, respectively (P <0.01). The cows with low and high TDN level had average enteric methane emission 0.81 and 0.65 kg per head per day, respectively (P <0.01). Farmers used manures as fertilizer, supported to reduce greenhouse gas emissions from chemical fertilizers and their transportation. It could reduce the GHG emission from rice straw burning. This dairy cattle and paddy rice integrated farming system supported food security, family income and friendly environment in Skon Nakhon Province, Thailand.

Keywords: enteric methane, dairy cattle, paddy rice

Factors Affecting on Enteric Methane Emission from Fattening Cattle Integrated with Paddy Rice Farming

Kalaya Boonyanuwat[1], Charurak Honggate[1], Nurzikree Sama[1]

[1]Biodiversity Research and Development Sector. Bureau of Animal Husbandry and Genetic Improvement. Department of Livestock Development. Meang District. Pathumthani Province. 12000. Thailand.

[2]Sakon Nakorn Livestock Research and Breeding Center. Bureau of Animal Husbandry and Genetic Improvement. Department of Livestock Development. Meang District. Sakon Nakorn Province. 47000. Thailand.

In 2018, in Sakon Nakhon province there were 3,378 fattening cattle, 964 fattening cattle farmers. They were integrated fattening cattle and paddy rice farming systems. The objective was to study the effect of age and feeding management on enteric methane emission from fattening cattle integrated with paddy rice farming in Sakon Nakhon Province. There were 2 parts of data, 1) primary data and 2) secondary data. Data were analyzed by least square analysis. Farmers raised Charolais crossbred. There were 3 levels of age, 1) 1-2 years, 2.1-3 years, and 3) more than 3 years. Fattening cattle from 1, 2 and 3 level of age had an average enteric methane emission of 0.21, 0.31 and 0.55 kg per head per day, respectively (P <0.01). The basic feeding were 14 %CP concentrate and rice straw. There were 2 levels of feed managements, 1) with 1 supplement source, and 2) with more than 1 supplement source. The fattening cattle of feed management level 1 and 2 had average enteric methane emission 0.50 and 0.21 kg per head per day, respectively (P <0.01). Farmers used manures as fertilizer, supported to reduce greenhouse gas emissions from chemical fertilizers and their transportation. It could reduce the GHG emission from rice straw burning. This fattening cattle and paddy rice integrated farming system supported food security, family income and friendly environment in Skon Nakhon Province, Thailand.

Keywords: enteric methane, fattening cattle, charolais, paddy rice

Greenhouse gas emission from the composting process of broiler litter

Mei-Ping Cheng[1], Min-Chen Cheng[2], Ren-Bao Liaw[3], Ting-Hsun Hsiao[4] and Hsin-Jung Lee[5]

[1]Ph. D of the National Taiwan University, Researcher and Chief Secretary, Livestock Research Institute, Tainan, Taiwan, Republic of China.

[2]Master degree of the National Pingtung University, Associate Researcher of Hengchun Branch, LRI.

[3]Ph. D of the National Taiwan University, Researcher of Livestock Management Division, LRI.

[4]Ph. D of the National Chung-Hsing University, Associate Researcher and Chief of Livestock Management Division, LRI.

[5]Master degree of the National Taiwan University, Associate Researcher and Chief of Livestock Management Division, LRI.

Abstract—The purpose of this study was to evaluate the greenhouse gas emission factors (EF) and the effect of aeration condition on the EFs of the composting process of broiler litter and propose strategies for reducing GHG emission. The broiler litter was piled in the composting plants with 3, 0.5 and 0 min/hr of aeration, respectively. The composting temperature was recorded daily. The GHG from the compost was measured triple a week. The composition of compost was analyzed once weekly. Total amounts of the greenhouse gases emitted during the composting processes were calculated by the GHG concentration of headspace gas of compost plants. The results showed the EFs of nitrous oxide were 0.62, 1.27 and 1.23% N_2O-N/initial N and 1.59, 1.96 and 2.04% CH_4-C/initial C, respectively. The more aeration time it was given, the less amount of methane emitted. Taking the power consumed into account, the total carbon dioxide equivalent of were 0.32, 0.43 and 0.42 kg/kg initial dry matter for the aeration condition of 3, 0.5 and 0 min/hr, respectively. The results of this study showed 3 min/hr of aeration could reduce 24% of the GHG from the broiler litter composting process.

Keywords: emission factors, nitrous oxide, methane, aeration

Greenhouse gas emission intensity from grazing beef steers with or without supplement in Argentina

Patricia Ricci[1], María Laura Testa[2], Soledad Alonso Ramos[3], Carlos Sebastián Maglietti[4], Enrique Pavan[1], Banira Lombardi[5], Patricia Inés Alvarado[6], Sergio Guzmán[7], María Paula Juliarena[8] and Horacio Leandro Gonda[9]

[1]Agr. Eng., PhD, Department of Animal Production, National Institute of Agricultural Technology, Balcarce, Argentina.

[2]Chem, MSc., Department of Animal Production, National Institute of Agricultural Technology, Balcarce, Argentina

[3]Agr. Eng., PhD student, Department of Animal Production, National Institute of Agricultural Technology, CIC, Balcarce, Argentina

[4]Zoot. Eng., MSc. Department of Animal Production, National Institute of Agricultural Technology, Balcarce, Argentina

[5]Bach. Environ. Tech., PhD student, Department of Physical and Environmental Sciences, UNICEN – CICPBA – CONICET, Tandil, Argentina

[6]Vet., MSc., Department of Animal Production, National University of the Centre of the Buenos Aires Province, Tandil, Argentina

[7]Biol. Lecturer, Faculty of Exact Sciences, National University of the Centre of the Buenos Aires Province, Tandil, Argentina

[8]Chem., PhD, Associate Professor, Department of Physical and Environmental Sciences, UNICEN – CICPBA – CONICET, Tandil, Argentina

[9]Agr. Eng., PhD, Associate Professor, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden

Beef production is a major industry in Argentina, but it is also responsible for the emissions of Greenhouse gases (GHG). The aim of the study was to measure the impact of supplementing grazing beef steers on their GHG emissions intensity. Twenty Angus steers (200 ± 10 kg) grazed tall fescue and alfalfa pasture without (P) or with maize grain as daily supplement (S, 1% body weight) during 90 days. Body weight was recorded every 21 days. Enteric methane (CH4) was measured on days 85 to 90 (SF6 technique). Methane and nitrous oxide (N2O) emissions from dung patches were measured using close static chambers (n = 5). Total CO2eq was equal to (enteric CH4 + dung CH4) * 25 + dung N2O * 298. Average daily body weight gain (ADG) was 0.38 vs. 0.55 kg and enteric CH4 was 4,045 and 4,300 g $CO_2eq \cdot anim^{-1} \cdot d^{-1}$ for P and S, respectively. Methane emission from dung patches decreased from 64.9 to 21.3, but N2O increased from 19.9 to 60.4 g $CO_2eq \cdot anim^{-1} \cdot d^{-1}$ for P and S, respectively. Although total emissions from P were numerically lower than S steers (4,130 and 4,382 g $CO_2eq \cdot anim^{-1} \cdot d^{-1}$, respectively), total emission intensity were reduced by 27% (10.87 vs. 7.97 kg $CO_2eq \cdot kg\ ADG^{-1}$, respectively) due to a 45% higher performance of supplemented steers. Although emissions from urine patches are still needed, this study demonstrated with local information that supplementing grazing steers have substantial impacts on improving productivity without altering enteric plus dung GHG emissions.

Keywords: cattle, methane, nitrous oxide, pasture, maize grain

Greenhouse gas emissions from sheep fed with increasing levels of *Tithonia diversifolia*

Márquez, S.P[1], Silva, V.O[2], Bompadre, T.J.V[3], Abdalla A.L[4] and Mauricio, R.M[5]

[1]Veterinary and Animal Scientist, Doctorate Student at Federal University of Minas Gerais
[2]Agronomist, Master Student at Centre for Nuclear Energy in Agriculture, University of São Paulo
[3]Animal Scientist, MSc, Doctorate Student at Centre for Nuclear Energy in Agriculture, University of São Paulo
[4]Agronomist, Post-Doc, Associated professor at Centre for Nuclear Energy in Agriculture, University of São Paulo
[5]Agronomist, PhD, Associated professor at Department of Biosystems Engineering, Federal University of São João del Rei

The increasing interest in livestock systems that are able to provide animal protein whilst reducing the impact on the environment has encouraged the use of shrub species in pasture systems as an alternative to high concentrate diets in conventional production systems. A novel approach for measuring *in vivo* gas emissions was used to evaluate the effects of the inclusion of *Tithonia diversifolia* (TD), a tropical shrub, in the diet of sheep. Four diets containing concentrate, Tifton hay and 0 (control), 0.09, 0.27 and 0.45 TD (as % of dry matter), were tested. Eight rams were individually allocated in ten respirometric chambers connected to a spectrometer (Picarro, Inc, USA) that allowed to continuously assess the concentration of CO_2, CH_4, NH_3 and N_2O throughout a 48 h assay. The treatments were arranged in a Latin Square Design (4x4) and data was analyzed by ANOVA and Tukey test. The results showed a significant difference ($P<0.05$) between treatments (ppm/kgDMI) for CO_2 (697, 796, 816, 792), N_2O (0.2617, 0.3198, 0.3361, 0.2959), NH_3 (4114, 4624, 4093, 4521) and CH_4 (35.8, 40.0, 39.6, 38.0) for T1, T2, T3 and T4, respectively. Overall, gas emissions were increased by the inclusion of TD when compared to control, however, higher inclusion (T4) accounted for lower concentrations when compared to T2. Further data procesesing still have to be made in order to assess the relationship of gas concentration, feed digestibility and volume of gas produced and also if higher inclusions of TD could reduce emissions.

Index Terms: Methane, Nitrous Oxide, Ammonia, Carbon Dioxide, Ruminants, Intensive Silvopastoral Systems

Greenhouse gases and ammonia emissions from the breeding of black soldier fly (*Hermetia illucens* L.) larvae

Elio Dinuccio, Marco Meneguz, Luca Rollè, Enrico Cosimo, Laura Gasco

Dipartimento di Scienze Agrarie, Forestali e Alimentari, Università di Torino, Largo Paolo Braccini 2, 10095 Grugliasco, Italy

There is an increased interest in using insect larvae to recycle organic waste in high-quality protein products for livestock and aquaculture feeds. Different species can be used for this propose and *Hermetia illuncens* L., the black soldier fly (BSF), is one of the most promising. However, during rearing, due to the metabolism of these insects and their excreted material, greenhouse gases (GHG) and ammonia (NH_3) can be produced and emitted. A study has been carried out to investigate carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and NH_3 emissions during rearing of BSF larvae. The diet tested were based on agro-industrial by-products: corn stover (CS), residues from vegetable processing (VW) and brewery waste (BW). Three diet were formulated: a cereal-based diet (Gainesville) used as control (C), C+25%CS and BW+25%CS. Black soldier fly larvae (BSFL) were housed in containers (5 replications per treatment) placed in a climate-controlled room. Air flow rate and temperature were set according to rearing conditions used by commercial BSFL rearing farms. Gaseous emissions were determined with dynamic chamber method by Infrared Photoacoustic Detection. BSFL rearing was shown to produce sizeable NH_3 and GHG emissions. Estimated NH_3 losses ranged from 2.15 mg (C) and 8.52 mg (BW) per gram of produced insect crude protein (CP), whereas cumulative GHG emissions averaged 2.68 gCO_2eq/gCP. A full evaluation of BSFL meal production system, including GHG related to energy used for BSFL rearing and processing as well as to the management of rearing residues, is already under study by our research group.

Inclusion of calcium-ammonium nitrate in in vitro ruminal fermentation using a wheat forage based substrate

Andrea M. Osorio[1], Sebastian Mejia-Turcios[3], Francine M. Ciriaco[4], Nicolas DiLorenzo[5], and Darren D. Henry[2]

[1]Texas Tech University, B.S., M.S. student, Department of Animal and Food Sciences, Lubbock, TX, 79409

[2]Texas Tech University, Ph.D, Assistant Professor, Department of Animal and Food Sciences, Lubbock, TX, 79409

[3]Texas Tech University, B.S., M.S. student, Department of Animal and Food Sciences, Lubbock, TX, 79409

[4]Texas Tech University, Ph.D., Post Doc. Research Associate, Department of Animal and Food Sciences, Lubbock, TX, 79409

[5]University of Florida, Ph.D., Associate Professor, North Florida Research and Education Center, Marianna, FL, 32446

A randomized complete block design was used to evaluate in vitro ruminal total gas and methane production, NH_3-N concentration, and digestibility of wheat forage when incubated with calcium-ammonium nitrate (CAN). In vitro fermentations comprised 50 mL of a 4:1 buffer:ruminal fluid inoculum and 0.7 g of substrate [DM; wheat (*Triticum aestivum*; 100%) or wheat:corn (88:12)] incubated for 48 h. Batches were incubated on 3 days. Treatments included: 1) wheat (W); 2) wheat+corn (WC); 3) WC+2% CAN in the substrate DM (WCN); and 4) WC+0.67% UREA in the substrate DM (WCU). In vitro organic matter digestibility (IVOMD) was determined after incubation for 48 h with inoculum, followed by a 48 h incubation with a HCl-pepsin solution. The statistical model included the fixed effect of treatment and random effect of day (block). Total gas production was reduced by WCN compared with WCU and WC ($P \leq 0.049$). The addition of corn without NPN increased ($P=0.004$) total gas production compared to W. An increased ($P=0.009$) IVOMD was observed for WC compared to W, while no differences ($P=0.416$) were observed between WCN and WCU. Ammonia-N concentration was similar ($P=0.463$) between WCN and WCU, and the inclusion of NPN increased ($P \leq 0.026$) NH_3-N concentration compared to W. Methane production (mmol/g OM fermented) was lesser ($P<0.001$) for WCN compared to WCU. Total VFA concentration and acetate:propionate were not affected by treatment ($P>0.05$). Therefore, CAN can potentially be used as a NPN source with the additional benefit of in vitro methane mitigation without negatively affecting IVOMD or total VFA concentration.

Index terms: *Bos taurus*, methane, digesibility

Inclusion of yerba mate extract levels on lamb diets: methane emissions and animal performance (1)

Richard Roberto Lobo[1], Paulo de Méo-Filho[2], Yuli Andrea Penã-Bermúdez[1], Danny Alexander Rojas Moreno[1], Rafaela Vincenzi[1], Alexandre Berndt[3] and Ives Claudio da Silva Bueno[4]

[1]Animal Scientist, Master student at College of Animal Science and Food Engineering at University of São Paulo, Pirassununga/SP, Brazil.

[2]Animal Scientist, Ph.D. student at College of Animal Science and Food Engineering at University of São Paulo, Pirassununga/SP, Brazil.

[3]Researcher at Embrapa Southeast Livestock, Brazilian Agricultural Research Corporation, São Carlos/SP, Brazil.

[4]Professor and Researcher at College of Animal Science and Food Engineering at University of São Paulo, Pirassununga/SP, Brazil.

This study was carried out to evaluate yerba mate (*Ilex paraguariensis* St. Hilaire) extract (YME) as a natural addictive and its effect on gas methane production and performance in lambs. Thirty-six male lambs (crossbreed Île de France x Dorper x Santa Inês), weighting 23.77±3.70 kg, were assigned into nine groups (following the initial weight), one of each animal inside of the group were assigned randomly to one of the four treatments (0, 1, 2 and 4% inclusion of YME), according to a randomized block design. The concentrate/roughage ratio was 60/40, body weight was measured every 14 days, dry matter intake was recorded daily and methane emissions were measured by SF6 technique during 5 consecutive days. The data were analyzed using PROC MIXED of SAS and the block like a random effect. The results show a tendency of YME to reduce linearly dry matter intake (DMI), final weight (FW) and daily methane production (P=0.0722, 0.0805 and 0.0709, respectively). However, daily weight gain (DWG; P=0.1526), feed conversion rate (FCR; P=0.3848), efficiency of conversion (EC; P=0.5015), methane production per kg DMI (P=0.9909) and per kg of live weight (LW) (P=0.5419) show no differences. Although YME can decrease daily methane production, high levels of this natural addictive can affect negatively the DMI. The performance index (FCR and EC) do not show differences because the proportion of total DMI in the experimental period l and body weight gain were the same between the treatments and the same behavior occurred with the proportion of methane produced per kg of DMI and kg of LW.

Terms for indexing: greenhouse gases, lamb production, methane, natural addictive, yerba mate.

(1)Grant #2017/25319-0 and 2018/10308-6, São Paulo Research Foundation (FAPESP).

Intensification of tropical pastures for beef cattle production in Brazil: intensity of greenhouse gases - GHG - emission and carbon balance (CO_{2eq})

Patricia Perondi Anchão Oliveira[1], Alexandre Berndt[1], André de Faria Pedroso[1], Teresa Cristina Alves[1], Leandro Sannomiya Sakamoto[2], Fábio Luís Henrique[1] and Paulo Mazza Rodrigues[3]

[1]Brazilian Agricultural Research Corporation

[2]Instituto de Zootecnia

[3]University of São Paulo

The objective of this study was to investigate the CO_{2eq} balance in beef cattle production systems in the Atlantic Forest Biome as affected by different levels of pasture intensification. Twenty four steers (*Bos indicus*, Nellore breed) were distributed between four production systems (two replicate): DEG (degraded pasture), IHS (irrigated pasture - high stocking rate), DLS (dryland pasture - low stocking rate) and DHS (dryland pasture - high stocking rate). Intensities of GHG emission were obtained by measuring methane and nitrous oxide emissions in the pastures and enteric methane production by the experimental animals, for two years. The annual C accumulation rate was established by: C stock in the pasture soil minus- C concentration in the native forest soil divided by the number of years of land use as pasture (0-100 cm soil layers, Atlantic forest as reference). The CO_{2eq} balance was calculated by: soil C sequestration in the pasture - GHG emissions in the system (the global warming potential by the IPCC, 1996). Data were analyzed by ANOVA and the Tukey test at 5% significance. Treatments DEG, IHS, DLS and DHS presented annual GHG emissions of 2.28, 10.43, 6.92 and 5.28 t $CO_{2eq}.ha^{-1}$ (±0.65; $P<0.05$) and annual balance of -6.23, -13.40, 0.14, 1.3 t $CO_{2eq}ha^{-1}$ (±1.90; $P<0.05$), respectively. As carcass yield per ha was higher in the irrigated pasture, the emission of CO_{2eq}/kg carcass was lower that system than in the degraded pasture. Production systems with intensively managed dryland pastures have greater CO_{2eq} sequestration capacity, mitigating emissions and generating C credits.

Keywords: carbon balance, carbon sequestration, beef cattle, emission, greenhouse gases, intensification

Intensification of tropical pastures for beef cattle production in Brazil: the need for C sequestration by trees to mitigate greenhouse gas emissions.

Patricia Perondi Anchão Oliveira[1], Alexandre Berndt[1], André de Faria Pedroso[1], José Ricardo Macedo Pezzopane[1], Fábio Luís Henrique[1], Paulo Mazza Rodrigues[2]

[1]Brazilian Agricultural Research Corporation

[2]University of São Paulo

The objective of this study was to investigate the need for tree planting in pasture production systems for beef cattle for the mitigation of the emission of greenhouse gases, according to the application of intensification (different uses of correctives, fertilizers and irrigation in degraded pasture). With the results of the C (PAG - IPCC 1996) balance of production systems and with the annual C sequestration rate by the tree bark of *Eucalyptus urograndis* (trees produced under the same conditions) the trees were calculated for the mitigation of emissions of greenhouse gases. DEG (degraded pasture), IHS (irrigated high stock), DHS (dry high stocking) and DLS (dry low stocked) were evaluated for two years in the rearing of twenty-four steers (Bos indicus Nellore breed) per year. We performed a variance analysis of the results, with a comparison of means over time by the Tukey test at 5% of significance. For the degraded system (DEG) it would be necessary to plant 101.7 trees.ha^{-1} for the mitigation of GHG emission and for the irrigated system (IHS) 218,75 trees.ha^{-1}; (DHS) and low stocking rate (DLS), soil C sequestration was able to reduce emissions from the production systems and generate C credits equivalent to 2.34 and 21.27 trees. ha^{-1} (± 37.19, P <0.05). As carcass yield per ha was higher for irrigated pasture, the number of trees/kg carcass was lower than that of pasture degraded for the mitigation of GHG emission.

Keywords: beef cattle, carbon fixation, *Eucalyptus urograndis,* greenhouse gases.

In-vitro methane production of tropical forage diets under silvopastoral systems on a RUSITEC

Aldo Ibarra[1], Alexandra Torres[2], Ana Pérez[3], James Betancur[4], Alejandra Arias[5] and Luis Giraldo[6]

[1]Zoot, MS, Universidad Nacional de Colombia sede Medellín
[2]Chem., MS, Universidad Nacional de Colombia sede Medellín
[3]DMV-PhD
[4]Zoot. cPhD
[5]Estudiante Zoot
[6]Zoot. PhD. Associate Professor, Universidad Nacional de Colombia sede Medellín. lagirald@unal.edu.co

Colombia has 24,4 million bovines grazing in 34,2 million hectares of pasture lands, emitting 1068Gg of enteric methane to the environment. Silvopastoralism is a technological alternative proven to be productive, efficient and generating associated environmental services incrementing sustainability in cattle production, especially through GHG mitigation at source. We evaluated the effect of different diets under silvopastoral arrangements in the Northern region of Colombia, on methane production and ruminal fermentation parameters under an *in-vitro* ruminal simulation system RUSITEC. Four different diet treatments(T) were considered: T0= 100% *Megathyrsus maximus forage-control*); T1= 70% *M. maximus* + 30% *Leucaena leucocephala*; T2= 70% *M. maximus* + 30% *Guazuma ulmifolia*; T3= 70% *M. maximus* + 30% *Crescentia cujete*). Methane production (mL/day) decreased (P<0.001) by 26%, 19% and 29% for T1, T2 and T3, respectively, compared to T0. Neutral detergent fiber degradation (NDFD) was lower (P< 0.05) for T1, T2 and T3 vs T0. Organic matter degradation (OMD) increased (P< 0.05) for T1 in comparison to all other treatments. Raw protein degradation (RPD) increased (P< 0.05) for T1 vs T2 (15%) and T3 (18%). There was no effect on Volatile fatty acid production (P< 0.05). In conclusion, incorporation of tree forage resources into bovine diet reduces *in vitro* methane production and improves some ruminal fermentation parameters.

Keywords: Ruminal fermentation, enteric methane, silvopastoral diets

In vitro pure cultures of methanogenic archaea exhibit different characteristics between species and incubation media

Mariana E. Garcia-Ascolani[1], Timothy Hackmann[2], Martin Ruiz-Moreno[3], Jose Carlos Batista Dubeux Jr.[4] and Nicolas DiLorenzo[5]

[1]University of Florida, M.S., Graduate Research Assistant and PhD Candidate, North Florida Research and Education Center, Marianna FL 32446

[2]University of Florida, Ph.D., Assistant Professor, Department of Animal Sciences, Gainesville FL 32611; University of California, Davis, Ph.D., Assistant Professor, Department of Animal Science, Davis CA 95616

[3]University of Florida, Ph.D., Biological Scientist II, North Florida Research and Education Center, Marianna FL 32446

[4]University of Florida, Ph.D., Associate Professor, North Florida Research and Education Center, Marianna FL 32446

[5]University of Florida, Ph.D., Associate Professor, North Florida Research and Education Center, Marianna FL 32446

In vitro incubations were conducted to characterize *Methanobrevibacter gottschalkii* Ho and *M. ruminantium* M1, incubated on growth media DSMZ 1523 (DSMZ GmbH, 2015) and DSMZ 119 (DSMZ GmbH, 2017). The experiment was conducted as a completely randomized design with a 2 × 2 factorial arrangement, plus 2 controls. Factors were methanogens species (*M. ruminantium* M1 or *M. gottschalkii* Ho), and growth media (DSMZ 1523 or DSMZ 119), and controls consisted of each growth media without inoculation with archaea culture. Media preparation, incubation, and growth conditions were based on recommendations by DSMZ, with modifications by Hackmann (2016). Incubations were conducted in triplicate. The model included the fixed effect of treatment and the random effect of incubation. Data were analyzed using the PROC GLIMMIX of SAS. *Methanobrevibacter ruminantium* M1 grew more slowly ($P < 0.01$) than *Methanobrevibacter gottschalkii* Ho, particularly when incubated in DSMZ 1523 ($P = 0.02$). *Methanobrevibacter gottschalkii* Ho had the greatest ($P = 0.01$) CH_4 production when incubated in DSMZ 119 but was not different from M1 when incubated in DSMZ 1523. There was a species × media interaction ($P < 0.05$) for the C isotopic signature of both the microbial pellet and the supernatant at the end of the incubation, as well as a tendency ($P = 0.09$) for a species × media interaction for the C isotopic signature of CH_4. Methanogens have differential growth responses between species and react differently to the same growing conditions in vitro.

Index terms: *Methanobrevibacter gottschalkii* Ho, *Methanobrevibacter ruminantium* M1, archaea, methanogens, methane, isotopic signature

Long term effects of oilseed supplementation on methane emissions of grazing dairy cows[(1)]

Camila Muñoz[1], Rodrigo Villalobos[2], Alejandra M. T. Peralta[3], María Sol Morales[4] and Emilio M. Ungerfeld[5]

[1]DVM, Ph.D., Scientist at Instituto de Investigaciones Agropecuarias, INIA Remehue, Ruta 5 km 8 norte, Osorno, Chile

[2]Undergraduate Student at Facultad de Ciencias Veterinarias y Pecuarias, Universidad de Chile, Av. Sta. Rosa 11735, La Pintana, Región Metropolitana

[3]DVM, Research Assistant at Instituto de Investigaciones Agropecuarias, INIA Remehue, Ruta 5 km 8 norte, Osorno, Chile

[4]DVM, M.Sc., PhD, Professor at Facultad de Ciencias Veterinarias y Pecuarias, Universidad de Chile

[5]M.Sc., Ph.D., Scientist at Instituto de Investigaciones Agropecuarias, INIA Carillanca, Km 10, Camino Cajón, Vilcún, Temuco, Chile.

Oilseeds can decrease methane emissions of pasture and TMR fed dairy cows. The aim of this study was to evaluate the effects of supplementation of unprocessed oilseeds on methane emissions of grazing lactating dairy cows in a long term experiment (22 wk). In a randomized block design, 60 multiparous Holstein Friesian cows were allocated to 1 of 4 treatments: concentrate without oilseeds (6 kg/d, control), or concentrate with whole cottonseed (6 kg/d), rapeseed (5.3 kg/d) or linseed (5.5 kg/d), all on an as-fed basis. Concentrates were iso-caloric and iso-nitrogenous and the linseed, rapeseed and cottonseed concentrates contained 55, 53 and 56 g EE/kg of diet DM, respectively, compared to 34 g EE/kg diet DM of the control. All cows strip-grazed a perennial ryegrass-based sward. On weeks 9 (spring) and 20 (summer), methane emissions were estimated for 5 days using the SF_6 technique. Data were analysed by ANOVA separately for each season. There were no effects of the treatments on methane emissions expressed either as total methane production (P = 0.12 and P = 0.61 for spring and summer, respectively) or methane per unit of milk yield (P = 0.20 and P = 0.09, in the same order). Lack of effects could be explained by the lack of processing of oilseeds, low level of lipid supplementation, or rumen adaptation to diets. In conclusion, the inclusion of whole oilseeds at the levels evaluated in this study was not an effective long term strategy for decreasing methane emissions of grazing dairy cows.

Keywords: oilseeds, methane, dairy cow, pasture, grazing, concentrate supplementation

[(1)]Supported by Comisión Nacional de Investigación Científica y Tecnológica (CONICYT), Chile, Fondo Nacional de Desarrollo Científico y Tecnológico (FONDECYT), Grant N° 1151355 and 1191476

Asparagopsis armata added to lactating dairy cows' diet reduces enteric methane intensity by 60 percent

Breanna M Roque[1], Joan K Salwen[2], Rob Kinley[3], and Ermias Kebreab[1]

[1]Department of Animal Science, University of California, Davis, CA, 95618, United States of America
[2]Stanford University, Palo Alto, CA, 94305, United States of America
[3]CSIRO Agriculture and Food, Townsville, QLD, Australia

In vitro studies have shown considerable reductions in methane emissions using *Asparagopsis spp.* This is the first study investigating the effect of any species of *Asparagopsis* in dairy cattle *in vivo*. Our objective was to quantitatively evaluate the response of cows consuming *Asparagopsis armata* on methane production. Twelve post-peak lactating Holstein cows were randomly assigned to three treatments (control, 0.5% and 1% inclusion levels of *A. armata* on organic matter basis) in a 3×3 Latin square design with three 14-day periods. Enteric methane emissions were measured using the GreenFeed system. Methane production (g/d) decreased significantly by 26.4% at the low (0.5%) level of *A. armata* inclusion and 67.2% at the high (1%) level of inclusion. Hydrogen production increased 163 and 236% with low and high levels of *A. armata* inclusion, respectively. Feed intake was reduced by 10.8 and 38.0%, respectively, in low and high levels of *A. armata* inclusion. Methane yield (g/kg DMI) decreased significantly by 20.3 at low level and 42.7% at high level (P = <0.0001). Hydrogen yield significantly increased with the addition of *A. armata* by 55.5 and 78.9% at low and high *A. armata* inclusion levels, respectively (P = <0.0001). Methane intensity (g/kg milk yield) significantly decreased by 26.8% at low levels and 60% at high levels of *A. armata* inclusion. Bromoform concentrations in milk were not significantly different between treatments. Our *in vivo* results showed that *A. armata* has potential to be used as a feed additive to reduce enteric methane emissions.

Keywords: bos taurus, dairy cows, *Asparagopsis*, seaweed, enteric methane, greenhouse gas

Plantago lanceolata use as mitigation strategy for reducing nitrous oxide emissions from cattle urine patches in New Zealand pastureland

Priscila L. Simon[1], Cecile A. M. de Klein[2], Wayne Worth[3], Jeferson Dieckow[4] and Tony J. van der Weerden[5]*

[1]Soil Science, PhD. Post-doctoral Scientist, AgResearch Invermay - New Zealand
[2]Applied Ecology, PhD. Principal Scientist, AgResearch Invermay - New Zealand
[3]Soil Science, MSc. Research associate, AgResearch Invermay - New Zealand
[4]Soil Science, PhD. Professor, Federal University of Parana - Brazil
[5]Soil Science, PhD. Scientist, AgResearch Invermay - New Zealand
*Contact e-mail: priscila.simon@agresearch.co.nz

Urine deposited by grazing animals is the main source of nitrous oxide (N_2O) emissions in New Zealand. Recent studies have suggested that certain pasture plants, for example plantain (*Plantago lanceolata*), can curb N_2O emissions from livestock systems. This study aimed to i) evaluate the potential of plantain for reducing N_2O emissions from cattle urine patches; ii) determine the effect of including plantain in animal diets on urine-N loading and its influence on N_2O emissions; and, iii) evaluate whether any effects on N_2O emissions reduction could be attributed to a 'urine' or a 'plant' effect. A static chamber method was used to measure N_2O fluxes from urine that was collected from cows fed on a 0, 15, 30 or 45 % plantain diet. This urine was poured onto plots with the corresponding percentage of plantain in the sward. In addition, we measured N_2O emissions from field plots with different proportions of plantain in the sward (0, 15, 30, 45, 60 and 100%), that received urine collected from cows fed on "standard" ryegrass/clover swards (*Lolium perenne/Trifolium repens*). Following applications of standard urine, nitrous oxide emissions reduced linearly as the proportion of plantain in the sward increased (r^2 = 0.969). Urine-N loading rate was significantly lower when animals were fed on plantain than on ryegrass/clover (r^2 = 0.987). There was a clear trend of lower N_2O emissions with increasing plantain in the diet, although differences in emission factors were not statistically significant (P > 0.10). The results suggest that the efficacy of plantain is due to both a reduction in urinary N excretion and a plant effect, the latter possibly due to biological nitrification inhibition (BNI) caused by the release of root exudates.

Keywords: Plantain, BNI, Greenhouse gases, Ammonium, Nitrate.

Methane emission of young bulls grazing Marandu palisadegrass in different levels of pasture intensification

Marcia Helena Machado da Rocha Fernandes[1], Lais de Oliveira Lima[2], Erick Escobar Dallantonia[3], Fernando Ongaratto[4], Abmael da Silva Cardoso[5], Ricardo Andrade Reis[6], Josiane Fonseca Lage[7] and Marco Antonio Alvares Balsalobre[8]

[1]Agronomic engineer, PhD, researcher, São Paulo State University (UNESP), Jaboticabal, Brazil
[2]Animal Scientist, BA, master student, São Paulo State University (UNESP), Jaboticabal, Brazil
[3]Animal Scientist, master, PhD student, São Paulo State University (UNESP), Jaboticabal, Brazil
[4]Animal Scientist, master, PhD student, São Paulo State University (UNESP), Jaboticabal, Brazil
[5]Agronomic engineer, PhD, postdoctoral fellow, São Paulo State University (UNESP), Jaboticabal, Brazil
[6]Animal Scientist, PhD, professor, São Paulo State University (UNESP), Jaboticabal, Brazil
[7]Animal Scientist, PhD, Research & Development Manager, Ruminants, Trouw Nutrition Brazil, Campinas, Brazil
[8]Agronomic engineer, PhD, consultant, Trouw Nutrition Brazil, Campinas, Brazil

We hypothesized that the improvement of grazing management by pasture fertilization will reduce enteric methane emission, contributing to its mitigation in Brazilian production systems. The experimental area consisted of 24 ha of Marandu palisadegrass pasture (Brachiaria brizantha 'Marandu') divided into 12 paddocks of approximately 2 ha each. The treatments consisted of three levels of intensification: zero (0N, no fertilization), moderate (75 kg N/ha/year; 75N) and high (150 kg N/ha/year; 150N), in a completely randomized design with four replicates (paddocks). The stocking rate over the experimental period was 1.7 (0N), 3.0 (75N) and 3.7 (150N) animal unit (animal unit = 450 kg)/ha. The source of N fertilizer was ammonium nitrate. Pasture were managed under continuous stocking to maintain grazing height fixed at 25 cm during the growing season, using the put-and-take methodology. Forty-eight tester and 31 put-and- take animals (initial body weight, BW of 295±16 kg) were used during rainy season that lasted from Nov 2018 until May 2019. The enteric methane emission was measured in 24 animals (8 per treatment) using the sulfur hexafluoride tracer-gas technique, in March 2019. The average daily gain (ADG) increased linearly ($P < 0.0001$) from 0.73 (0N) to 1.00 (150N) kg/d with increasing level of intensification. However, methane production did not differ among treatments ($P > 0.13$) and was in average 167.5 g CH_4/d or 212.6 g CH_4/kg ADG. Results indicate no effect of intensification achieved through N fertilization on individual enteric methane emission. São Paulo Research Foundation (FAPESP) (grant ≠ 2017/18750-7; 2018/26492-0).

Keywords: ammonium nitrate, continuous stocking, nitrogen, pasture, sulfur hexafluoride

(1)Research funded by São Paulo Research Foundation (FAPESP) (grant ≠ 2017/18750- 7; 2018/26492-0).

Methane emissions in response to supplementation in beef-cattle fed a tropical grass-based in Colombian Caribbean[1]

Lorena Mestra[2], Andrea Sierra[3], Claudia Ariza[4], Olga Mayorga[5]

[2]MSc Animal Sciences. Corporación Colombiana de Investigación Agropecuaria-Agrosavia. CI Turipana
[3]Animal Sciences. Corporación Colombiana de Investigación Agropecuaria-Agrosavia. CI Tibaitata
[4]Animal Sciences, PhD. Corporación Colombiana de Investigación Agropecuaria-Agrosavia
[5]Chemist, MSc.PhD Corporación Colombiana de Investigación Agropecuaria-Agrosavia. CI Tibaitata.

In Colombian Caribbean, livestock base-diet is tropical-pastures. Finding the best strategy for feeding supplements is important to enhance the animal performance. The objective of this study was to evaluate the effects of energetic-protein supplementation (ENS) on growth, bodyweight (BW) and enteric methane emission of beef cattle grazing pastures. Twenty Brahaman steers (474±34,05 kg) were distributed in four paddocks of six hectares each under a continuous stocking grazing system and assigned to a completely randomized design with four treatments: T1: grazing on *Cynodon nlemfluensis (CN)*, T2: grazing on *Brachiaria hybrid (BH)*; T3: CN+ENS and T4: BH+ENS. T3 and T4 received 1.3 $kg.day^{-1}.animal^{-1}$ of supplement during two hundred seventy seven days. The methane was measured and collected in the last month before slaughter during three days at 6, 12 and 18 Hours using the laser methane detector (LMD). Daily weight gain (DWG), dry matter intake (DMI), emission factor (EF), grams of CH_4 per kilograms of BW (CH4BW), grams of CH_4 per kilograms of dry matter intake (CH_4DMI), and net energy loss as CH4 (YM), were evaluated. Statistical analysis was carried out using GLIMMIX-SAS. A significant effect by treatment diet ($P< 0.05$) was observed on performance animal (DMI, DWG) and methane emissions (CH4gd, CH4DMI, CH4LWG, and YM); obtained the best response with BH+ENS, increased above-average DMI 11.37%; and DWG by 3.05%. CH_4DMI decreased by 49.1% and CH4BW by 44.8%, representing lower energy losses by 57.2% with YM = 5.01%. ENS animals improves beef production and reduces methane emissions compared to traditional grazing system.

Keywords: Beef cattle, greenhouses gases, supply, grazing

[1]Project from internal agenda, supported by Agrosavia.

Methane emissions related to meat production by cattle grazing on pastures based in *megathyrsus maximus*[1]

Olga Mayorga[2], Lorena Mestra[3], Andrea Sierra[4], Erika Duran[5], Diana Parra[6], Claudia Ariza-Nieto[7] and Sergio Mejia[8]

[2]Chemist, MSc.PhD Corporación Colombiana de Investigación Agropecuaria-Agrosavia. CI Tibaitata, Colombia
[3]Animal Sciences. Corporación Colombiana de Investigación Agropecuaria-Agrosavia. CI Turipana, Colombia
[4]Animal Sciences. Corporación Colombiana de Investigación Agropecuaria-Agrosavia. CI Tibaitata, Colombia
[5]Chemist, MSc. Corporación Colombiana de Investigación Agropecuaria-Agrosavia. CI Tibaitata, Colombia
[6]Animal Sciences, Corporación Colombiana de Investigación Agropecuaria- Agrosavia. CI Tibaitata, Colombia
[7]Animal Sciences, PhD. Corporación Colombiana de Investigación Agropecuaria-Agrosavia. CI Tibaitata, Colombia
[8]Animal Sciences, PhD. Corporación Colombiana de Investigación Agropecuaria-Agrosavia. CI Tibaitata

Agrosavia has developed a meat production system based on Romosinuano creole cattle crosses and grazing on improved pastures of Megathyrsus maximus, located in Sinú Valley, Colombia. The aim of this study was evaluating the enteric methane emissions related to this meat production system. Fourteen F1 Romo x Brahman (450.5 ± 37.18 Kg), were grazing on two Megathyrsus maximus pastures (Mombasa and Sabanera) under a rotational system with three occupation days and 28 resting days. Three methane (CH4) sampling during a 10-day period were taken in the last month before slaughter, measurements were collected 4 times during the day (5am, 9am, 1pm, 5pm), using the laser methane detector (LMD). Daily weight gain (DWG), dry matter intake (DMI), grams of methane per day (CH4gd), grams of CH4 per kilograms of live weight (CH4LW), grams of CH4 per kilograms of live weight gain (CH4 LWG), grams of CH4 per kilograms of dry matter intake (CH4DMI), and net energy loss as CH4 (YM), were evaluated. Data were analysed by random design using the mixed procedure of SAS. The results showed that F1 animals grazing on both pastures were similar in DMI (8,8 Kg/d) and DWG (0,71 Kg). However, the animals, grazing on Sabanera reduced ($p<0.0009$) CH4LW by 4.98% and YM by 4.36% and consequently representing a methane emission reduction of 7.9% in this meat production system. These results confirm that grazing on improved pastures are essential to ecosystem functioning, contribute to lead to reductions in GHG emissions and drive to sustainable meat production.

Keywords: Sustainable, Green houses gases, Guinea, Romosinuano x Brahman.

[1]Project from internal agenda, supported by Agrosavia.

Nitrous oxide and methane emissions from dung patches in tropical conditions

S.G. Durango Morales[1], J. Arango[2], R. Barahona Rosales[1], D. M. Bolivar[1] and N. Chirinda[2]

[1]Genetic and Molecular Biodiversity - BIOGEM Research Group, Agricultural Sciences Faculty, Department of Animal Production, Universidad Nacional de Colombia, Street 59 A

63-20 (+57 4) 4309000 Medellín-Colombia

[2]Tropical Forages and Agroecosystem and Sustainable Landscapes (ASL) research area. International Center for Tropical Agriculture (CIAT). Km 17 Palmira- Colombia

In Colombia, cattle production is commonly based on monoculture pastures and farms with low productivity indicators, including nutrients use inefficiency. Poor nutritional balances generate loss of nutrients that are excreted in manure, contributing to emissions of greenhouse gases (GHG). This study aimed at evaluating methane (CH_4) and nitrous oxide (N_2O) emitted by dung collected from cows that grazed two types of diet (*Brachiaria humidicola* and *B. humidicola + Arachis pintoi)*. Dung patches were simulated in plots located in each grazing system. Soil GHG emissions from control (water added) and dung patches were monitored over a 43-day period through the static chamber technique. Milk production by cattle in the two pastures was quantified. The abundance of ammonia-oxidizing bacteria (AOB) and ammonia oxidizing archaea (AOA) was estimated in soil samples collected before grazing. The potential nitrification was estimated through a soil incubation experiment. The results showed that the associated *B. humidicola + A. pintoi* pasture generated less cumulative CH_4 and N_2O fluxes from dung patches and better milk productivity compared to the *B. humidicola* pasture. Therefore, the monoculture presented higher emission factors for N_2O and CH_4 (0,09% EF-CH_4^+; 0.008% EF-N_2O) than the legume-grass pasture (0.004% EF-CH_4; 0.003% EF-N_2O). There was no difference between the nitrification rate in both grazing systems and the abundance of AOA and AOB was low for the compared systems. Our findings suggest that the association of *B. humidicola* with *A. pintoi*, constitutes a mitigation strategy for greenhouse gases from deposited dung patches in soil.

Keyword: Legume, Nitrification rate, Emission Factor, dung patches, milk production

Pearl-millet grazing decreases daily methane emissions in dairy cows receiving total mixed ration

Maurício Civiero[1,2], Luís Henrique Schaitz[1] and Henrique Mendonça Nunes Ribeiro-Filho[3]

[1]PhD Student at the University of Santa Catarina State – UDESC, Lages, SC, Brazil.
[2]Professor at the University of Vale do Iguaçu, União da Vitória – UNIGUAÇU, PR, Brasil.
[3]Professor at theUniversity of Santa Catarina State – UDESC, Lages, SC, Brazil.

Tropical pastures for dairy cows receiving total mixed ration (TMR) deserves further studies. This work aimed to evaluate the enteric methane emission from dairy cows receiving TMR exclusively (control), 75%TMR + pearl- millet (*Pennisetun glaucum* cv. Campeiro) pasture (TMR75) or 50%TMR + pearl-millet pasture (TMR50). Nine Holstein and F1 Jersey × Holstein multiparous cows averaging 136±40 days in milk and 520±41 kg body weight were distributed in a Latin square 3×3. The methane emission was measured using the SF6 and herbage intake by N-alkanes technique. Cows in TMR75 and TMR50 treatments strip grazed pearl-millet pastures between morning and afternoon milking (7 h/day). The crude protein and NDF content of TMR were 149 and 340 g/kg DM, respectively; for the pearl-millet pasture were 200 and 646 g/kg DM. The total DM intake was 19.4 kg/day in dairy cows receiving TMR exclusively and decreased linearly ($P < 0.01$) to 18.4 and 18.2 in the TMR75 and TMR50 treatments, respectively. The daily methane emission decreased linearly ($P < 0.01$) from 543 g/day (control treatment) to 495 and 451 g/day on TMR75 and TMR50, while the daily methane yield and methane intensity were similar between treatments, averaging 26.5 g/kg DM intake and 21.9 g/kg milk. The energy losses as methane in relation to the energy intake did not differ between treatments, averaging 7.91%. Dairy cows grazing pearl-millet pasture and receiving up to 50% of TMR *"ad libitum"* did not change daily methane yield and intensity, but decreased daily methane emissions.

Terms for indexing: *Pennisetun glaucum*, *Bos taurus*, dairy cows, grazing, methane emission, methane intensity and tropical pasture.

Performance and methane emissions of lambs in two feeding systems in summer and winter pastures[(1)]

Alda Lúcia Gomes Monteiro[2], Amanda Moser Coelho da Fonseca Faro[3], Mylena Taborda Piquera Peres[4], Rafael Batista[4], Alexandre Berndt[5], Ana Claudia Ruggieri[6] and Leonardo Deiss[7]

[1]Part of thesis (2nd author) and dissertation (3th[2]Agron., PhD, Professor, Universidade Federal do Paraná, Curitiba, PR, Brazil

[3]Vet., PhD, Professor, Instituto Federal Catarinense, Camboriú, SC, Brazil

[4]Animal Sci. Graduate Course, Universidade Federal do Paraná, PR, Brazil

[5]Agron., PhD, Researcher, Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Brazil

[6]Agron., PhD, Professor, Universidade Estadual Paulista (UNESP), Jaboticabal, SP, Brazil

[7]Agron., PhD, Pos Doct., Ohio State University, USA

The Brazilian sheep farming system is pasture-based, with different feeding and weaning strategies for lambs. We hypothesized that different feeding systems, commonly used in South of Brazil, can promote different animal performance and affect the methane emissions per kg of liveweight gain (LWG). We evaluated the lamb methane emissions in summer (2014) and winter (2016) pastures. The experimental design was a randomized complete block with two feeding systems and four replicates: (S1) lambs weaned at 60 days of age and supplemented with concentrate (2% LW.day-1) until slaughter at 40 kg LW; (S2) no weaned and no supplemented lambs until slaughter at 40 kg LW. 24 White Dorper x Suffolk lambs were studied for each feeding system in both years. The forage species were *Cynodon* spp (38.5%). and *Paspalum* spp. (28.5%) (summer); *L. multiflorum* Lam. (53%) and *A. strigosa* (21.5%) (winter). The CH_4 was collected by SF_6 tracer technique. Analysis of variance was performed by a GLM procedure. Weaned and supplemented lambs produced more methane (P=0.048) in summer (S1 - 288±74.8 x S2 - 106.3±17.1 g.kg LWG^{-1}) with no difference (P=0.73) in winter (S1 - 90.1 ±15.7 x S2 - 78.1±14.2 g.kg LWG^{-1}). In summer, live weight gain was 133 g/d for S1 and 45 g/d for S2 lambs (P=0,016) where as in winter, LWG were 195 and 140 g/d (P=0,04), respectively for S1 and S2 lambs. We concluded that methane emission can be modified by the feeding system, closely related to liveweight gain, in summer and winter pastures.

Keywords: Greenhouse gases, *Ovis aries*, production systems, sheep

Plant extracts reduced enteric methane emission with increased growth performance and nutrient digestibility in Merino sheep(1)

Abiodun Mayowa Akanmu[1] and Abubeker Hassen[2]*

[1]Animal Science, PhD, Research Associate, Department of Animal and Wildlife Sciences, University of Pretoria, Private bag X20, Hatfield 0028, Pretoria. South Africa

[2]Ruminant Nutrition and Pasture Science, PhD, Associate Professor, Department of Animal and Wildlife Sciences, University of Pretoria, Private bag X20, Hatfield 0028, Pretoria. South Africa

*Corresponding author: Abubeker Hassen, Department of Animal and Wildlife Sciences, University of Pretoria, Private bag X20, Hatfield 0028, Pretoria. South Africa E-mail: abubeker.hassen@up.ac.za

Plant extracts (PE) have the tendency to reduce methane emission from ruminants and are effective against pathogenic bacteria, disease and methanogens which impede growth and animal performance. This study tested the effectiveness of Moringa oleifera (MO), Jatropha curcas (JA) and Aloe vera (AV) PE on feed digestibility, methane emission, and growth performance of South African Mutton Merino sheep. Forty 15-week old Merino lambs were ranked according to their body weight and blocked into 4 treatment groups. Methanolic PE of MO, JA and AV were prepared and reconstituted by adding 96 g of each to 120L distilled water to produce plant extract solutions (PES). Lambs were housed and fed total mixed ration (42% roughage, 17% Soybean, 28% maize) and PES administered twice a day using drench gun at the recommended application rate of 50 mg/kg DM feed while the control group received distilled water. Methane emission was measured using open circuit respiratory chamber. Oral drenching of MO, JA and AV PES increased ($P<0.05$) dry matter and crude protein digestibility of lamb when compared with the control. MO, JA and AV PES reduced ($P<0.05$) methane emission from lambs by 21, 35 and 28%, respectively. Average daily weight gain of lambs on MO and JA PES were higher by 15.2 and 5 % respectively compared to the control. Application of 50 mg MO and JA PES/kg DM feed did not affect negatively rumen fermentation parameters and hence can be used as an alternative additive to reduce methane emission and improving animal performance.

Keywords: Nutrient digestibility, Moringa oleifera, Jatropha curcas, Aloe vera

Potential anti-methanogenic effects of barley based finishing rations compared to maize using prediction pathway analysis

Paul E Smith[1], Ciara A Carberry[2], Alan K Kelly[3], Natasha Ferguson[4], Aidan P Moloney[5], Sinéad M Waters[6] and David A Kenny[7]

[1]B.Agr.Sc, PhD Research Student, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

[2]PhD, Research Technologist, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation

Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

[3]PhD, Lecturer in Animal Science, UCD, School of Agriculture and Food Science, University College Dublin Belfield, Dublin 4, Ireland

[4]B.Agr.Sc, PhD Research Student, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

[5]PhD, Principal Research Officer, Teagasc, Animal & Grassland Research and Innovation Centre, Grange, Dunsany, Co.Meath, Ireland

[6]PhD, Principal Research Officer, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

[7]PhD, Principal Research Officer, Teagasc, Animal and Bioscience Research Department, Animal and Grassland Research and Innovation

Centre, Teagasc, Grange, Dunsany, County Meath, Ireland

Holstein Friesian bulls (n=120), blocked on the basis of age and liveweight, were offered one of four diets in a 2 (cereal type) x 2 (level of supplementary fat) factorial designed study. Cattle were offered either a (i) barley or (ii) maize based (70% of DM) dominant concentrate ration which was, in turn, supplemented with a partially rumen inert palmitate based at either zero (-SF) or 5%(+SF) of DM. Diets were offered on an ad libitum basis from 10 to 16 months of age at which time the animals were slaughtered. Feed intake was recorded for 70 days towards the end of the experimental period. Rumen fluid samples were collected from 15 animals across all four treatments, via stomach intubation, at the start and end of the feed intake recording period. Rumen microbial DNA was extracted with 16S rRNA amplicon libraries generated and sequenced on the Illumina MiSeq. Sequence analysis was carried out using DADA2 with predicted functional pathway analysis conducted using CowPI. A significant reduction in in the abundance of archaea was observed in samples obtained from barley-SF compared to the maize-SF fed bulls (adj P <0.05). Treatment had a significant impact on pathways predicted to be associated with methane, with a higher methanogenic potential predicted in maize+SF compared to barley-SF fed bulls (adj P<0.05). In addition, regardless of SF, samples obtained from barley fed bulls had a reduced predicted methanogenic potential. This analysis suggests a greater potential methanogenic inhibitory capacity for barley compared to maize dominant finishing rations.

Index terms: bos taurus, beef production, rumen microbiome

Potential of *Brachiaria humidicola* and dicyandiamide for reducing nitrous oxide emissions from cattle urine patches in the subtropical climate of Brazil

Priscila L. Simon[1], Jeferson Dieckow[2], Cecile A. M. de Klein[3], Josileia A. Zanatta[4], Bruna Ramalho[5] and Ricardo H. Ribeiro[6]*

[1]Soil Science, PhD. Post-doctoral Scientist, AgResearch Invermay - New Zealand
[2]Soil Science, PhD. Professor, Federal University of Parana - Brazil
[3]Applied Ecology, PhD. Principal Scientist, AgResearch Invermay - New Zealand
[4]Soil Science, PhD. Scientist, Brazilian Agricultural Research Corporation – Brazil
[5]Soil Science, Ms. PhD student, Federal University of Parana - Brazil
[6]Soil Science, Ms. PhD student, Federal University of Parana - Brazil
*Contact e-mail: priscila.simon@agresearch.co.nz

Nitrous oxide (N_2O) emissions from pasture-based livestock systems contribute about 34% of Brazil´s agricultural greenhouse gas emissions. A field and a greenhouse experiment were conducted to (i) evaluate the potential of *Brachiaria humidicola*, a forage species known for its ability to inhibit soil nitrification, to reduce N_2O emissions from urine patches, and (ii) determine the efficacy of the synthetic nitrification inhibitor dicyandiamide (DCD) to decrease N_2O emissions. The field experiment was carried out in a split-plot experimental design, with forage species (*Brachiaria* and Guinea grass) as main plot treatments and cattle urine and DCD treatments (No urine, Urine and Urine+DCD) as subplots. Over the 67-day measurement period, N_2O emissions were 20% lower from urine patches in the *Brachiaria* treatment compared to guinea grass ($P < 0.10$). The results of the greenhouse experiment, using pots with either *Brachiaria* or guinea grass plants that received the same treatments as in the field experiment, suggested that this could have been due to lower soil nitrate (NO_3^-) concentrations and intensities under *Brachiaria* forage than in guinea grass. This indicates that biological nitrification inhibition (BNI) could be a possible mechanism for lower N_2O emissions from *Brachiaria*. The DCD application was effective in both forage species, decreasing N_2O emissions by 40-50% ($P < 0.10$) compared with the urine only treatment. Overall, the results demonstrated that *Brachiaria* and DCD use are strategies that can reduce N_2O emissions from urine patches.

Keywords: BNI, Forage species, Livestock, Ammonium, Nitrate

Potential of selected forages for reducing nitrous oxide emissions from New Zealand dairy systems

Ronaldo E. Vibart[1] and Cecile de Klein[2]*

[1]AgResearch, Grasslands Research Centre, Private Bag 11008, Palmerston North 4442, New Zealand.
[2]AgResearch, Invermay Agricultural Centre, Private Bag 50034, Mosgiel 9053, New Zealand.
*Corresponding author: ronaldo.vibart@agresearch.co.nz

To examine the use of selected forages to reduce the impact of nitrous oxide (N_2O) emissions from New Zealand dairy farms, an integrated modelling assessment was conducted for the Waikato, Canterbury and Southland regions of New Zealand using the farm-scale models FARMAX® and OVERSEER®. Mid-intensification dairy farms were modelled, and six scenarios were examined; a Baseline scenario, two diverse pasture options (20 and 50% of the farm area; DP20 and DP50), two fodder beet options (10 and 20% of the farm area; FB10 and FB20) and a combined option (DP20+FB10). In addition to perennial ryegrass / white clover, diverse pastures also contained an extra grass and legume specie, and two forbs. Within each region, all scenarios were assumed to have similar pasture yields. The modelling assessment suggested that including diverse pastures and/or fodder beet in the diet of dairy cows could reduce total and paddock N_2O emissions by up to 16 and 21%, respectively. However, the full N_2O mitigation benefits from the inclusion of forbs in pastures and fodder beet were not assessed, since differential and seasonal plant N uptake, niche complementarity and root architecture remain to be fully captured by the modelling.

Keywords: Fodder beet (Beta vulgaris), prairie grass (Bromus willdenowii), chicory (Cichorium intybus), plantain (Plantago lanceolata), lucerne (Medicago sativa), red clover (Trifolium pratense).

Promising Nutritional Strategies to Reduce Enteric Methane Emission from Ruminants – a Meta- Analysis[1]

Claudia Arndt[1], Alexander N. Hristov[2], Shelby C. McClelland[3], Ermias Kebreab[4], Joonpyo Oh[5], André Bannink[6], Ali R. Bayat[7], Les A. Crompton[8], Jan Dijkstra[9], Maguy A. Eugène[10], Michael Kreuzer[11], Mark McGee[12], Cécile Martin[13], C. J. Newbold[14], William J. Price[15], Christopher K. Reynolds[16], Angela Schwarm[17], Kevin J. Shingfield[18], Jolien B. Veneman[19], David R. Yáñez-Ruiz[20], Zhongtang Yu[21]

[1]Dairy Science, PhD, postdoctoral fellow, Programa de Agricultura, Ganadería y Agroforestería, Centro Agronómico Tropical de Investigación y Enseñanza, Turrialba, Cartago, 30501, Costa Rica

[2]Animal Science, PhD, professor, Department of Animal Science, The Pennsylvania State University, University Park, PA 16802, USA

[3]Ecology, PhD student, Colorado State University, Fort Collins, CO 80523

[4] Integrative Biology, PhD, Professor, Department of Animal Science, University of California, Davis, CA 95616, USA

[5]Animal Science, PhD, ruminant research and development manager, Cargill Korea, Seoul, South Korea

[6]Animal Science, PhD, Senior Scientist, Wageningen Livestock Research, Wageningen University and Research, Wageningen, The Netherlands

[7]Animal Science, PhD, Senior Researcher, Natural Resources Institute Finland, Finland

[8]Animal Science, PhD, Senior Researcher, School of Agriculture, Policy and Development, University of Reading, Earley Gate, Reading RG6 6AR, UK

[9]Animal Science, PhD, Associate Professor, Animal Nutrition Group, Wageningen University & Research, Wageningen, The Netherlands

[10]Animal science, PhD, Senior Scientist, INRA UMR1213 Herbivores, F-63122 Saint-Genès-Champanelle, France

[11]Animal Nutrition, Dr, Professor, ETH Zurich, Institute of Agricultural Sciences, 8092 Zürich, Switzerland

[12]Animal Science PhD, Principal Researcher, Teagasc, AGRIC, Grange, Ireland

[13]Animal science, PhD, Senior Scientist, INRA UMR1213 Herbivores, F-63122 Saint-Genès-Champanelle, France

[14]Dairy Science, PhD, Academic director, Professor, SRUC, Edinburgh EH9 3JG, United Kingdom

[15]Statistics, PhD, Director, Statistical Programs, College of Agricultural and Life Sciences, Moscow, Idaho 83844, USA

[16]Animal Science, PhD, Professor, School of Agriculture, Policy and Development, University of Reading, Earley Gate, Reading RG6 6AR, UK

[17]Animal Science, Dr, Associate Professor, Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences, Postboks 5003, 1432 Aas, Norway

[18]Animal Science, Dr., Natural Resources Institute Finland, FI-31600 Jokioinen, Finland

[19]Animal Science, PhD, Researcher Ruminant Nutrition, Cargill Animal Nutrition, Velddriel, 5334 LD, The Netherlands

[20]Animal Nutrition, PhD, Senior Researcher, Estación Experimental del Zaidin, CSIC, 18008, Granada, Spain;
[21]Microbiology, PhD, Professor, Department of Animal Sciences, The Ohio State University, Columbus, OH 43210, USA.

The present meta-analysis examined the effects of mitigation strategies on absolute methane emission (g/d) and yield [g methane/kg dry matter intake (DMI)], DMI (kg/d), average daily gain (ADG; kg), milk production (kg/d), and neutral detergent fiber digestibility (%). Only studies that reported measures of variance were included in the analysis [295 studies (66% cattle, 31% small ruminants, 3% other ruminants), 644 mean comparisons (treatment vs. control), and 4,087 observations]. A standard random-effects meta-analysis weighted by inverse variance was carried out. Mitigation effects based on the standardized mean difference (SMD; mean difference divided by standard deviation) were classified as small (-0.5< SMD ≤-0.2), medium (-0.8< SMD ≤-0.5), and large (SMD ≤- 0.8). Compared to control, inclusion of chemical inhibitors, alternative electron sinks, and lipids had large statistically significant effects (all $P < 0.001$) on both absolute methane emission (SMD ± SE = -2.1 ± 0.5, -1.6 ± 0.2, and -1.3 ± 0.2, respectively) and yield (SMD ± SE = -1.8 ± 0.3, -1.2 ± 0.2, and -1.0 ± 0.1, respectively). The inclusion of chemical inhibitors did not impact animal productivity

(milk production and ADG; $P > 0.15$), whereas electron sinks and lipids led to small decreases in DMI (SMD ± SE = -0.2 ± 0.1, and -0.4 ± 0.1, respectively; $P \leq 0.01$) without affecting animal productivity ($P > 0.05$). Although these nutritional strategies effectively reduced methane emission without compromising animal productivity, their practical implementation will depend on proven long-term effects, economic feasibility, regulatory mechanisms, and consumer acceptance.

Terms for indexing: Cattle, sheep, goat, mitigation, CH_4

[1]This study is part of the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI)'s "GLOBAL NETWORK" project and the "Feeding and Nutrition Network" (http://anialscience.psu.edu/fnn) of the Livestock Research Group within the Global Research Alliance for Agricultural Greenhouse Gases (www.globalresearchalliance.org).

Replacing urea with nitrate increase growth and reduce enteric methane production in sheep(1)

Festus Adeyemi Adejoro[1], Abubeker Hassen[2], Abiodun Mayowa Akanmu[3] and Diego P. Morgavi[4]*

[1]Animal Production Management, PhD, Postdoctoral fellow, Department of Animal and Wildlife Sciences, University of Pretoria, Private bag X20, Hatfield 0028, Pretoria. South Africa

[2]Ruminant Nutrition and Pasture Science, PhD, Associate Professor, Department of Animal and Wildlife Sciences, University of Pretoria, Private bag X20, Hatfield 0028, Pretoria. South Africa

[3]Animal Nutrition, PhD, Research Associate, Department of Animal and Wildlife Sciences, University of Pretoria, Private bag X20, Hatfield 0028, Pretoria. South Africa

[4]Animal Nutrition, PhD, Herbivore Research Unit, Department of Animal Physiology and Livestock Systems, French National Institute for Agricultural Research, INRA Clermont- Ferrand, France

*Corresponding author: Abubeker Hassen, Department of Animal and Wildlife Sciences, University of Pretoria, Private bag X20, Hatfield 0028, Pretoria. South Africa E-mail: abubeker.hassen@up.ac.za

Use of non-protein nitrogen (NPN) is a useful strategy to increase the nutritional value of protein-deficient diets. Urea is the most common NPN source but replacing it with nitrate may offers additional benefits in methane reduction, whereas the concurrent use of NPN and tannin extract offer potential for modulating rumen nitrogen metabolism. This study investigated the effect of urea or nitrate with or without the inclusion of Acacia tannin extract on dry matter intake, digestibility, growth and methane emission of sheep. Forty Merino lambs (95 days old) were randomly allocated to four groups fed diets containing: urea; nitrate; urea + tannin; nitrate+ tannin (tannin, 42 g/kg feed). The lambs were adapted to the diets for 21 days followed by sixty days of measures; methane was measured on open-circuit respiratory chambers. Dry matter and nutrient intake were not influenced by diets with the exception of the crude protein intake, which was higher ($p<0.05$) in lambs fed urea-based diets. A higher average daily gain (13 %) and lower methane emission (16 %) were recorded for lambs fed nitrate-based diets compared to those fed urea-based diets. In contrast, the inclusion of tannin reduced the final body weight and average daily gain of the lambs. Most haematology and serum variables were not affected by NPN source or tannin inclusion. This study demonstrated that nitrate could be safely used as a source of non-protein nitrogen with the additional benefit of reducing enteric methane emission and improving the average daily gain of sheep.

Keywords: Growth performance, Methane emission, Nitrate, Non-protein nitrogen, Serum biochemistry, Tannin

Response to combination of yeast and oregano oil on feed degradability and methanogenesis[1]

Andrea Milena Sierra-Alarcón[1], Eva Ramos-Morales[2], Claudia Ariza-Nieto[3], Olga Lucia Mayorga-Mogollón[4] and Jamie Newbold[5]

[1]Animal Sciences. Corporación Colombiana de Investigación Agropecuaria-Agrosavia. CI Tibaitata, Colombia

[2] Biological Sciences PhD. Scotland's Rural College.Edinburgh, UK

[3]Animal Sciences, MSc.PhD. Corporación Colombiana de Investigación Agropecuaria- Agrosavia. CI Tibaitata

[4]Chemist, MSc.PhD Corporación Colombiana de Investigación Agropecuaria-Agrosavia. CI Tibaitata, Colombia

[5]PhD. Academic Director, Scotland's Rural College.Edinburgh, UK

In recent years, a variety of plant bioactive compounds have been evaluated as rumen manipulators. Although the potential of essential oils to increase productivity and decrease methane emissions has been shown, adverse effects on fiber digestion and fermentation have been reported. In this study was tested a novel additive based on a Colombian native strain of yeast and oregano oil (rich in thymol, 70%) for its long-term effect on feed degradability and methanogenesis. The Rumen Simulation Technique was used to study the effect of a control diet and supplemented with yeast (*Meyerozyma guilliermondii*, 10^9 nonviable cells) plus 0.25% p/p of oregano oil (*Lippia origanoides*-Kunth) at 0.5 $g.L^{-1}$. A single incubation period using 8 vessels inoculated with rumen fluid from four different cows (four replicates) was carried out. The experiment lasted for 16 days, using the first 12 days for adaptation and the last 4 for sampling. Fermentation gases were collected in gas-tight bags to measure total gas and methane production. Dry matter disappearance after 48 h incubation was calculated from the loss in weight. The residue was then analysed for organic matter (OM), nitrogen (N), Neutral- detergent (NDF) and Acid-detergent fibre (ADF) to determine nutrient disappearance. Data were analysed statistically by randomized block ANOVA, with individual cows as a blocking term. The novel additive decreased total gas (P=0.038) without affecting feed digestibility (P>0.05); a numerical decrease in methane was also observed. Our results showed the potential of the combination of yeast and oregano oil as feed additive to reduce gas emissions.

Keywords: Greenhouses gases, Yeast *Meyerozyma guillermondii, Lippia oreganoides*

[1]Project from internal agenda, supported by Agrosavia.and Newton-Caldas Institutional Links.

Rumen dissolved gases saturation and enteric gas emission unaffected by forage particle sizes in goats

Muhammed Adebayo Arowolo[1], Chao Wang[2], Min Wang[3] and Jianhua He[4]

[1]Ruminant nutrition/rumen ecology, PhD-in-view, Student, Hunan Agricultural University, Changsha, PR. China.

[2]Ruminant nutrition, Student, Institute of Subtropical Agriculture, CAS, Changsha, PR. China.

[3]Ruminant nutrition/rumen ecology, Associate Professor, Researcher, Institute of Subtropical Agriculture, CAS, Changsha, PR. China.

[4]Animal nutrition/Feed Science, Professor, Researcher/Teacher, Hunan Agricultural University, Changsha, PR. China.

This study investigated the effect of forage particle sizes on the saturation factor of rumen dissolved gases, microbial community and enteric gas emission in goats. Ten Xiangdong goats of average bodyweight of 37±5kg were randomly assigned to two treatments in a cross-over design. The animals were fed concentrate and forage with a theoretical cut length of 100 mm and 20 mm, respectively. The 100 mm forage showed a lower density (216.2vs237.3 g/L) and longer total chewing time, rumination count and bout/time ($P<0.05$) compared to the 20 mm, but the total tract nutrient digestibility was not significantly different. Although not significantly different from the 20 mm treatment, the100 mm forage reduced the saturation factor of dissolved H_2 and CH_4 in the liquid phase (8.27, 4.81 *vs* 10.18, 5.29) and the H_2 and CH_4 concentrations increased in the rumen headspace. The CH_4 emission/kg of DM digested followed the same trend as observed in the rumen headspace. The rumen pH, total VFA and their specific molar percentages were not affected by the treatments ($P>0.05$). However, the 20 mm diet significantly increased ammonia concentration in the rumen liquids (+10.27%), the copy numbers of fungi (+2.67%), *Selenomonas ruminantium* (+1.44%), *Ruminococcus amylophilus* (+1.57%) and *Ruminococcus flavefaciens* (+4.36%). In conclusion, the two treatments stimulated the animals' rumen physiological functions in almost the same manner despite the vast difference in the diets' particle size. Nevertheless, from the evolution trend of dissolved gases in the present study, smaller particle sizes might significantly reduce the rate of enteric methane emission per time.

Index Terms: dissolved methane, hydrogen, feed physical structure, reticulo-ruminal contractions, effective factor.

Rumen fermentation and microbial changes in grazing heifers treated with 3- nitrooxypropanol under tropical conditions(1)

Gonzalo Martinez-Fernandez[1], Maik Kindermann[2], Nicola Walker[3], Stephane Duval[4], Nathan Bird[5], Stuart E. Denman[6] and Christopher S. McSweeney[7]

[1]PhD, Postdoctoral scientist, CSIRO, Agriculture & Food, 306 Carmody Road, St Lucia, QLD 4067, Australia

[2]PhD, Innovation Project Manager, DSM Nutritional Products, Wurmisweg 576, 4303 Kaiseraugst, Switzerland

[3]PhD, Senior Scientist, DSM Nutritional Products, Wurmisweg 576, 4303 Kaiseraugst , Switzerland

[4]PhD, Centre Head, Research Centre for Animal Nutrition and Health, DSM Nutritional Products, BP 170, F- 68305 Saint-Louis Cedex, France

[5]PhD, Regional Director Asia, Mohua Consulting Pte Ltd Australia

[6]PhD, Senior Research Scientist, CSIRO, Agriculture & Food, 306 Carmody Road, St Lucia, QLD 4067, Australia

[7]PhD, Chief Research Scientist, CSIRO, Agriculture & Food, 306 Carmody Road, St Lucia, QLD 4067, Australia

The aim of this trial was to study the effect of the methane inhibiting compound, 3-Nitrooxypropanol (3-NOP), an investigational product, on rumen metabolites and microbial community in cattle grazing tropical forage. Approximately 2 months prior to calving forty pregnant heifers were allocated to two groups and maintained in replicate paddocks at Lansdown Research Station (Australia). Each group received a treatment for 6 months: 3- NOP (2.5 g / animal/ day (DSM Nutritional Products, Switzerland; application form contains 10% 3-NOP mixed with silicon dioxide and propyleneglycol) or as a placebo control silicon dioxide/ propyleneglycol (50/50) (23 g placebo / animal/ day). The treatments were first mixed with steam flaked barley (88.8%) and molasses (7.4%) and offered daily at 8:00 and 14:00 h (675 g/head) to the respective groups. Rumen fluid samples were collected by stomach intubation at 3 h post feeding the morning treatment at 1.5, 4 and 6 months to determine the effect on rumen fermentation parameters and rumen microbial communities. No significant differences were observed on live weight between 3-NOP and control groups. Overall, increases in rumen formate, ammonia and all VFAs concentrations (except acetate) were observed in 3-NOP supplemented animals. Significant differences ($P < 0.05$) in rumen bacterial composition between 3-NOP and control animals were observed with increases in Prevotella and Succiniclasticum and decreases in methanogenic species in the 3-NOP supplemented group. The response to 3-NOP feeding appears consistent with the methane inhibiting mode of action of the compound and elevated hydrogen levels observed in previous studies.

Index terms: methane inhibitor, microbiota, hydrogen sinks, volatile fatty acids.

Small ruminants' methane emissions from biodiesel coproducts as alternative feed

Wilian dos Santos da Costa[1], Beatriz Elisa Bizzuti[2], Vagner Ovani da Silva[3], Adibe Luiz Abdalla[4]

[1]Universidade de Sao Paulo – CENA/USP, MSc in Science, Piracicaba-Brazil
[2]Universidade de Sao Paulo – CENA/USP, MSc student, Piracicaba-Brazil
[3]Universidade de Sao Paulo – CENA/USP, MSc student, Piracicaba-Brazil
[4]Universidade de Sao Paulo – CENA/USP, Associated Professor, Piracicaba-Brazil

Reducing edible food used in livestock and enteric CH4 emission are desirable as for food security and climate issues. The goal was to evaluate CH4 emission (CH4e) for biodiesel coproducts (BC) replacing traditional feed (TF). Sheep were fed either with Control diet (CN: corn (28%), soybean meal (12%) and Tifton hay (TH, 60%)) or Coproduct diet (CP: sunflower meal (18%), corn (16%), cottonseed meal (6%) and TH (60%)) in two 21-day metabolism trial with 3 days' gas-collect chambers assay. Gases were sampled, CH4 (%) was quantified using gas chromatography and outgoing air flow rate determined for measuring CH4e. Organic matter intake (OMI) and dry matter (DMI) intake were determined. ANOVA and Tukey test were performed. No differences ($P < 0,05$) were observed for CH4e (CN = 15,7; CP = 17,0 L/day) as well CH4/DMI (CN = 11,8; CP = 14,0 L/kg) and CH4/OMI (CN = 15,3; CP = 19,4 L/kg). Replacing TF by BC at the proportion evaluated reduced CH4e per non edible food intake by 15% in metabolism trial. It is expected similar production efficiency, once there were no statistical differences on nutrients digestibilities.

Index terms: Ruminant sustainability, non-edible food, sheep.

Soil Carbon Content of Canadian Native Grassland Improved by Grazing Management and Higher Species Diversity

Alan D. Iwaasa[1], Brain G. McConkey[1] and Elijah Atuku[1]

[1]Agriculture and Agri-Food Canada – Swift Current Research and Development Centre, Ph.D., Research Scientist, #1 Airport Road, Swift Current , Saskatchewan S9H 3X2, Canada (alan.iwaasa@Canada.ca)

Study objective was to determine the effect of grazing management and native mixtures on soil carbon content (SOC) of a re-established native Canadian grassland. Native mixtures were seeded in 2001 on 16 paddocks of 2.1 ha that had cropland history of wheat and fallow. Study (2000-2017) was completely randomized (rep = 2) with Simple (7 species) and Diverse (12 species) native mixes and continuous (CG) and deferred- rotational grazing (DRG) systems. Paddock contained a ungrazed enclosure and were grazed (50% utilization) by steers (344 ± 17 kg)from 2001-2017. The CG and DRG stocking rates were 0.7 and 1.8 AU ha^{-1}, respectively. Plant biomass, litter and dung were measured. Bulk density and SOC measurements occurred at three or five micro-sites per paddock at four depths (0-15, 15-30, 30-45 and 45-60 cm). For 2000 to 2015, most of the SOC change was in the upper 30 cm. Additional SOC between 30-45 cm and 45-60 cm was most pronounced in 2017. By 2017, most of the SOC change was below 30 cm. Average C sequestration rates from 2000 to 2017 were 0.24 and 0.34 Mg C ha-1 yr-1 to 45- and 60-cm, respectively. Ungrazed treatment gained more SOC from 2000 than the grazed, with effect more pronounced the diverse mix. Grazed had 0.3 to 0.8 Mg C ha-1 more above ground C in form of plant biomass, litter and dung. The SOC at depths below 30 cm are important to account for in native grasslands and more long term research is needed.

Keywords: Soil organic carbon, Native grasslands, Grazing systems, Biodiversity

Starch resulted in greater recovery of metabolic hydrogen than cellulose in methanogenesis inhibited rumen batch cultures(1)

Emilio M. Ungerfeld[1] and M. Fernanda Aedo[2]

[1]MSc, PhD, Scientist, Instituto de Investigaciones Agropecuarias INIA, Temuco, Chile

[2]BSc, Research Technician and Laboratory Manager, Instituto de Investigaciones Agropecuarias INIA, Temuco, Chile

The objective of this 2 × 2 × 2 factorial arrangement experiment was to understand the effects of inhibiting methanogenesis in rumen batch cultures growing with different sources of energy (cellulose or starch) and nitrogen (ammonium or trypticase) on fermentation and microbial synthesis of protein and amino acids. 9, 10-anthraquinone was chosen as a model inhibitor based on previous results suggesting the greatest disruption of electron relocation among various methanogenesis inhibitors. Cultures were incubated for 96 (cellulose) or 72 (starch) h. 9, 10- anthraquinone decreased total gas production with cellulose but increased it with starch, and decreased methane production and increased dihydrogen accumulation with both substrates. 9, 10- anthraquinone increased final pH and acetate molar percentage with cellulose and decreased them with starch. With both substrates, 9, 10-anthraquinone decreased Eh and propionate molar percentage, and increased butyrate molar percentage. Apparent digestibility and total VFA concentration were decreased by 9, 10-anthraquinone with cellulose only. Total microbial amino acids-N was not affected by 9, 10-anthraquinone with either substrate. With both substrates, 9, 10- anthraquinone increased the percentages of glutamate and alanine in total amino acids and decreased tyrosine and phenylalanine. 9, 10-anthraquinone increased the percentages of serine and glycine in total amino acids with cellulose but not with starch, increased valine with starch only, and decreased leucine and isoleucine with cellulose only. The decline in the recovery of metabolic hydrogen with methanogenesis inhibition was lesser with starch than with cellulose and was not affected by amino acids biosynthesis.

Index terms: rumen, methane, fermentation, electron balance

(1)Supported by Comisión Nacional de Investigación Científica y Tecnológica (CONICYT), Chile, Fondo Nacional de Desarrollo Científico y Tecnológico (FONDECYT), Grants N°1160764 and 1190574.

Sulphur hexafluoride (SF_6) tracer gas methodology modifications for highlands conditions[1]

Juan Vargas[2], Edgar Mancipe[3], Andrea Sierra[4], Erika Duran[5], Yesid Avellanda[6], Nicolás DiLorenzo[7] and Olga Mayorga[8]

[2]Zoot, MSc. Corporación Colombiana de Investigación Agropecuaria-Agrosavia. Mosquera, Colombia.
[3]Zoot. Corporación Colombiana de Investigación Agropecuaria-Agrosavia. Mosquera, Colombia
[4]Zoot. Corporación Colombiana de Investigación Agropecuaria-Agrosavia Mosquera, Colombia
[5]Quim, MSc. Corporación Colombiana de Investigación Agropecuaria-Agrosavia. Mosquera, Colombia
[6]Zoot, MSc. Corporación Colombiana de Investigación Agropecuaria-Agrosavia. Mosquera, Colombia
[7]Ing. Agron, PhD. Associated Professor. University of Florida. Marianna, Florida
[8]Quim, PhD. Corporación Colombiana de Investigación Agropecuaria-Agrosavia. Mosquera, Colombia

SF_6 as artificial tracer have been used to determine enteric methane emissions in ruminants, however, there is few technical information to set up the methodology under highland conditions. This study aimed to evaluated permeation rates of SF_6 tubes and capillary flow passage in Colombian highlands conditions. Two types of experiments were conducted to adjust the methodology. The first experiment examined the permeation rate from15 permeation tubes saturated up to 2.2±0.1 g SF_6, incubated at 39°C during 6 weeks and weighted weekly in Mariana (USA) at 51 *MASL*. After that, these tubes were relocated at 2547 MASL in Mosquera (Colombia), incubated at 39°C over 12 weeks and weighted weekly. The data set was compared between places by one-way design. The second experiment took place on Mosquera to determinate the final pressure inside the yokes by different capillary restrictions (0.3 to 1.2 sccm). A regression analysis was used to define the adequate restriction. For the first experiment, the SF_6 permeation rate was lesser ($p<0,05$) in Mariana respect Mosquera (1.49 y 2.03 $mg.d^{-1}$ respectively). In the second one, the restriction in the capillary increased ($p<0,05$) the vacuum inside the yoke, obtaining the regression equation $Y = 7.75x – 15.74$ R^2: 0.8, where x = capillary restriction. In highlands conditions, capillary flow of 0.48 sccm allowed to saturate up to 33% of total volume of yoke. The results suggested that is necessary to calibrate permeation tubes and capillary restriction according to environmental conditions to improve the estimate methane enteric emissions from ruminants.

Keywords: Enteric emission, greenhouse gases, methane production

[1]Proyecto FTG/RF-14653-RG, supported by Fontagro and Agrosavia.

Supplementation of steers with polyclonal antibody preparations against methanogenic Archaea decreases methane production ex situ

Mariana E. Garcia-Ascolani[1], Martin Ruiz-Moreno[1], Gleise M. Silva[1], Tessa M. Schulmeister[1], Federico Podversich[1], Federico Tarnonsky[1], Sergio Roskopf[2], Timothy J. Hackman[3], José Carlos Batista Dubeux Jr.[1], Nicolas DiLorenzo[1]

[1]University of Florida

[2]Universidad Nacional del Litoral

[3]University of California Davis

An experiment was conducted to evaluate the effect of supplementing fourteen ruminally cannulated Angus crossbred steers with different levels of polyclonal antibody preparations (PAP) from avian origin against the methanogenic archaea *Methanobrevibacter gottschalkii* Ho (Ho) and Methanobrevibacter ruminantium M1 (M1). The experiment was a randomized block design with a 3 × 2 + 1 factorial arrangement replicated in two periods. Factors were proportion of PAP against M1 and Ho in the mixture (100:0, 50:50, and 0:100 M1:Ho) and level of supplementation of each mixture (3 or 6 mL hd-1 d-1). Steers were fed bermudagrass hay ad libitum and 2 kg hd-1 d-1 of corn gluten feed (CGF). Steers were adapted to PAP treatments for 14 days prior to the start of the experiment. Ruminal fluid from each steer (experimental unit) was collected and mixed individually with McDougal buffer (1:3 ratio) to inoculate serum bottles and polycarbonate tubes each containing 0.7 g of the same diet. Serum bottles and tubes were incubated for 48 h at 39°C for determination of methane production, fermentation profile, and in vitro organic matter digestibility. There was no effect of PAP supplementation level ($P > 0.10$) on CH4 production variables. Incubations containing PAP with 100:0 M1:0 decreased ($P \leq 0.03$) total CH4 production (mmol) and CH4 production (mmol) per gram of OM fermented when compared with control. Incubations with 100:0 M1:Ho decreased ($P = 0.02$) methane production when compared with 0:100 M1:Ho, while 50:50 M1:Ho were intermediate and did not differ from the other two proportions.

Index terms: Methanobrevibacter gottschalkii Ho, Methanobrevibacter ruminantium M1, Angus crossbred steers, ex situ incubations, passive immunization.

Supplementing beef cattle diets with hydrolyzable tannins impacts manure emissions of ammonia and carbon dioxide

Christine L. Rosser[1], Isaac A. Aboagye[2], Karen M. Koenig[3], and Karen A. Beauchemin[4]

[1]B.Sc. Agriculture, University of Saskatchewan; M.Sc. Animal Science, University of Saskatchewan; Ph.D. Animal Science, University of Alberta. Research Biologist. Agriculture and Agri-Food Canada, Lethbridge Research and Development Centre, Lethbridge, AB, Canada T1J 4B1

[2]B.Sc. Agriculture, University of Ghana; M.Sc. Environmental Science, Thompson Rivers University; Ph.D. Animal Science, University of Alberta. Research Affiliate. Agriculture and Agri-Food Canada, Lethbridge Research and Development Centre, Lethbridge, AB, Canada T1J 4B1

[3]B.Sc. Agriculture, University of British Columbia; M.Sc. Animal Science, University of British Columbia; Ph.D. Animal Science, University of Saskatchewan. Research Scientist. Agriculture and Agri- Food Canada, Lethbridge Research and Development Centre, Lethbridge, AB, Canada T1J 4B1

[4]B.Sc. Agriculture, McGill University; M.Sc. Animal Science, Université Laval; Ph.D. Animal Science, University of Guelph. Research Scientist. Agriculture and Agri-Food Canada, Lethbridge Research and Development Centre, Lethbridge, AB, Canada T1J 4B1

This study examined the effects of feeding hydrolyzable tannins (**HT**) to beef cattle on ammonia and greenhouse gas emissions from manure. Eight beef heifers (480 ± 29.2 kg) were used in a replicated 4 × 4 Latin square experiment that had four 28-d periods, with 7-d washout between periods. The heifers were fed a forage-based diet (19.7% crude protein), that was supplemented with the following treatments; control (no HT; **CON**), chestnut extract (**CHE**; 2% of diet dry matter [**DM**]), tannic acid (**TAN**; 1.5% of diet DM), and gallic acid (**GAL**; 1.5% of diet DM). Total tract digestibility of crude protein was greater for CON and GAL (average 69.0%) compared to CHE and TAN (average 62.4%; $P \leq 0.001$). Samples of feces and urine were mixed according to excreted proportions to reconstitute 2.0 kg of manure (as-is basis). The manure was incubated in steady-state flux chambers for 96 hours to determine the effect of feed treatment on gas emissions from manure. After incubation, manure DM was greatest for CHE and TAN (16.2 and 16.8%, respectively), intermediate for GAL (15.5%), and least for CON (14.6%; $P = 0.030$). While there was no effect of treatment on methane or nitrous oxide manure emissions ($P \geq 0.35$), both CHE and TAN had greater ammonia and carbon dioxide emissions compared to CON and GAL ($P \leq 0.018$). Dietary supplementation with GAL resulted in greater total tract digestibility of crude protein, and reduced manure emissions of ammonia and carbon dioxide compared to the other tannin treatments.

Keywords: chestnut extract, forage diet, gallic acid, greenhouse gas emissions, tannic acid

Use of a novel nitrogen fertilizer to reduce nitrous oxide and ammonia emissions from pastures

Marta Alfaro, researcher, Ph.D.[1], Sara Hube research assistant, BSc[1], María de Bernardi Ph.D.c[2], Francisco Salazar, researcher, Ph.D.[1], Marion Rodríguez, research assistant, MSc.1, Luis Ramírez, research assistant, Tec.1 and Jaime Mejías, researcher, Ph. D.[3]

[1]Instituto de Investigaciones Agropecuarias, Centro de Investigación Remehue, Casilla 24-O, Osorno, Chile.
[2]Instituto de Física Arroyo Seco (IFAS-CIFICEN), Universidad Nacional del Centro de la Provincia de Buenos Aires.
[3]Instituto de Investigaciones Agropecuarias, Centro de Investigación Carillanca, Casilla 58-D, Temuco, Chile.

Nutrients losses to the atmosphere could be a limitation for livestock production worldwide. Novel forms of fertilizers are proposed to increase dry matter production and reduce nitrogen (N) gaseous emissions (e.g. NH_3 and N_2O) in grassland systems. Thus, the objective of this study was to evaluate foliar N fertilization using a nanomaterial. For this, intact soil cores from a permanent pasture were collected in PVC lysimeters (0-15 cm) and transported to a controlled experiment (20°C) in laboratory. Three treatment were tested: a nanoformulation of Hidroxiapatite-urea (HA-urea), dissolved urea in water ($urea_d$, 1:10) and the traditional granular ($urea_g$), at an equivalent rate of 25 kg N ha^{-1}. A control treatment was also included (0 kg N ha^{-1}). Cumulative emissions of N_2O and NH_3 (kg N ha^{-1}) were measured using static and dynamic chambers, for 58 and 21 days respectively. The experiment was set up on a complete randomized design with four replicates and results were analyzed by ANOVA. The results showed that the use of a nanoformulation decreased N_2O emissions by 41% and 45% compared to granular and dissolved urea ($p<0.05$), respectively. However, for NH_3 emissions, N losses were higher for the two liquid formulations (HA-urea and $urea_d$) compared to $urea_g$ ($p<0.05$) given the presence of urease in plant leaves. Therefore, the use of HA-urea could reduce N_2O emission, but further studies are required to understand its effect on NH_3 losses as well as on pasture yield and quality, including the testing of N- nanoformulations at different chemical forms and rates.

Index terms: Nanomaterial: material sized between 1-100 nanometers; Nanoformulation: synthesized enhanced material between the range of 1-100 nanometers. Pasture: land used for grazing; Nitrous oxide (N_2O): greenhouse gas present in atmosphere due to soil ecosystem.

Acknowledgements to Fondecyt project 1180775

Use of Mootral™, a garlic and citrus based feed additive, to reduce enteric methane production in feedlot cattle

Breanna M. Roque[1], Henk J van Lingen[1], Hilde Vrancken[2], and Ermias Kebreab[1]

[1]Department of Animal Science, University of California, Davis, Davis, CA 95616
[2]Mootral GmbH, Waldseeweg 6, 13467 Berlin, Germany

Enteric methane production is the main source of greenhouse gas emissions from livestock globally, with ruminants particularly beef cattle contributing the most. Studies conducted *in vitro* have shown reduced methane production when using garlic and citrus extracts. However, limited research has been done investigating garlic and citrus extracts *in vivo*. The objective of this study was to quantitatively evaluate the response of Angus-Hereford cross steers consuming the feed additive Mootral™ on methane production. Twenty steers (419 ± 16 kg BW) were randomly assigned to two treatments: control (no additive) and Mootral™ applied at 15 g/d in a completely randomized block design with 3 week sampling intervals and 12 week data collection periods. Enteric methane emissions were measured using the GreenFeed system during the covariate period and experimental weeks 2, 6, 9, and 12. Methane yield (g/kg DMI) remained similar in both treatments for weeks 2 to 9. However, in week 12 there was a significant decrease in methane yield (23.2%) in treatment compared to control steers, this might be due to an increase in pellet consumption which contained the Mootral™ additive. Overall methane production during the entire experimental period was not significantly different. Carbon dioxide yield (g/kg DMI) was not significantly different between treatments. Dry matter intake, average daily gain and feed conversion efficiency also remained similar in control and supplemented steers. The *in vivo* results showed that Mootral™ has a potential to reduce enteric methane yield in beef cattle.

Index Terms: bos taurus, enteric methane, feedlot cattle, environmental sustainability, greenhouse gas

Variations in Methane Emissions from Chinese Holstein Dairy Cows Offered Diets with Different Forage Concentrations

Lifeng Dong[1], Bei Wang[1] and Qiyu Diao[1]

[1]Feed Research Institute, Chinese Academy of Agricultural Sciences. Beijing, China

This study was to investigate effects of dietary forage (maize silage and alfalfa hay) to concentrate proportions on enteric methane emissions from Chinese Holstein cows at different stages of lactation. Three different groups of 18 cows were selected from a commercial farm, and each group was offered 3 diets (6 cows/diet) of low, medium and high concentrate proportions (DM basis) during the early (44%, 53% and 59%), middle (46%, 53%, and 61%) and late (30%, 37% and 42%) lactation (average milk yield = 25.7, 20.2, and 17.9 kg/d, respectively). Each period consisted of 20 days for adaptation and 5 days for methane measurements using the sulphur hexafluoride technique. Methane emissions reduced linearly ($P < 0.01$) with increasing dietary concentrate proportions during the early (392 vs. 347 vs. 325 g/d), middle (400 vs. 331 vs. 261 g/d) and late (396 vs. 329 vs. 242 g/d) lactation. A similar reduction in methane energy output as a proportion of gross energy intake ($P < 0.01$) was also observed during the early (8.3% vs. 5.9% vs. 4.9%), middle (10.6% vs. 7.6% vs. 5.2%) and late (8.3% vs. 6.5% vs. 4.9%) lactation. The present data provide benchmark information for development of methane emission inventories for dairy production systems in China.

Keywords: Chinese Holstein cow, concentrate proportion, lactation stage, methane emission, sulphur hexafluoride technique

2.1 Adaptation (Oral)

Teff diet with or without direct fed microbial and mixed enzymes affects the nutrient digestibility and methanogenesis

Rebin Omar[1], Yosra Soltan[2], Mohamed Abdalla[3], Sobhy Sallam[4]

[1]MSc, Assistant lecturer, Koya University, Faculty of Science and Health, Department of Biology, Koya, Iraqi Kurdistan, Iraq

[2]PhD, Associate Professor, Animal and Fish Production Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt

[3]PhD, Full Professor, Animal and Fish Production Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt

[4]PhD, Full Professor, Animal and Fish Production Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt

Abstract/ Teff (*E. tef*) is grown to produce gluten-free grains, this leads to production of sustainable abundance amounts of teff straw which is mostly neglected. Direct fed microbial and fibrolytic enzymes (DFM) can be used to upgrade the quality of teff straw and mitigate ruminal methanogenesis. Twelve Barki lambs were randomly allotted into three dietary treatments as: control (per kg DM, 500 g clover berseem hay (*T. alexandrinum)* and 500 concentrate), teff diet (the control diet proportionately replaced by 25 % of clover hay with teff straw), and DEM teff diet (0.5 DFM g /kg DM of teff diet). The tested DFM mainly contained *Saccharomyces cerevisiae*, species of *Bacillus* and *Propionibacteria*, cellulase, xylanase and phytase. The treatments were lasted for 21 days, while the last 7 days were assigned for the nutrient digestibility and nitrogen balance trial. Teff diet had higher neutral detergent fiber and lower crude protein than the control. The teff diet exhibited a reduction ($P<0.05$) in the total volatile fatty acids concentrations and the digestibility of fibre fractions, while exhibited the highest ($P<0.05$) methane production among the experimental diets. Similar nutrients digestibility, urine N excretions, and ruminal fermentation characteristics were found for DFM teff and the control diets except for ruminal pH. These results suggested that teff straw treated with DFM can replace partially the most traditional forage of ruminants in many developing countries.

Keywords: *Eragrostis tef*, yeast, *Bacillus* species, fibrolytic enzymes, fiber digestibility, methane emission

2.1 Adaptation (Poster)

Blood Methaemoglobin in two sheep breeds during the process of adaptation to encapsulated nitrate supplementation[(1)]

Andressa Santanna Natel[2], Rafael Canonenco de Araujo[3], Paola Cristina de Piza[2], Pedro Ivo Sodré Amaral[2], Rafael Cedric Möller Meneghini[4] and Adibe Luiz Abdalla[5]

[1]Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP, Brazil, 2012/02592-0)

[2]University José do Rosário Vellano, Postgraduate program in Animal Science, Alfenas, Minas Gerais, Brazil. E-mail: andressa.natel@unifenas.br

[3]GRASP Ind. & Com. LTDA, Division of Research and Development, Curitiba, Paraná, Brazil.

[4]Federal Institute of Education, Science and Technology of São Paulo, Campus Avaré, Avaré, São Paulo, Brazil.

[5]University of São Paulo, Centre for Nuclear Energy in Agriculture, Laboratory of Animal Nutrition, Piracicaba, Sao Paulo, Brazil.

Sixteen ewe lambs (mean BW 32.7±3.86 kg) were used in a randomized complete block design with 2×4 factorial arrangement, two breeds (Santa Inês and Ile de France) and four levels encapsulated nitrate product (ENP) addition (0, 1.0, 2.0, and 3.0% DM), to evaluate adaptation to dietary ENP based on levels of blood methaemoglobin (MetHb). The ENP was increased by 1% every 4d from 0 to 1.0, 2.0, and 3.0% of dietary DM (12.2% CP and 0, 0.71, 1.4 and 2.14% $NO3^-$ dietary DM). The MetHb (measured on day after ENP addition) and dry matter intake (DMI, measured on 3th and 4th day) were evaluated at 0, 4, and 8 h after feeding. There was an interaction (P<0.01) between breed and ENP for MetHb measured 0 h before feeding when diet change from 2% to 3% ENP. The MetHb increased linearly (y=0.5619+1.0512*ENP, r^2=0.44) as ENP was increased from 2% to 3% ENP, whilst Santa Inês showed greater mean MetHb (15.12%) compared to Ile de France (3.9%). There was an interaction (P=0.047) between breed and ENP for DMI at 8 h after feeding when level ENP increased to 0, 1, 2 and 3%, Ile de France showed a decrease in DMI (0.93, 0.91, 0.80 and 0.69 kg, respectively) when compared to Santa Inês (1.17, 0.99, 1.27, 1.26 kg, respectively). Ile de France breed was more sensitive to ENP supplementation than Santa Inês, showing a reduction in DMI according to ENP inclusion. Santa Inês showed greater ENP intake, which as associated to greater increase in blood MetHb.

Keywords: Methemoglobinemia, Nitrate poisoning, Slow-release.

Ruminal fermentation and *methane* mitigation of salt tolerant Mediterranean shrubs in relation to their phenolics[(1)]

Yosra Soltan[1], Hani El-Zaiat[2], Amr Morsy[3], Nesrein Hashem[4], Kheir El-Din El- Azrak[5], Marwa Attia[6], Eman Elwakeel[7], Osama Matloup[8] and Sobhy Sallam[9]

[1]PhD, Associate Professor, Animal and Fish Production Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt

[2]PhD, Assistant professor, Animal and Fish Production Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt

[3]PhD, Associate Professor, City of Scientific Research and Technological Applications, Arid Lands Cultivation Research Institute, Livestock Research Department, Alexandria, Egypt

[4]PhD, Associate Professor, Animal and Fish Production Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt

[5]PhD, Associate Professor, Animal and Fish Production Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt

[6]PhD, *Laboratory Assistant*, Animal and Fish Production Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt

[7]PhD, Assistant Professor, Animal and Fish Production Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt

[8]PhD, Associate professor, Dairy Science Department, National Research Centre, Giza, Egypt

[9]PhD, Full Professor, Animal and Fish Production Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt

Using salt tolerant polyphenol containing shrubs (STFS) may cover the feed limitation during drought in the Mediterranean. Chemical and phenolic composition of acacia *(A. saligna),* atriplex *(A. halimus),* leucaena *(L. leucocephala*) and moringa (*M. oleifera*) leaves were evaluated using the *in vitro* semi-automatic system for gas production. All comparisons were made using berseem clover hay (*T. alexandrinum*). The highest protein concentration was observed for leucaena compared to the other plants. Acacia had the highest total phenolics, while berseem had the lowest values among the experimental plants. Moringa and leucaena were similar in total phenolics, while they were different in their individuals. The most abundant phenolics found in moringa were rutin and caffic, while in leucaena were pyrogallol and hisperdin. The major compounds of acacia were rutin and gallic, while pyrogallol existed in abundance in atriplex. Quretin only existed in berseem. All STFS decreased methane ($P<0.01$) compared to control. Among the STFS, moringa and atriplex had the highest ($P<0.05$) values of nutrient degradability and total volatile fatty acids, while acacia resulted in the lowest ($P<0.05$) values. Atriplex and leucaena had the lowest ($P<0.01$) ammonia concentration and acacia reduced ($P<0.05$) the protozoal count. These results indicated that STFS can substitute the traditional forages and reduce ruminal methane emission through different mechanisms.

Keywords: alternative forages, bioactive components, nutrient degradability, methanogenesis

[(1)]This study was partially funded by the Egyptian Science and Technology Development Fund (STDF), project ID no.18575 & STDF-DDP

Session 3

Regional low carbon initiatives, Landscape, regional management and Nationatal Commitments

3.1 Regional level (Oral)

Carbon neutralization potential of beef cattle system in cerrado biome of maranhao, Brazil

Antonio Carlos Reis de Freitas[1], Falberni de Souza Costa[2], Eliane Gonçalves Gomes[3], Geraldo da Silva e Souza[4], Marcos Antônio Souza dos Santos[5], Ana Laura dos Santos Sena[6], Paulo Campos Christo Fernandes[7], Jesus Fernando Mansila Bacca[8], Dirceu Klepker[9]

[1]Graduated in Agronomy, DSc in Sustainable Development, Researcher, Embrapa Cocais
[2]Graduated in Agronomy, DSc in Soil Science, Researcher, Embrapa Acre
[3]Graduated in Chemical Engineering, DSc in Operations Research, Researcher, Embrapa/SIRE
[4]Graduated in Economics and Mathematics, PhD in Statistics, Researcher, Embrapa/SIRE
[5]Graduated in Agronomy, DSc in Animal Science, Researcher, UFRA
[6]Graduated in Economy, DSc in Sustainable Development, Researcher, Embrapa Amazônia Oriental
[7]Graduated in Veterinary Medicine, DSc in Animal Science, Researcher, Embrapa Cerrados
[8]Graduated in Cartography, DSc in Geography, Researcher, Embrapa Solos
[9]Graduated in Agronomy, DSc in Agronomy, Researcher, Embrapa Cocais

This paper evaluated the municipal performance of beef cattle production systems in 2006 and 2017, in relation to the enteric methane emissions in CO2 equivalent. The 109 municipalities evaluated belong to the Cerrado biome of the Maranhao state,Brazil. In this period the cattle population increased 20% and reached 3.3 million head; the pasture area remained at 2.6 million hectares. The total enteric methane emission, computed by the Agriculture and Land Use National Greenhouse Gas Inventory Software (ALU), was 3,867 Gg of CO2eq in 2006 and 4,654 Gg of CO2eq in 2017. The municipalities with higher cattle numbers were classified as “Regions of net CO2 sink”. The performance score was calculated considering the pasture and forest area, herd size, enteric methane emissions and the stock of biomass. These scores were computed as a data envelopment analysis (DEA) measure for each year, under the variable return scale (VRS) hypothesis and output orientation. There is a statistically significant difference between years, with higher performance in 2017 (p-value 0.0193). We estimated the probability of a municipality being sink of CO2 (p) considering the DEA-VRS score, the agricultural financing via ABC Program, the livestock financing and the agricultural GDP. The analysis, considering the two periods showed that there is a positive and significant effect of time, with higher p in 2017. It also showed that only the livestock financing has a positive and significant effect in p. These results show that the introduction of biomass stock technologies was beneficial to the performance of these municipalities.

Keywords: Carbon sink, Carbon Source, GEE, Grassland Management, Livestock, Pasture Degradation

Soil carbon in New Zealand hill country under contrasting phosphorus fertiliser and sheep stocking regimes[1]

Alec D. Mackay[2], Ronaldo E. Vibart[2], Des Costall[2], Catherine McKenzie[2] and Frank M. Kelliher[3]*

[1]Funding from the Sustainable Land Management and Climate Change fund of the Ministry for Primary Industries and AgResearch Strategic Science Investment Fund.

[2]AgResearch, Grasslands Research Centre, Private Bag 11008, Palmerston North 4442, New Zealand.

[3]AgResearch, Lincoln Research Centre, 1365 Springs Road, Lincoln 7674, New Zealand.

*Corresponding author: ronaldo.vibart@agresearch.co.nz

We examined soil carbon (C) stocks at the Ballantrae Hill Country Research Station, in southern Hawke's Bay. Soils were sampled to three depths in 2003 (0-75, 75-150, 150-300 mm) and to the two upper depths in 2014, in three farmlets under different annual phosphorus (P) fertiliser and stocked with sheep to maintain similar grazing pressure (i.e., stock units per unit pasture production) across farmlets since 1975. Farmlets: LFNF = no P applied since 1980, LFLF = 125 kg single superphosphate (SSP) ha^{-1}, and HFHF = 375 kg SSP ha^{-1} since 1980. Corresponding annual mean stocking rates were 6.0, 10.6, and 16.1 stock units ha^{-1}. Soil C stocks in 2003 increased from 30.9 to 32.5 and 35.1 Mg C ha^{-1} on the LFNF, LFLF and HFHF farmlets, but remained relatively unaffected at greater depths in 2003 and both depths in 2014. Adding these findings to earlier measures from the same farmlets provides a time series (1972-2014) that supports the view that soil C stocks are relatively stable under permanent pastures managed under the current conditions. In contrast, slope and aspect affected soil C stocks, evidenced by slope × farmlet and aspect × farmlet interactions (P<0.001). Data from this long-term study provide science, policy and industry with invaluable insights into the changes in soil C stocks in pastoral hill-country soils.

Keywords: Soil carbon stocks, pastures, phosphorus fertiliser, sheep grazing, long-term grazing experiment.

3.1Regional level (Poster)

Carbon capture potential of different silvopastoral arrangements under stable stocking rate in the northern Coast of Colombia

Luis Giraldo[1], James Betancur[2] y Ana Pérez[3]

[1]Zoot. PhD. Profesor Asociado Universidad Nacional de Colombia sede Medellín
[2]Zoot. cPhD Estudiante de posgrado Universidad Nacional de Colombia sede Medellín
[3]DMV-PhD.

Carbon capture under silvopastoral systems with grazing cattle depends on the combinations of tree, pasture and shrub species. Evaluate carbon capture potential of 4 silvopastoral arrangements (SA), compared to traditional pasture (without trees), under stable stocking rate of 3,5UA/Ha (UA=Animal unit; 1UA=360kg live weight) and a paddock rotation system, in the Montes de Maria region located in the Northern Coast of Colombia. Treatments were: T0= Megathyrsus maximus (without trees): T1= Eucalyptus tereticornis (ET) + Brachiaria híbrido cv Mulato II (BhM) + Cajanus cajan (CC) - CIAT-18701; T2= ET + BhM + CC-CIAT-913; T3= ET + Brachiaria brizantha cv Toledo (BbT) + CC-CIAT-18701; T4= ET + BbT + CC- CIAT-913. For all SA trees were planted in stripes (6m) with 3 lines of trees each (2mx2m/tree), and 30m wide pasture stripes inbetween tree stripes, with 441 trees/Ha resulting density, and trees were 3.5 years old at first measurement. All treatments were managed under 6 paddocks (7 days occupation and 42 days rest) during 12 full cycles of paddock rotation. Full random block design was used with 6 Animals per treatment. Significant differences ($P<0.05$) in Carbon Stock (CS) were found for groups T1 + T2 vs. T3 + T4 vs. T0 (T1= 82,47**a**; T2= 83,25**a**; T3= 75,58**b**; T4= 76,27**b**; T0= 70,28**c** TCO2/Ha). Pasture CS was higher ($P<0.05$) for T0 vs. T1 + T2 vs. T3 + T4 (T0= 16,74**a**; T1= 16,25**b**; T2=16,19**b**; T3=12,94**c**; T4=12,90**c** TCO2/Ha). Tree CS(aerial+radicular portions) was higher ($P<0.05$) for T1 and T2, and similar ($P>0.05$) for T3 and T4 (T1= 94,13**a**; T2= 97,48**a**; T3= 82,56**b**; T4= 84,36**b** TCO2/Ha). Overall CS(including soil carbon until 80cm) was significantly higher ($P<0.05$) for T1 + T2 vs. T3 + T4 vs. T0, which had the lowest carbon stock of all treatments (T1= 192,85**a**; T2= 196,92**a**; T3= 171,08**b**; T4= 173,84**b**; T0= 87,02**c** TCO2/Ha). Use of silvopastoral systems significatly improved the CS capture capacity (TCO2/Ha) in the region of Montes de Maria, Northern Coast of Colombia, with SA using BhM, showing the highest carbon immobilization capacity.

Keywords: Carbon immobilization, Trees+pasture, *Eucalyptus tereticornis*, *Megathyrsus maximus*, *Brachiaria* híbrido cv Mulato II, *Brachiaria brizantha* cv Toledo, *Cajanus cajan*

Climate Ready Riverina - Adapting agriculture to reduce the impacts of climate change

Natalie Doran-Browne[1], Jessica Hill[2] and Richard Eckard[1]

[1]Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, Parkville VIC 3010, Australia. n.doran-browne@unimelb.edu.au

[2]Riverina Local Land Services, New South Wales Government, Griffith NSW 2680, Australia

The Riverina is a productive agricultural region in south-eastern Australia around 57,000 km^2 in size and the major land use (78%) is agriculture. Grazing occupies over half of the agricultural land, with approximately 560,000 cattle and 5.5 million sheep in the region in 2017. The Riverina has extensive floodplains, tablelands, rangelands and irrigation districts with a variable long-term annual rainfall of around 240-620 mm. Recent studies have shown that the Riverina will be severely affected by climate change. Increased temperatures, variations in seasonal rainfall and changes to available irrigation water are expected to impact on livestock production and current land use. Broadacre and rangeland farm systems in particular will be highly impacted due to their dependence on dryland pastures. Livestock farmers have several options to negate the effects of climate change, including the use of best management practices, Climate Smart agriculture, greenhouse gas mitigation methods and climate adaptation options. Climate change has created an urgency to initiate discussions with farmers on preparing their farms to be climate-ready. This study provides a simple framework for farm advisors to identify and communicate relevant, industry-specific climate adaptation messages to livestock farmers. Livestock producers in the Riverina require management changes if current levels of productivity and profitability are to be maintained in the shorter-term. The framework considers the current farm practices and presents a hierarchy of adaptation priorities for livestock producers in the region, including building soil organic matter, proactively managing heat stress in animals and pastures, and developing animal and plant genetic adaptations.

Enteric methane emissions in small-scale dairy systems: Five case scenarios

Maria Danaee Celis-Alvarez[1], Felipe López-Gonzalez[1], Carlos Manuel Arriaga-Jordán[1], Lizbeth E Robles-Jimenez[2] and Manuel Gonzalez-Ronquillo[2]

[1]Instituto de Ciencias Agropecuarias y Rurales (ICAR), Universidad Autónoma del Estado de México (UAEM), Instituto Literario #100, C.P. 50000 Toluca, Estado de México, Mexico

[2]Facultad de Medicina Veterinaria y Zootecnica. Universidad Autónoma del Estado de México (UAEM), Instituto Literario #100, C.P. 50000 Toluca, Estado de México, Mexico

The production of greenhouse gases by ruminants is influenced by factors such as diet composition, intake and digestibility, so that five scenarios (E) were evaluated using different supplements (E1: Without supplementation as a control diet, E2: 4.5 kgDM / cow /day of commercial concentrate (19% CP), E3: 200 gDM / kg of milk produced, commercial concentrate, E4: Corn grain and wet distillers grains and E5: E4 plus corn silage), using two pasture managements (cut vs grazing), and two varieties of legumes (Red clover vs. white clover). Six dairy cows per scenario in small scale systems, with average milk yield 13.9 kg / day in the second third of lactation, were used to estimate methane (CH_4) and carbon dioxide (CO_2) emissions per kg of milk FCM 3.5% using the equations proposed by the Intergovernmental Panel on Climate Change Tier 2. A completely randomized design with in a 5x2x2 a factorial arrangement (scenarios x pasture managements x legumes), with six replications (cows) was carried out for the evaluation of the supplementation strategies. Differences were found ($P < 0.001$) in the scenarios and the pasture management with respect to the emissions of enteric fermentation, L CH_4 /day, g CH_4 /day and g CH_4 / kilogram of milk produced. E2 had the highest methane emission, 27.2 kg CH_4/kg milk yield, and E3 and E4 produce the lower CH_4/kg milk yield (22.6±0.2). As a conclusion E3 and E4 reduce the environmental impact being more efficient in terms of methane / kg milk produced in small- scale dairy systems.

Keywords: IPCC, supplementation, grazing, milk, cow

Insect Activity Affects N_2O Emissions from Cattle Dung on Pastures

Xiying Hao[1], Jessica Stoeckli[2], Courtney Soden[1], Ben W. Thomas[2], Jennifer Owens[1], Newton Lupwayi[1], and Kevin Floate[1]*

[1]Lethbridge Research and Development Centre, Agriculture and Agri-Food Canada, Lethbridge, AB, Canada
[2]Agassiz Research and Development Centre, Agriculture and Agri-Food Canada, Agassiz, BC, Canada
*Presenting author: xiying.hao@Canada.ca

Past studies have shown ivermectin reduces insect activity in dung pats. Using chambers, we monitored dung pats for two years (June 2016-June 2018) to assess the effects of insect activity (without vs. with mesh covers to deter insects), and the addition or exclusion of ivermectin, on N_2O emissions from a semiarid native pasture. A bare surface soil was also included as a control resulting in a 2×3 factorial design with four replications. In both years, N_2O emissions were higher from dung pats than bare soil. In Year 1, cumulative annual N_2O emissions were affected by the presence/absence of dung, insect activity and their interaction; N_2O emissions from dung decreased with insect activity and, in the absence of insect activity, N_2O emissions were lower from dung without ivermectin. This equated to between 0.07 and 0.28% of the original N in the dung lost as N_2O (emission factor = EF), but EFs were only affected by insect activity (0.09 with vs. 0.26% without insect activity). In Year 2, the presence of dung increased N_2O emissions, while the other factors were not significant due to large variability between replications. The EF ranged from 0.24 to 0.85%, and did not differ between dung treatment or presence/absence of insect activities. Insect activity in dung may to be important for mitigating N_2O emissions on semiarid native pastures, but the conditions under which this mitigation occurs requires further study.

Keywords: greenhouse gas, dry mixedgrass prairies eco-region, native pasture, cattle grazing, nitrous oxide emission factor.

Methane and nitrous oxide emissions from grazing steers' dung with or without supplement in Argentina

Banira Lombardi[1], Patricia Inés Alvarado[2], Patricia Ricci[3], María Paula Juliarena[4] and Horacio Leandro Gonda[5]

[1]Bach. Environ. Tech., PhD student, Physics and Engineering Research Centre, National University of the Centre of the Buenos Aires Province – CICPBA – CONICET, Tandil, Argentina

[2]Vet., MSc., Department of Animal Production, National University of the Centre of the Buenos Aires Province, Tandil, Argentina

[3]Agr. Eng., PhD, Department of Animal Production, National Institute of Agricultural Technology, Balcarce, Argentina

[4]Chem., PhD, Associate Professor, Physics and Engineering Research Centre, National University of the Centre of the Buenos Aires Province – CICPBA – CONICET, Tandil, Argentina

[5]Agr. Eng., PhD, Associate Professor, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden

Increasing the proportion of starch rich supplements in the diet of ruminants can decrease the emission of enteric methane (CH_4) and can increase its emission from manure. However, the effect of diet composition on nitrous oxide (N_2O) emission from manure is less known. The objective of this study was to quantify CH_4 and N_2O emissions, and estimate their emission factors (EF) from fresh dung collected from 20 steers grazing pasture without (P) or with daily maize grain supplementation (S; equivalent to 1% steer's body weight). Emissions were measured, over 125 days, in static chambers (5 chambers/treatment plus 2 chambers as control) placed on a plot without grazing. Fresh dung was collected once from two groups of steers and homogenized to form a composite sample for each diet. One kilo of composite sample was placed on the ground inside the chambers. As dung dry matter in P was lower, S had a major carbon and nitrogen concentration. Even so, with greater amount of carbon, S cumulative CH_4 emissions (1738 mg CH_4-C m^{-2}) were lower than P (4033 mg CH_4-C m^{-2}; $P<0.001$). Instead, S produced significantly more N_2O than P (392 and 123 mg N_2O-N m^{-2} respectively; $P<0.01$). P and S CH_4 and N_2O EF were 0.94±0.10 and 0.30±0.06 kg CH_4 $head^{-1}$ $year^{-1}$ and 0.06 and 0.13% respectively. In conclusion, dung emissions responded differently to each diet. These preliminary results suggest that current EF (1 kg CH_4 $head^{-1}$ $year^{-1}$ and 2% of N_2O-N) may overestimate dung contribution to the National Inventory.

Keywords: Greenhouse gasses, Livestock manure, Emission factors

Milk and methane production in crossbreed tropical dairy cows grazing tropical pastures supplemented with concentrate

*Lizbeth E. Robles-Jimenez[1], Arni Xochitemol[2], Mohammed Benaaouda[3], Luis Corona[2], Epigmenio Castillo[2], Octavio A. Castelan-Ortega[1] and Manuel Gonzalez-Ronquillo[*1]*

[1]Universidad Autonoma del Estado de Mexico, Facultad de Medicina Veterinaria y Zootecnia. Toluca, Mexico

[2]Universidad Nacional Autónoma de México, Facultad de Medicina Veterinaria y Zootecnia. Ciudad de México, Mexico

[3]INRA -Research Center. Clermont Ferrand. France

The objective of this study was to evaluate the effects of different concentrate supplementation levels on milk production, estimate methane (CH_4) and Nitrous oxide (N_2O) emissions in dairy cows grazing native pastures. The study included 12 crossbred F1 dairy cows (*½ Bos taurus - ½ Bos indicus*) over 60 days of lactation. Cattle grazed tropical grasses (*Paspalum spp.*, *Axonopus spp.*, *Brachiaria spp.* and *Cynodon neumfluensis*) and were supplemented with 0, 150, 300 and 450 g of concentrate per kg of milk yield, in three periods of 15 days each one in a crossover design. N_2O emissions from excreta were calculated according of IPCC, 2006. The quantity of daily CH_4 production was calculated (kg • head^{-1} • day-1). The data were analyzed with the SAS MIXED procedure and the means were subjected to a trend analysis using orthogonal polynomials. There were no differences ($P > 0.05$) for live weight and Milk yield between treatments. The supplementation with concentrate in tropical dairy cows did not increase milk yield, but increased CH_4 and N_2O ($P < 0.001$) excretion per cow. The use of concentrates in crossbreed F1 dairy cows fed with local tropical pastures affects negatively the emission of greenhouse gases, producing more CH_4 and N_2O per cow per day, however cow supplemented present a greater concentrate intake, which means more gross energy intake and higher dry matter ingested, but not showing more milk yield production.

Keywords: Greenhouse gases, Nitrous oxide, Tropical grasses, Crossbreed

Nitrogen utilization and methane emission in lactating cows fed diets with different nitrogen contents

María Paz Tieri[1], Eduardo Alberto Comerón[2], Banira Lombardi[3], Sergio Guzmán[4], María Paula Juliarena[5] and Horacio Leandro Gonda[6]

[1]Agr. Eng., PhD student, Department of Animal Production, National Institute of Agricultural Technology, Rafaela, Santa Fe, Argentina

[2]Agr. Eng., PhD, Department of Animal Production, National Institute of Agricultural Technology, Rafaela, Santa Fe, Argentina

[3]Environ. Tech. degree, Physics and Engineering Research Centre, National University of the Centre of the Buenos Aires Province-CICPBA-CONICET, Argentina

[4]Nat. Sci. lecturer, Faculty of Exact Sciences, National University of the Centre of the Buenos Aires Province, Argentina

[5]Chem., PhD, Associate Professor, Physics and Engineering Research Centre, National University of the Centre of the Buenos Aires Province-CICPBA-CONICET, Argentina

[6]Agr. Eng., PhD, Associate Professor, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden

Dietary nitrogen utilization, enteric methane emission, and milk production and composition in dairy cows fed diets with different crude protein (CP) contents were studied. Twelve Holstein multiparous cows averaging 70 days in milk, 645 kg of body weight, and 35 kg of milk yield, were randomly assigned to 1 of 3 diets, according to a replicated 3 × 3 Latin square design. Diets were composed, on dry matter basis, of 27% lucerne hay, 31% maize silage and 42% concentrate based on maize grain (MG) and soybean meal (SBM). Proportions of MG and SBM were such to result in diets with 13 (CP13), 16 (CP16) and 19% (CP19) CP content. Throughout the trial, cows were kept in individual pens. Each experimental period lasted 29 d (20 d for adaptation and 9 d of data and sample collection: 3 d for nitrogen balance, 1 d for blood sampling, and 5 d for enteric methane emission -SF6 technique-). Dry matter intake (23.8 kg/cow/d) and digestibility (74.7%) were similar among treatments. Increased CP intake resulted in an increased ($P<0.001$) milk (30.1, 32.4, 34.9 kg/cow/d) and milk protein production (0.93, 10.03, 1.13 g/cow/d), and urinary (120, 209, 318 g/cow/d) and faecal (131, 141, 157 g/cow/d) N excretion, for CP13, CP16, CP19, respectively. Daily methane emission (532 g/cow/d), intensity (16.6 g CH_4/kg milk), and Ym (6.84) were similar among treatments. Milk and milk protein yields increased with increasing N intake at expenses of a threefold excretion of N to the environment without affecting CH_4 emission.

Keywords: dairy cattle, nitrogen balance, greenhouse gasses emission

3.1 National level (Oral)

First Tier 2 enteric methane emissions national inventory for cattle in Mexico and analysis of spatially distributed emissions. A baseline for mitigation

Octavio Alonso Castelán-Ortega[1], Juan Carlos Ku-Vera[2], Juan Carlos Ángeles-Hernández[3], Gloria Stefanny Hernández-Pineda[4], Mohammed Benaouda[5], Luisa T. Molina[6], Laura Ramírez-Cancino[7], Sofía Viridiana Castelán-Jaime[8], Manuel González Ronquillo[9], María Fernanda Vázquez-Carrillo[10], Hugo Montelongo-Pérez[11], Eduardo Cardoso-Gutiérrez[12] and Daniela Villegas- Estrada[13]

[1]Veterinarian, BSc., MSc, PhD. Profesor of animal science. Faculty of Veterinary Medicine and Animal Science, Universidad Autónoma del Estado de México, Toluca, Estado de México, México

[2]Veterinarian, BSc., MSc., PhD. Professor of ruminant nutrition. Faculty of Veterinary Medicine and Animal Science Universidad Autónoma de Yucatán, Mérida, Yucatán, México

[3]Veterinarian, BSc., MSc., PhD. Research associate. Faculty of Veterinary Medicine and Animal Science, Universidad Autónoma del Estado de México, Toluca, Estado de México, México

[4]MSc. Research assistant. Faculty of Veterinary Medicine and Animal Science. Faculty of Veterinary Medicine and Animal Science, Universidad Autónoma del Estado de México, Toluca, Estado de México, México

[5]Veterinarian, BSc., MSc, PhD. Postdoctoral fellow. INRA, Clermont Ferrand, France

[6]Earth Scientists. PhD. President of the Molina Center for Energy and the Environment. La Jolla, California, United States

[7]Veterinarian, BSc., MSc., PhD. Research fellow. Faculty of Veterinary Medicine and Animal Science

Universidad Autónoma de Yucatán, Mérida, Yucatán, México

[8]Geologist, BSc. Research assistant. Faculty of Geography, Universidad Autónoma del Estado de México, Toluca, Estado de México, México

[9]Veterinarian, BSc., MSc, PhD. Professor of ruminant nutrition. Faculty of Veterinary Medicine and Animal Science, Universidad Autónoma del Estado de México, Toluca, Estado de México, México

[10]Veterinarian. BSc. MSc. PhD student. Faculty of Veterinary Medicine and Animal Science, Universidad Nacional Autónoma de México, Mexico City, México

[11, 12, 13]Research assistants. Faculty of Veterinary Medicine and Animal Science. Faculty of Veterinary Medicine and Animal Science, Universidad Autónoma del Estado de México, Toluca, Estado de México, México

The aim of the present work was to calculate the inventory of enteric methane (CH_4) emissions from cattle of the five geo-climatic regions of Mexico using the IPCC 2006 Tier 2 main method. We generated for the first time in Mexico country specific emissions factors through several experiments conducted in five open circuit respiration chambers (OCRC). Two chambers are located in the southern tropical region and three in the temperate climate region of Mexico. We then conducted a geo-spatial disaggregation of national cattle herd by dividing the country´s territory into five geo-climatic regions: dry, very dry, temperate, tropical humid and tropical sub-humid and allocating the national cattle population to each region. The population of each region was divided into seven categories: calves, young steers, young heifers, steers, heifers, cows and bulls. The cow's category was further divided into dairy, beef and dual-purpose cows because cows represent the largest enteric methane producers and there is sufficient scientific evidence that CH_4 emission differ between them. We used ArcMap ver 10.2.2 in order to spatially allocate cattle to the corresponding geo-climatic region. A national survey was conducted in order to characterize the regional cattle production systems and feeding practices. Typical diets were defined for each region and then reproduced in the OCRC in order to generate regional specific emission factors for categories and subcategories. The total CH_4 emissions from enteric fermentation of cattle in Mexico calculated using the main method of the Tier 2 approach is 2,039.21 Gg of CH_4 $year^{-1}$.

Keywords: Methane, inventory, Mexico, bovines, Tier 2.

Partnerships for dairy and beef low carbon initiatives in France

Dollé Jean Baptiste[1], Andurand Josselin[2], Brocas Catherine[2], Castellan Elisabeth[3], Geslain Thierry[4], Guinot Caroline[5], Moreau Sindy[6], Velghe Mathieu[7]

[1]Agronomist, Master and Engineer, Environment Head department, Institut de l'Elevage - French Livestock Institute, 54-56 avenue Roger Salengro - BP 80039 - 62051 St Laurent Blangy, France

[2]Agronomist, Master and Engineer, Project manager, Institut de l'Elevage - French Livestock Institute, Monvoisin - 35652 Le Rheu cedex, France

[3]Agronomist, Master and Engineer, Project manager, Institut de l'Elevage - French Livestock Institute, 54-56 avenue Roger Salengro - BP 80039 - 62051 St Laurent Blangy, France

[4]Agronomist, Master and Engineer, Scientific Director, CNIEL, 42 rue de Châteaudun, 75314 PARIS Cedex 9, France

[5]Agronomist, Master and Engineer, Environment Head department, INTERBEV, 207 rue de Bercy, 75564 PARIS CEDEX 12, France

[6]Agronomist, Master and Engineer, Project manager, Institut de l'Elevage - French Livestock Institute, Agrapole, 23 rue Jean Baldassini - 69364 LYON cedex 7, France

[7]Agronomist, Master and Engineer, Project manager, Institut de l'Elevage - French Livestock Institute, Boulevard des arcades – 87060 Limoges Cedex 2, France

A voluntary initiative supported by French dairy and meat boards aims to reduce milk and beef carbon footprint at farm level by 15 to 20% from 2015 to 2025. To achieve this goal, a partnership has been built in order to reduce GHG emissions and increase carbon sequestration in French cattle farms. To implement the farm evaluation, a national Life Cycle Assessment tool CAP'2ER® has been developed to calculate milk and beef carbon footprint as other environmental burdens (eutrophication, acidification, energy consumption) and ecosystem services (carbon sequestration, biodiversity). Named Low Carbon Dairy Farm and Beef Carbon, the programs aim at improving farming practices efficiency through herd management and animal health, forage production, soil practices and manure management, energy consumption... A multi-stakeholder collaboration is in course with cooperatives, farmers' organizations, advice companies, milk and beef enterprises… By bringing together complementary skills in environment, technical and economic analysis of production systems, it represents an opportunity to reduce carbon footprint and to increase livestock sustainability. Thanks to training sessions, farm assessments, demonstrative farm network, farm advices in mitigation actions, 12,000 farmers (12 % of French cattle farmers) are now involved in. The national and regional coordination represents an opportunity to continue the dissemination to all farmers in France. The next step in course consist in improving methods for measuring, reporting and verifying the effects of mitigation actions, in order to communicate on the progress and to create collective carbon accounting projects for selling carbon avoided on the carbon market.

Terms for indexing: cattle, carbon, partnership, farming efficiency

Pathways to a carbon neutral Australian red meat industry

Thomas M. Davison[1], Di Mayberry[2], Harriet Bartlett[3], Jonathan Moss[4], Stephen Wiedemann[5] and Mario Herrero[6]

[1]PhD, Professor, University of New England, Armidale, New South Wales, 2350, Australia
[2]PhD, Senior Research Scientist, CSIRO Agriculture and Food, St Lucia, Queensland, 4067, Australia
[3]PhD student, University of Cambridge, Departments of Zoology (Downing Street, CB23EJ), England
[4]PhD, Lecturer, University of New England, Armidale, New South Wales, 2350, Australia
[5]PhD, Principal Consultant, Integrity Ag and Environment, Toowoomba, 4350, Queensland, Australia
[6]PhD, Chief Research Scientist, CSIRO Agriculture and Food, St Lucia, Queensland, 4067, Australia

The Paris Climate Agreement of 2016-17 has seen 185 out of 197 countries ratify the Agreement. The targets will effectively require global greenhouse gas (GHG) emissions be net zero by 2050. This will require the major emitting industries to be carbon neutral by 2050. The Australian red meat industry is a large industry with a total value of $18.4 billion including $13.3 billion of export value. It is also a significant contributor to the national GHG emissions. We calculated baseline (2005) and current (2015) GHG emissions for the red meat sector (farm and processing sectors) based on the national inventory. Emissions from the Australian red meat industry have decreased from 124.1 Mt CO2e in 2005 (21% total national emissions) to 68.6 Mt CO2e in 2015 (13% of total national emissions), primarily through reductions in land clearing. This paper includes the rationale behind the feasibility of carbon neutrality at an industry level, including the likely costs and financial returns to producers and the community. The assumptions include changes in land management, adoption of new supplement technologies and new legumes to reduce enteric methane emissions from grazing livestock with clear links to established carbon market offsets. Our results show that it is possible for the Australian red meat industry to substantially reduce GHG emissions and feasibly become carbon neutral as determined by the Australian Greenhouse Gas Inventory. This will require substantial research and development investment along with policy support in carbon markets from private and government bodies.

Index terms: greenhouse gas, enteric methane, livestock, land management

3.1National level (Poster)

Carbon Agri: A monitoring reporting verification process for capturing carbon reductions in French cattle systems

Dollé Jean Baptiste[1], Gac Armelle[2], Andurand Josselin[2], Brocas Catherine[2], Foucherot Claudine[3], Geslain Thierry[4], Guinot Caroline[5], Rapin Thierry[6]

[1]Agronomist, Master and Engineer, Environment Head department, Institut de l'Elevage - French Livestock Institute, 54-56 avenue Roger Salengro - BP 80039 - 62051 St Laurent Blangy, France

[2]Agronomist, Master and Engineer, Project manager, Institut de l'Elevage - French Livestock Institute, Monvoisin - 35652 Le Rheu cedex, France

[3]Agronomist, Master and Engineer, Institute for Climate Economics, 2 Boulevard de Strasbourg, 75010 Paris, France

[4]Agronomist, Master and Engineer, Scientific Director, CNIEL, 42 rue de Châteaudun, 75314 PARIS Cedex 9, France

[5]Agronomist, Master and Engineer, Environment Head department, INTERBEV, 207 rue de Bercy, 75564 PARIS CEDEX 12, France

[6]Agronomist, Master and Engineer, Director, Commission Nationale de L'Elevage, 149 rue de Bercy, 149, rue de Bercy 75595 PARIS CEDEX 12, France

Regarding the dairy and beef low carbon initiatives launched in France to reduce carbon intensity, there is a strong interest and need to improving methods for measuring, reporting and verifying (MRV) the effect of mitigation actions. Complying with the French Low Carbon Standard published in November 2018, a MRV process named CARBON AGRI has been developed for cattle farms. This methodology covers the whole farm considering dairy, beef and crops productions. To capture emissions reductions and carbon sequestration increases, CARBON AGRI measures progress from a range of mitigation practices as herd and feed management, crops fertilization, energy consumption, inputs purchased, grassland management, planting hedges, no tillage, cover crops,… Based on the national Life Cycle Assessment tool CAP'2ER®, the methodology consist in calculating the baseline carbon intensity of products for all farms involved corresponding to a collective or individual reference. On a five year crediting period, the carbon reduction represents the carbon intensity differences between the baseline and the project, multiplied by the milk and beef productions. By this way, CARBON AGRI permits to demonstrate additionality, track progress and communicate the efforts in a transparency way after a technical expert review. In order to implement new practices or make new investments to reduce carbon intensity the certified reduction permits to contract external financial supports for farmers. In that way, French representative's farmers created the France CARBON AGRI Association as an aggregator. The aim is to helping individual farmers for taking part in collective carbon accounting projects and selling carbon avoided on the carbon market.

Terms for indexing: MRV, cattle, mitigation, carbon

Uncertainty of the Tier 2 enteric methane emissions inventory for cattle in Mexico: a Monte Carlo Approach

Octavio Alonso Castelán-Ortega[1], Juan Carlos Ku-Vera[2], Juan Carlos Ángeles-Hernández[3], Gloria Stefanny Hernández-Pineda[4], Mohammed Benaouda[5], Sofía Viridiana Castelán-Jaime[6], María Fernanda Vázquez-Carrillo[7], Hugo Montelongo-Pérez[8], Eduardo Cardoso-Gutiérrez[9]

[1]Veterinarian, BSc., MSc, PhD. Professor of animal science. Faculty of Veterinary Medicine and Animal Science, Universidad Autónoma del Estado de México, Toluca, Estado de México, México

[2]Veterinarian, BSc., MSc., PhD. Professor of ruminant nutrition. Faculty of Veterinary Medicine and Animal Science Universidad Autónoma de Yucatán, Mérida, Yucatán, México

[3]Veterinarian, BSc., MSc., PhD. Research associate. Faculty of Veterinary Medicine and Animal Science, Universidad Autónoma del Estado de México, Toluca, Estado de México, México

[4]MSc. Research assistant. Faculty of Veterinary Medicine and Animal Science. Faculty of Veterinary Medicine and Animal Science, Universidad Autónoma del Estado de México, Toluca, Estado de México, México

[5]Veterinarian, BSc., MSc, PhD. Postdoctoral fellow. INRA, Clermont Ferrand, France

[6]Geologist, BSc. Research assistant. Faculty of Geography, Universidad Autónoma del Estado de México, Toluca, Estado de México, México

[7]Veterinarian. BSc. MSc. PhD student. Faculty of Veterinary Medicine and Animal Science, Universidad Nacional Autónoma de México, Mexico City, México

[8,9]Research assistants. Faculty of Veterinary Medicine and Animal Science. Faculty of Veterinary Medicine and Animal Science, Universidad Autónoma del Estado de México, Toluca, Estado de México, México

The aims of this work are: 1) identification of the sources of uncertainty associated with the first Tier 2 enteric CH_4 emissions inventory for cattle; 2) estimation of the uncertainty of the Tier 2 method inputs using a bootstrap methodology, and 3) uncertainty propagation assessment of the input variables using Monte Carlo simulation (MCS). Uncertainty calculation comprises: calculation of the uncertainty associated to the input parameters and calculation of the uncertainty associated with the Tier 2 main method. The first was calculated by quantifying the inter-unit variability in activity and emission data. This step included choice of appropriated probability density function (PDF), estimation of its parameters and evaluation of the goodness of fit of selected PDF. We also used bootstrap simulations, means, standard deviations and 95 % confidence intervals to estimate the uncertainty of the inputs according with their PDF. For the Tier 2 method we used the uncertainty propagation approach. Mean and standard deviation of emissions and activity data were used as inputs to the Tier 2 method and MCS was carried out to propagate their uncertainty and to calculate the inventory's uncertainty. Finally, we conducted a sensitivity analysis to identify the variables that affect most the uncertainty of the inventory. Total CH_4 emission from enteric fermentation of cattle is 2,039.21 Gg CH_4 $year^{-1}$ with a level of uncertainty of -18.28 and +21.2 %. The variables that most affect uncertainty of emissions are gross energy intake, methane conversion factor, milk fat content, daily milk yield and dry matter intake.

Keywords: Methane, cattle, Mexico, uncertainty, Tier 2, Monte Carlo Simulation.

Update of methodology for calculation of enteric methane emissions from dairy cows in Norway(1)

Angela Schwarm[1], Helge Bonesmo[2], Alemayehu Kidane[3], Bente Aspeholen Åby[4], Tonje Storlien[5], Michael Kreuzer[6], Clementina Alvarez[7] and Egil Prestløkken[8]

[1]Biology, Dr, Associate Professor, Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences, Ås, Norway

[2]Agricultural Science, PhD, Developer, Felleskjøpet Fôrutvikling/Klimasmart landbruk, Norway

[3]Animal Science, PhD, Researcher, Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences, Ås, Norway

[4]Animal Science, PhD, Researcher, Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences, Ås, Norway

[5]Animal Science, PhD, Consultant, TINE, Norway

[6]Agricultural Science, Dr habil, Professor, Institute of Agricultural Sciences, ETH Zurich, Switzerland

[7]Animal Science, Master, PhD student, Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences, Ås, Norway

[8]Animal Science, PhD, Associate Professor, Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences, Ås, Norway

In Norway, circa 50% of methane emissions derive from animal husbandry, with enteric methane production in about 200.000 dairy cows as major source. The objective was to update the methodology used in the national inventory for estimation of enteric methane emissions from dairy cows in Norway. The model development dataset from 2014 (n = 42) was extended with recent data to 65 treatment means in total. Number of individuals per treatment means was considered by using the WEIGHT statement in SAS. Updated equations for methane prediction were developed, which slightly differed from extant models used in Norway. The unchanged evaluation dataset from 2014 (n = 36) was used to compare prediction ability of the updated models (n = 2), the extant models (n = 2) and recently published models (n = 5). All tested models included dry matter intake as input variable. In addition, some models included one or several of the following parameters (g/kg dry matter): total fatty acids, neutral detergent fibre, crude fat. Model selection was based on low root mean squared prediction error, high concordance correlation coefficient and residuals versus predicted values. All models slightly overestimated methane emissions at low emission level and underestimated emissions at high levels. The updated model including dry matter and contents of fatty acids and neutral detergent fibre recommended for national inventory had the second lowest root mean squared prediction error (13.9%), greatest accuracy and precision of predicting methane emissions (concordance correlation coefficient = 0.69) and the smallest linear and mean bias.

Keywords: Bos taurus, inventory, model, methane production

(1)This project is funded by Miljødirektoratet, Oslo, Norway

Session 4

International low carbon initiatives

4.1International Policies (Poster)

Accounting for and reducing agricultural greenhouse gas emissions in Fiji

Natalie Doran-Browne[1], Richard Eckard[1], Max De Antoni Migliorati[2], Rowena Maguire[3], Rebecca Colvin[4], Elaine Mitchell[2], Mark Howden[4] and Peter Grace[2]

[1]Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, Parkville VIC 3010, Australia
[2]Science and Engineering Faculty, Queensland University of Technology, Brisbane QLD 4000, Australia
[3]Faculty of Law, Queensland University of Technology, Brisbane QLD 4000, Australia
[4]College of Science, Australian National University, Canberra ACT 2600, Australia

The Paris Agreement aims to address climate change and keep global temperatures well below 2°C. At the heart of this agreement are Nationally Determined Contributions (NDCs), the voluntary commitments that countries make to reduce their greenhouse gas (GHG) emissions. Small Island Developing States contribute little to global GHG emissions but are disproportionately affected by the negative impacts of climate change. Many potential barriers exist when trying to reduce GHG emissions from developing countries due to the parallel issues of food security and the importance of maintaining livelihoods that are dependent on agriculture. This research analyses deemed emissions from the agriculture sector in Fiji and current commitments as defined by Fiji's NDC. Agriculture contributes around 40% of Fiji's GHG emissions with the majority (92%) of agricultural emissions coming from animal production as a result of enteric fermentation (51%) and manure (deposited on pastures 27%, effluent management 11%, applied to soils 3%). This project is working with the Fijian government to identify and prioritise livestock mitigation options in Fiji, based on which options have the greatest emissions reduction potential, the feasibility of various options and their associated cost. There is potential to apply the same process for analysing and prioritising livestock GHG mitigation options within other countries. The presentation will detail identified mitigation options, in the context of improving food security, consistent with agricultural policy, governance, land ownership, land tenure, legal and gender issues.

Ensiling rice straw with different additive combinations impacts on *in vitro* gas and methane production

Jialiang Ouyang[1], Shuo Zhang[2], Ruxin Qi[3] and Mengzhi Wang[4]*

[1]Postgraduate, College of Animal Science and Technology, Yangzhou University, R. P. China
[2]Undergraduate, College of Animal Science and Technology, Yangzhou University, R. P. China
[3]Postgraduate, College of Animal Science and Technology, Yangzhou University, R. P. China
[4]Corresponding author, Professor, College of Animal Science and Technology, Yangzhou University, R. P. China
*Email: mengzhiwangyz@126.com

This experiment was carried out to investigate the effects of rice straw silage with different additive combinations on *in vitro* rumen fermentation parameters, gas and methane production, and to select the most suitable additive combination for rice straw ensiling. Rice straw silage with different additive combinations (Treatment 1 was *Bacillus licheniformis*+*Aspergillus niger*+glucose, treatment 2 was *Bacillus licheniformis*+*Trichoderma viride*+bran, treatment 3 was *Bacillus licheniformis*+cellulase+starch, treatment 4 was *Lactobacillus plantarum*+*Aspergillus niger*+bran, treatment 5 was *Lactobacillus plantarum*+*Trichoderma viride*+starch, treatment 6 was *Lactobacillus plantarum*+cellulase+glucose, treatment 7 was *Enterococcus faecalis*+*Aspergillus niger*+starch, treatment 8 was *Enterococcus faecalis*+*Trichoderma viride*+glucose, treatment 9 was *Enterococcus faecalis*+cellulase+bran) were used as substrates, which were incubated for 72 h for an *in vitro* fermentation gas production test and a batch *in vitro* fermentation test. A pressure sensor was used to measure gas production through *in vitro* incubation at 39°C. The results showed that the concentration of ammonia nitrogen, total volatile fatty acid, propionic acid and butyrate acid in treatment 3 were significantly higher than those in other treatments ($P<0.05$). Similarly, gas production in treatment 3 was significantly higher than that in other treatments ($P<0.05$). However, the methane production in treatment 3 showed no differences with other treatment ($P>0.05$), except for treatments 2 and 5. In conclusion, treatment 3 improved the *in vitro* fermentation properties and gas production without the increase of methane emission. Therefore, treatment 3 (*Bacillus licheniformis*+cellulose+starch) is the optimum additive combination for rice straw ensiling.

Index terms: rice straw silage, ensiling additives, *in vitro* fermentation, methane

The ratio of 50:50 of *Urtica cannbinau* to *Leymus chinensis* improves rumen microbial fermentation and gas production *in vitro*

Zhenbin Zhang[1], Shan Wang [1], Ruxin Qi [1], Liangfeng Shi [1], Mengzhi Wang[1], Xiaoqing Zhang[2]*

[1]College of Animal Science and Technology, Yangzhou University, Yangzhou, Jiangsu 225009, P.R. China

[2]Institute of Grassland Science, Chinese Academy of Agricultural Sciences, Huhehote, Inner Mongolia 010010, P.R. China

*Corresponding author: Mengzhi Wang, mengzhiwangyz@126.com

This experiment was conducted to investigate the effect of the ratio of Urtica cannbinau and *Leymus chinensis* on rumen fermentation parameters in vitro. The experiment was divided into 5 groups according to the ratio of Urtica cannbinau and Leymus chinensis: 0:100 (A), 30:70 (B), 50:50 (C), 70:30 (D), 100:0 (E) respectively. The culture medium was collected to detect the fermentation parameters at 0, 1, 3, 6, 12 and 24 h after incubation. The results showed that: 1) Gas production and dynamic gas production parameters: Gas production in 0~1 h and 1~3 h were higher in groups A, B and C ($P<0.05$), with group C recording the highest data ($P<0.05$). The dynamic gas production parameters were all higher in both group A and group C ($P<0.05$). What's more, there were no differences between group C and group A in theoretical maximum gas production, potential gas production and cumulative gas production. 2) Fermentation parameters: pH at 1, 3, 6 h, 24 h were higher in group A and group C, and was the highest in group C ($P<0.05$); NH_3-N concentration were higher in groups D and E at 3, 6, 12, 24 h ($P<0.05$), and group C was lowest at 24h. 3) Bacterial protein and protozoal protein: The bacterial and protozoal proteins in group A and group C were higher at 1 h and 3 h ($P<0.05$), and group C was the highest at 24 h. All in all, as for the ratio of Urtica cannbinau to Leymus chinensis, 50:50 is an optional level for rumen fermentation in vitro, by increasing the gas production and microbial protein, decreasing the ammonia concentration.

Keywords: Urtica cannbinau; Leymus chinensis; rumen microbe; gas production; *in vitro*

author), funded by CNPq (n. 456957/14-6)

methane, microbiome, rumen, 16s rRNA

sion potential during slurry storage.

Promocion |Organization

Institutional Support

Sponsor

CGPE: