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Greenhouse gas emission in Cattle Livestock System, the challenge in quantification and mitigation strategies: meta-synthesis

Emission factors are references to compose future projections related to global emissions, climate change, and sustainable practice. The inventories are commonly based on theoretical standard emission factors according to the Intergovernmental Panel on Climate Change and European Monitoring and Evaluation Program, which is susceptible to uncertainties. Global demand for livestock productions tends to grow by about 70% by the year 2050. Ammonia and nitrous oxide produced by bovine waste constitutes 40% of the anthropogenic production of GHG. Emissions related to enteric fermentation and waste represent 80% of methane emissions from agriculture or almost 40% of global emissions. This pressure on producers and natural resources will require sustainable management as a mitigation process. In order to identify the main challenges of the quantification of greenhouse gas emissions from cattle livestock, we developed a qualitative meta-synthesis of scientific experimental studies, and we find an integrated assessment related to 53 papers. The result shows the challenges of scientific research in standardizing methodologies and clarifying the gaps in relation to emissions from cattle raising sources. The mitigation strategy that can actually be used in the short term to reduce emissions from waste is the anaerobic digestion process. Reducing enteric methane emissions through diet modification still presents numerous challenges. Quantification of greenhouse gas emission and mitigation potential, in loco, are necessary to better elucidate the effects of diets and management of the animal production system, to promote technical orientations at the farm level.

Keywords: Climate change; Emission factor; Enteric fermentation; Waste management.

Emissão de gases de efeito estufa no Sistema Pecuário, o desafio nas estratégias de quantificação e mitigação: meta-síntese

Fatores de emissão são referências para compor projeções futuras relacionadas a emissões globais, mudanças climáticas e práticas sustentáveis. Os inventários são comumente baseados em fatores de emissão padrão teóricos de acordo com o Painel Intergovernamental sobre Mudanças Climáticas e o Programa Europeu de Monitoramento e Avaliação, que é suscetível a incertezas. A demanda global pela produção pecuária tende a crescer cerca de 70% até o ano 2050. A amônia e o óxido nitroso produzidos por dejetos bovinos constituem 40% da produção antropogênica de GEE. As emissões relacionadas à fermentação entérica e resíduos representam 80% das emissões de metano da agricultura ou quase 40% das emissões globais. Essa pressão sobre os produtores e os recursos naturais exigirá um manejo sustentável como processo de mitigação. A fim de identificar os principais desafios da quantificação das emissões de gases de efeito estufa da pecuária, desenvolvemos uma metassíntese qualitativa de estudos experimentais científicos, e encontramos uma avaliação integrada relacionada a 53 artigos. O resultado mostra os desafios da pesquisa científica em padronizar metodologias e esclarecer lacunas em relação às emissões de fontes pecuárias. A estratégia de mitigação que pode realmente ser usada em curto prazo para reduzir as emissões de resíduos é o processo de digestão anaeróbia. A redução das emissões de metano entérico por meio da modificação da dieta ainda apresenta inúmeros desafios. A quantificação da emissão de gases de efeito estufa e o potencial de mitigação, in loco, são necessários para melhor elucidar os efeitos das dietas e do manejo do sistema de produção animal, a fim de promover orientações técnicas na propriedade.

Palavras-chave: Mudanças climáticas; Fator de emissão; Fermentação entérica; Gestão de resíduos.

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INTRODUCTION

Global demand for livestock productions tends to grow by about 70% by the year 2050. This additional pressure on producers and natural resources will require sustainable management including the mitigation process of greenhouse gas emissions (GHG) (SILVA et al., 2015). It was estimated in 2018 there were 1.002 billion cattle in the world (USDA, 2018) and part of this herd is commonly confined for long periods, resulting in GHG emission and degradation of soils and pastures (MINET et al., 2016).

Livestock farming systems are the main source of GHG emission, as ammonia, methane, and nitrous oxide. Ammonia and nitrous oxide produced by bovine waste constitutes 40% of the anthropogenic production of GHG. Emissions related to enteric fermentation and waste represent 80% of methane emissions from agriculture, equivalent to almost 40% of global emissions (HOU et al., 2015).

The strategies for reducing GHG emissions are recognized and quantify the sources of emission as methane (CH_4), nitrous oxide (N_2O), and ammonia (NH_3) (BERNDT et al., 2013) for the sector's providence and sustainability. Emissions of ammonia cause eutrophication and acidification of nitrogen-limited ecosystems, and oxide nitrous and methane emissions contribute to the atmosphere radiative forcing, due to the great global warming potential of both gases (HOU et al., 2015).

Researches on quantification of GHG emissions from livestock systems increased substantially, however, more studies on mitigation strategies and technical orientations at the farm level are needed (CONOR, 2014; SCHADER et al., 2013; BAEK et al., 2014; HOU et al., 2015; RAWNSLEY et al., 2018).

Global GHG emissions by livestock systems were estimated to be 18% of total anthropogenic emission; it is close to the emission caused by transport systems in the world. The enteric fermentation is responsible for most of the GHG emissions of cattle raising. This emission depends on the diet offered to animals, as well as age and breed (FAO, 2006; DUDLEY et al., 2014). Livestock waste treatment is another important source of emission, which also presents variability about the type of waste, the composition, and other factors (MASSÉ et al., 2011).

The measurement methods of emission factors used in GHG inventories are determined by the Intergovernmental Panel on Climate Change (IPCC). The uncertainties in the model output are related to the uncertainties in model inputs, parameters, structure, and resolution. The variability in experimental conditions is the most important cause of uncertainties of emissions factors (KARIMI-ZINDASHTY et al., 2012). Therefore, due to the wide variability of conditions in which the animals are exposed and also about the waste storage conditions, the inventories, based on complex empirical models and inputs, not commonly measurement cannot represent the real conditions of GHG emissions in a specific local (BARRANCOS et al., 2013; HASSOUNA et al., 2013).

It should also be considered that GHG emissions occur simultaneously in the various production systems and that there may be interactions between these emissions. Authors mention that NH_3 mitigation can increase N_2O emissions in slurry storage, or increase CH_4 emission in solid waste storage systems (HANSEN et al., 2009; VELTHOF et al., 2011; HOU et al., 2015). Some research suggests systematic quantitative analyzes of production systems to obtain information on the effects of mitigation strategies related to manure management (CHADWICK et al., 2011; HOU et al., 2015).

The great variability of the production systems added to the variability of GHG emissions in time and space are challenged to the search for cattle emission factors (SANTOS et al., 2018). In order to identify the main challenges on quantification of GHG emissions from cattle livestock systems, their uncertainties, technology advances in research, and mitigation strategies, we developed a qualitative meta-synthesis of scientific literature, by discussing and integrated assessment of results presented by experimental research.

METHODOLOGY

Method - Meta-synthesis

Meta-synthesis is a method that involves a systematic review and an integration of findings from qualitative studies. This method is consolidated in medical research in order to find clinical evidence (LACHAL et al., 2017). This qualitative method involves an interaction of findings related to a sample of scientific studies (PATERSON et al., 2009; GASCON et al., 2016). Particularly, in this case, we used the method to help us critically analyze the articles in accordance with the research objective.

We followed a guideline and papers for Qualitative Meta-synthesis (QMS) (GREENHALGH, 1997; THORNE et al., 2004; PATERSON et al., 2009; GASCON et al., 2016; LACHAL et al., 2017) to synthesize a number of research papers to identify an integrated assessment about experimental studies on GHG emissions from beef and dairy cattle livestock systems.

Literature Database

Relevant studies were identified by searching in the Google Scholar database using the keywords ‘beef cattle’ AND ‘emission factor’ AND ‘greenhouse gas’ added to ‘quantification’ OR ‘mitigation’, and ‘dairy cattle’ AND ‘emission factor’ AND ‘greenhouse gas’ added to ‘quantification’ OR ‘mitigation’. In the previous analysis, these keywords combinations showed articles with experimental data and concerning GHG quantification and discuss emission factors. The search was limited to the English language and papers published between 2000 and 2018.

Study selection

Identification and the first screening of the articles were performed using the information available in the titles and the abstracts. Two reviewers independently worked on article selection observing the relevant issues for the present study. The agreement was reached via consensus. Studies were considered relevant if they were empirical studies using quantitative techniques to measure GHG emissions and /or presents results of mitigation processes related to dairy and beef cattle livestock systems.

We obtained full-text for all relevant articles and select the articles using the inclusion criteria: a) original research papers (we excluded proceedings paper, meeting abstract and reviews); b) papers related to GHG production by cattle clearly related to the experimental situation (we excluded articles that used mathematical models or simulations); c) indexed scientific journals; d) papers with the same research questions and that present similar discussion and results were compared for screening. The paper with the highest number of citations was included in the study.

The lists of selected articles produced by two reviewers were compared to the search for consensus and discussion on the inclusion or exclusion of items. A single list of articles was adopted related to the discussions about the topic in question, their comprehensibility, and consistency as the research objectives.

Extracting findings to meta-synthesis

To understand the research questions and results of each paper included in this study, after full reading, we extracted and organized in a support table the information related to: - Identification, as authors names and country; - research questions; - the method used for GHG quantification and/or mitigation strategies; obtained results and conclusions or compelling considerations.

For the last item, we compare and relate the results between articles with the same theme to identify justifications in issues that may contribute to another study.

These data were exposed in a way that would allow the reviewers to construct their own opinions about each study. Each paper was read at least two reviewers.

After this compilation, it was possible to compare and relate the articles with each other and identify themes. The articles were grouped in themes according to the similarities related to research issues, the kind of gas quantified and mitigation strategies proposed. Comparisons between studies were carried out, focusing on objectives and results obtained, followed by an integrated analysis of the themes.

THEORETICAL DISCUSSION

Study selection and characteristics

A total of 2,237 papers were initial identified by database search, using the keyword sets adopted. The partial reading, considering the titles and abstracts, resulted in 153 studies. The most part of the papers excluded by the search was related to the following literature types: modeling emission factor, theoretical manuscript, life cycle analysis, estimate using the IPCC models, and other issues do not accept for this study, as papers with the experimental and results in equals.

After the construction of two support tables with characteristics list from each paper, the reviewers, by consensus, accepted 50 studies for reviewing (Table 1). We justified these restrictions by analyzing originality, innovations, and clear discussion about a direct measurement of GHG emissions. All articles presented experimental data *in situ*, *in vivo,* at the farm level, or on a laboratory scale. These data are related to emission rates of greenhouse gases such as CH_4, NH_3, N_2O, and CO_2.

The themes identified for the meta-synthesis were related specifically with 1) Diet and enteric fermentation; 2) Manure management emissions; and 3) Global GHG emissions in cattle livestock systems, techniques, and methodologies.

For the content analysis, we came to a consensus on important domains of interest for each theme. Table 1 shows the summaries about the finds. The articles included in the research were published between 2005 and 2018. Most articles are related to theme 1 (20), followed by themes 2 and 3 (15).

Table 1: Themes and references of included studies.

Theme / Domain interest	Author	Year	Country
1 - Diet and enteric fermentation	Chagunda	2013	UK
	Chung et al.	2011	Canada
	Dijkstra et al.	2011	The Netherlands
	Donoghue	2016	Australia
	Fitzsimons et al.,	2013	Ireland
	Grainger et al.	2007	Australia
	Hammond et al.	2014	UK
	Hellwing et al.	2012	Denmark
	Hunerberg et al.	2014	Canada
	Hynes et al.	2016	UK
	Jones et al.	2011	Australia
	Jonker et al.	2016	New Zealand
	Ku-Vera et al.	2018	Mexico
	Lee et al.	2018	South Korea
	Madsen et al.	2010	Denmark
	Pedreira et al.	2009	Brazil
	Pinares-Patino et al.	2007	France
	Ramírez-Restrepo	2016	New Zealand
	Suzuki et al.	2008	Japan
	Yan et al.	2009	UK
2 - Manure management emissions	Amon et al.	2006	Austria
	Arriaga et al.	2010	Spain
	Askri et al.	2016	France
	Barneze et al.	2015	Brazil
	Byrnes et al.	2017	Colombia
	Fangueiro et al.	2018	Portugal
	Lazcano et al.	2016	USA
	Louro et al.	2016	Spain
	Luo et al.	2018	New Zealand
	McGinn et al.	2016	USA
	Misselbrook et al.	2016	UK
	Pereira et al.	2012	Portugal
	Rivera et al.	2018	Colombia
	Silva Cardoso et al.	2017	Brazil
	Sun et al.	2016	Australia
3 - Global GHG emissions in livestock systems and micro meteorological measurements	Barrancos et al.	2013	Spain
	Gao et al.	2010	Canada
	Hassouna et al.	2013	France
	Hindrichsen et al.	2006	Switzerland
	Kaiyapperuma et al.	2018	Canada
	Kille et al.	2017	USA
	Klevenhusen et al.	2010	Switzerland
	Lee et al.	2012	USA
	Menezes et al.	2016	Brazil
	Montanholi et al.	2008	Canada
	Ngwabie et al.	2009	Sweden
	Rzeźnik et al.	2016	Poland
	Spiehs et al.	2016	USA
	Stackhouse et al.	2011	USA
	Wu et al.	2016	The Netherlands

Meta-synthesis

Diet and enteric fermentation

The United Nations Framework Convention on Climate Change and Kyoto Protocol require from signatories to regularly report national GHG emissions using methods compatible with the "best practice" guidelines to determines CH_4 emissions from different livestock species, with attention on an estimate of populations, monthly feed intake, and a relationship between CH_4 emission and dry matter intake (IPCC, 1996; RAMIREZ-RESTREPO et al., 2016).

Some articles, which estimate the emission of enteric methane, present the SF_6 gas technique, using greenhouse gas as the tracer of the enteric methane emission. This is a technique considered invasive since it is necessary to insert a permeable capsule containing SF_6 into the animal's rumen. The gas is inert, not reacting with the substances in the rumen, and is eliminated at a constant and known rate. Leaving the animal's rumen, via eructation, methane and SF_6 are aspirated by a vacuum pressurized necklace with a suction hole at the known rate placed on the animal's neck. The concentration of the gases is determined by gas chromatography using a sample taken from the pressurized necklace. The emission rate of CH_4 is the product of the permeation capsule emission rate, located in the rumen, by the ratio of CH_4 and SF_6 concentrations in the sample (WESTBERG et al., 1998; PINARES-PATINO et al., 2007). This technique presents a great variability of measurements when compared to the closed or calorimetric chambers, considered as the gold standard for the CH_4 measures.

The calorimetric chambers present greater experimental control, easy methodological reproducibility, portray dynamic environmental conditions, and greater control of food intake by the animals (SUZUKI et al., 2008; RAMIREZ-RESTREPO et al., 2016). However, when analyzed in terms of animal welfare, this system may not be the best option to have stress as a present factor, which may alter the rate of food intake (WESTBERG et al., 1998) that changes the rate of actual field conditions, or confinement.

Considering the need to promote well-being, researchers constructed a closed and low-cost chamber with an air conditioner system and used infrared and electrochemical sensors for flow analysis and GHG concentration (HELLWING et al., 2012). The authors state the fact that the chamber walls are transparent and because it is located in the same confinement environment of dairy cows, there were no change behaviors and even food intake, which favors the use of the system in long-term studies. Closed chambers may be a strategy of long-term estimation (KU-VERA et al., 2018) if the dimensions do not affect the animals' natural behavior and provide accurate measurements of gas flows.

These techniques present a certain efficiency in measuring methane emissions at controlled experimental levels but extremely limited to describe the real gas emission under commercial conditions (CHAGUNDA, 2013), which is the focus of the inventories required by the committees on climate change.

As in human medicine, for years it is used breath analysis to understand metabolic disorders, a non-invasive technique. The Laser Methane Detector (LMD) is an example that can be used for breath analysis, obeying the animal welfare requirements. The LMD uses highly sensitive IR absorption measurements of methane, which has two abortion bands, using a hand-held optical instrument. The data analyzed in a comparative experiment between measurements of methane in a closed chamber and a real-time cattle breath by LMD show a strong results agreement (CHAGUNDA, 2013).

Researchers used portable equipment (Gasmet Technologies Oy, Pulttitie 8A, FI-00880 Helsinki, Finland) to analyze air in stables or in individual stalls, and identified that it is possible to calculate the proportion of carbon present in the air that is not metabolized in CO_2 but excreted as CH_4 (Madsen et al., 2010). The method uses the relationship between CO_2 excreted and heat produced by animals. This ratio is used as a parameter for the estimation of CO_2 not transformed into CH_4 (85-90% produced via enteric fermentation and the remainder from the emissions of waste). Measurements of the CO_2/CH_4 ratio are carried out inside and around the stable and by the difference between these rates, methane production is estimated. The authors critique the technique in relation to the CH_4 origin (enteric or waste fermentation), but indicate that the relation CO_2/CH_4 reflects the type of diet and characteristics specific to the herd, which may contribute to quantification methods.

There are challenges to improving techniques to be used as standards for enteric methane measurements since under grazing conditions microclimatic factors such as wind intensity and direction, relative humidity, and atmospheric pressure affect the results. The problematic about greenhouse gases produced by beef and dairy cattle has resulted in efforts to develop technologies and strategies to reduce principally methane emissions (FITZSIMONS et al., 2014; HAMMOND et al., 2014; HUNERBERG et al., 2014), but there is still a need for long-term analysis. Most of the studies included in theme 1 reported the increasing interest in developing strategies to reduce enteric CH_4 emissions by supplementation cattle diets.

Dry matter intake, in kg per day, is related to methane production. It is estimated that the intake of 5 kg of dry matter per day produces 163 g of methane (SUZUKI et al., 2008), but the dry matter quality also interferes with the emission of gases (HAMMOND et al., 2004; HUNERBERG et al. al., 2014). It is difficult to obtain the individual measure of food intake in practice. Estimates are made for the purpose of approximate analyzes and therefore inaccurate emission factors per animal are obtained (RAMIREZ-RESTREPO et al., 2016; LEE et al., 2018).

It is also necessary to consider the live weight of the animal, and details of the diet in the aspect of amounts of cellulose, hemicellulose, and lignin (YAN et al., 2009). This information is important because high fiber content affects the potential of dry matter consumption in cattle, increasing the retention time in the rumen reducing feed intake, and low productivity.

Enteric fermentation and consequent emissions by ruminants also represent an energy loss that depends on type and dietary proportions of different carbohydrates. Concentrate or mixed-based diets generally result in lower enteric CH_4 emission than forage-based diets, such as low-quality pastures in tropical countries (SUZUKI et al., 2008).

Supplementation cattle diets as linseed and crop barley silage (CHUNG et al., 2011) may be an effective strategy for methane emission mitigation but may have a negative effect on the digestibility and animal performance. Some studies about supplementation to decreasing methane emission or milk fatty acid markers to estimated methane emissions cited the inconclusive results and necessity of a long time for the experiments (DJIKSTRA et al., 2011).

The significant reduction in feed intake suggests a decreasing methane emission and it is maybe a suitable methane mitigation strategy (FITZSIMON et al., 2014). However, the low Residual feed intake (RFI), that is the difference between real and basal feed intake, necessary to metabolism maintenance, may determine the low methane emission, compared to the high RFI animals, if the pasture is of high quality, with adequate contents of fibers, proteins, lipids, and carbohydrates, otherwise, this difference is not observed (JONES et al., 2011).

Studies related to pasture quality and methane reduction may present inconsistencies. Jonker et al. (2016) observed that even in relation to high-quality pastures, considering the maturity of pasture and seasons, it may not cause significant effects on CH_4 emission, suggesting greater questioning and analysis time. About supplementation of crude protein concentration in the dairy cattle diet, studies did not observe changes in the CH_4 emission (g/day) and, like the previous authors, indicate that more studies are needed, considering the greater diet variability, extended time of experimentation and analysis of animals in different stages of breeding (HYNES et al., 2016; KU-VERA et al., 2018).

In Korea, studies to determine the enteric methane emission factor of a dairy cow show that if we do not consider the live weight factor of the animals, which would be the same when analyzing emission by age, the emission values will be underestimated, as in the case of emission factors presented in inventories from Canada, Japan, the UK, and the USA (LEE et al., 2018).

Routine measurement of methane emission by livestock is not an easily accepted task for the farmers. A quantification routine will be difficult to establish, so in the long term, selection for breeds that emit less methane may be a solution. Even genetic selection in ruminates can be a way to reduce methane emissions. However, an emission reduction by some strains does not imply that the animals are more productive. Thus, genetic selection studies should be planned to obtain high productive performance and low emission factors (DONOGHUE et al., 2016).

However, studies related to enteric methane emissions are still inconclusive. The methodologies used for the quantification are diverse, there are no standards adopted to be used for inventory estimates. There is much variability in terms of measures related to each of the above-mentioned methodologies.

Each production system has its peculiarities, which makes it difficult for an emission factor for each country, or even for each climatic region. There is a need for greater efforts in studies that analyze long-term dietary interference in enteric methane emissions, but there is a need to consider details such as sex, age, live weight, and even variables that are difficult to measure as feed intake.

Manure management emissions

The countries that are signatories to the climate treaty are obliged to report emissions of NH_3, N_2O, and CH_4 annually. Ammonia is estimated following CORINAR methodology and the other gases are estimated according to the 'Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories' (IPCC, 1996). These protocols present several values of each gas maximum emission, conversion factors for each climatic region, and other details, which are often used as a basis for estimation, including numerous uncertainties (AMON et al., 2006).

The information required in animal waste gas emission inventories is related to the discovered anaerobic lagoons, slurry systems, solid manure storage, and dry waste (TODD et al., 2011). Due to the uncertainties associated with the standard emission factor, the IPCC (2001) recommends that accurate measurements in local experimental arrangements can reduce inaccuracies.

The local waste emission measures are usually made by a sampling of inserted waste in reactors on a laboratory scale, in order to provide an anaerobic process, and after a certain period of emission, gas samples are collected and analyzed by gas chromatography (PEREIRA et al., 2012). When measurements are performed *in situ*, on pastures, PVC static chambers are installed for gas retention and a gas sampling is by gas chromatography (BYRNES et al., 2017; RIVERA et al. 2018). There are also portable devices, such as the photoacoustic infrared gas analyzer which presented ease of operation and quantification of gases *in loco* (ARRIAGA et al., 2010).

Researchers are analyzing the efficiency of urine sensors to track pasture spots in time and space. The sensor is coupled to a GPS system that informs the location and time of the urine deposit and placed next to the urinary tract of the animals, trapped by lateral harnesses. The sensor has shown it is possible to track the spots, and efforts must now be directed to find efficient ways of emission quantifying at these sites (MISSELBROOK et al., 2018).

Sustainable agriculture must find ways to utilize these nutrients present in animal waste since the direct application of this biomass in the soil can cause nutrient losses and gas emissions (NH_3, N_2O, NO_x, N_2). The high amount of dry matter and carbon cause emissions and losses during storage and also when subjected to certain treatments, such as composting (AMON et al., 2006).

According to information from the IPCC, the default N_2O emission factor for manure and urine deposited on pastures is 2% of N excreted by animals (BYRNES et al., 2017), but in some experiments, this value was considered overestimated (BARNEZE et al. 2015). Nitrous oxide is a greenhouse gas with a global warming potential of 270 to 320 times greater than CO_2 and contributes 6% to heating. The production of this gas emitted by the soil of agriculture is caused by biological processes in nitrification reactions of the ammonia in nitrate under aerobic conditions and mainly by the reduction reaction of nitrites under anaerobic conditions. The two conditions occur simultaneously in the soil causing N losses (PEZZOLLA et al., 2016).

Other factors that may influence N_2O production in soils are the availability of oxygen, water-filled pore size, mineral N content, temperature, pH, and C availability. All these factors have spatial and temporal variability influencing the flows of gases (LOURO et al., 2016).

Many studies on the application of nitrification inhibitors (IN), chemicals such as Dicianodiamide, in cattle urine under grazing conditions present positive results in reducing N_2O emissions and improving soil N utilization. This reduction of emission is possible due to the inhibition of the bacteria’s action that produces nitrites. Most of these studies were developed in autumn and spring, with little information on inhibitor applications in summer.

Experiments carried out in the summer of a UK region showed that in the pastures with urine storage it was found lower emission factors than those recommended by the IPCC estimation models, and also observed that even with the action of nitrification inhibitors there was no significant reduction of emissions (BERNEZE et al., 2015).

Biological nitrification inhibitors (BNI) can also be used to inhibit N_2O emission, by the action of Brachiaria bacteria in pasture areas, and can be effective mainly in tropical humid and sub-humid pastures, but studies suggest long periods of analysis to verify possible soil changes (BYRNES et al., 2017).

In addition, the nitrogen: phosphorus (N: P) ratio in manure applied as fertilizer does not correspond to crop requirements, since the amount of manure applied is calculated on the basis of the concentration of N and not P, which can be toxic when in high amounts to plants (FANGUEIRO et al., 2018).

The application of fertilizers, such as animal waste, results in losses of 0.2 to 1.5% of the nitrogen applied by the emission of N_2O. Some efforts have been made to analyze the emission of N_2O from liquid digestates, with separation of the solid phase, where the surplus dry matter and organic matter are removed (ASKRI et al., 2006). The digestate is produced when animal waste passes through the anaerobic digestion process, producing a fertilizer with low GHG emission power. Due to the high mineralization power of the anaerobic digestion process and the consequent availability of nutrients to the plants, the produced digestate has low N_2O emission and other gases, considered environment friendly (AMON et al., 2006; ASKRI et al. 2016).

The anaerobic digestion process is mainly used for energy production, but it also has the potential to make the production of fertilizers with low GHG emission rate feasible, mainly liquid digestates that do not influence the emission rate of NH_3 (AMON et al., 2006).

Among the various NH_3 emission reduction strategies, such as manure management, animal nutrition, bedding, and ventilation, the manipulation of diets is considered to be the most effective strategy, but there are no conclusive studies on the influence of this manipulation in N_2O emissions (ARRIAGA et al., 2010). The authors inferred through laboratory experiments that the reduction of dietary crude protein (CP) can reduce the excretion of N by the animals and emission of NH_3, with the temperature being a factor of control of the gas volatilization.

In relation to N_2O, they did not find a significant relationship with diet change. However, it is important to indicate the experiment carried out had a duration of 4 days of measurement, after 11 days of adaptation of the animals to the modified diets. Another important aspect is that the volatilization of ammonia must be tested in different climatic conditions so that over a year there can be a more accurate estimate.

The slurry acidification technique is indicated as a reduction strategy for NH_3 emission, but lack information about the emission of other GHG. In a study in the Mediterranean region, acidification of the slurry was analyzed by soil incorporation and it was verified there was a reduction of NH_3 and also of other GHG (FANGUEIRO et al., 2018), but the soil properties were not analyzed, which should be done to validate the technique of mitigation without damage to crops.

Some researchers mention that the emission factors advocated by the IPCC differ from the actual field conditions, as with highly fertilized pastures, and it is crucial that there be studies on extensive pasture areas considering the types of fertilization (RIVERA et al., 2018).

The combined application of liquid and inorganic fertilizers, routinely used in the USA, causes the release of N_2O from inorganic fertilizer. This information was obtained through more than one-year commercial studies (Lazcano et al., 2016). Irrigation strategies may also influence N_2O emissions due to changes in soil conditions due to the change in soil water content and the oxygen availability, especially in irrigation conditions with excess liquid manure, which may contribute to the nitrification and denitrification processes.

In research comparing the GHG emission rates between pastures with mineral fertilizer application and manure slurry in the spring and summer seasons in Spain, it was verified that in both dry seasons there are similar and low emissions of N_2O, compared to times when there is precipitation, but in the spring, after rain periods, gas emissions are still reduced. The authors indicate the need for long-term studies for more accurate analysis of emissions and climatic factors that can alter them (Louro et al., 2016).

It is common in the Southern Hemisphere, in temperate climates, and in some regions of Europe, that the grazing system of cattle is rotated, in fenced pastures to change pasture areas. In these systems, the accumulation of urine and manure is the main cause of N_2O emission. It is of extreme importance to identify the spatial and temporal distribution of urine spots to verify N losses, and this may be related to the cattle diet, grazing management, pasture type, and season (LUO et al., 2018; MISSELBROOK et al., 2018).

The rotation of forage crops in these pickets can supply the nutritional demand of the animals and reduce the emissions of gases, such as herb lucerne and plantain because they have deep rooting, which gives them great ability to extract water and N from the soil.

In an experiment in New Zealand, Luo et al. (2018) observed that pasture with forage herb lucerne showed lower emission compared to picket with ryegrass only in winter. For the plantain, the emission reductions were perceived during winter and fall. It is believed during dry periods, there is a reduction of emission when using this fodder. Further studies should be carried out so that it is possible to verify the relationships between plants, seasons of the year, and emissions.

In addition to the characteristics of forage crops, soil conditions may also alter N_2O emissions, such as soil moisture, compaction, urine deposit, and manure, considering their volumes (CARDOSO et al., 2017).

Ammonia emissions, from animal waste, generate human health problems, devaluation of manure fertilizer due to loss of N, and is still considered a greenhouse gas. In cattle containment systems, where food intake and production are controlled, greenhouse gas emissions are more prominent, especially ammonia (MCGINN et al., 2016).

When the pasture surface or the confinement floor is wet and the water evaporates, ammonia is emitted as gas, in contrast, on dry surfaces, when there is a high concentration of ammonia in the air, there is the deposition of this on the surface. This was verified under conditions of confinement of beef cattle and identified that in the local vicinity to the confinement, there is the deposition of NH_3 in the soil, as well as emission, being the deposit 10 times superior to the emission. The authors highlight the importance of quantifying NH_3 emissions and deposits for large-scale inventories, with sensors that can continuously analyze such inputs and outputs (MCGINN, et al., 2016).

In livestock confinement, studies have shown that daytime NH_3 emissions are directly related to air temperature, as warmer surfaces promote higher emissions from waste, including urine. Another important fact is that a large part of N ingested via feed is volatilized from cattle manure under confinement conditions (MCGINN et al., 2016). In intensive confinement systems, there may be higher GHG emissions in fertilized grazing areas when compared to silvopastoral system areas, due to the higher N retention capacity of the latter (RIVERA et al., 2018).

Cattle confinements are largely responsible for the emission of NH_3. The emission of N_2O in these systems is considered low when compared to extensive systems, but still lack information regarding this type of emission in these systems. Researchers mention that the application of lignin in these containment systems can reduce the ammonia emission by the change of pH caused, which results in greater N mineralization in manure, which stops emitting the gas. High N content can still be applied to crops, which may offset the expense of lignin (SUN et al., 2016).

It is noticed that there are numerous information gaps in relation to emission rates and environmental and handling conditions. There is great variability in production systems as to the destination of the manure, use of fertilizers, and ownership of manure and local soil. Estimates, when based on models indicated by the IPCC tend to underestimate the emissions, mainly of N_2O. Studies that consider the spatial and temporal variability of emissions in several types of production systems and their peculiarities are required, but there are several obstacles to obtaining a standard emission methodology, due to these particularities of production systems.

Global GHG emissions in livestock systems and micrometeorological measurements

This topic is related to the GHG quantification in integral confinement systems, analyzing all *in situ* emissions of the whole animal production system. In this way, emissions from cattle waste and enteric fermentation are considered for cattle containment systems.

It is estimated that the emission factors of CH_4 and NH_3 present around 30% uncertainty in their values, due to the numerous factors that alter the emissions of these gases, considering the system of confinement, feeding, climatic conditions among others (BARRANCOS et al., 2013).

The thermography technique considered noninvasive and that can be used in the natural confinement environment, was used to associate temperature and methane emission. Montanholi et al. (2008) found evidence that there is an association between the temperature between the left and right flanks of cattle and the emission of methane. The correlations observed between flank temperature and methane emission after feeding was 0.77, indicating that above to 100 minutes after the meal it is possible to verify a certain relation with the production of enteric methane and temperature. This technique can be used as an estimation resource in real time.

Experiments that use calorimetric chambers for the confinement of animals for GHG measurements are other examples of uncertainties. In addition to altering the behavior of the animal, modifying food intake and consequently the GHG emission, there are also changes in the natural physical environment (GAO et al., 2010). Thus, the results obtained can not be used to extrapolate estimates since we do not have control of all the factors that can change emissions. Barrancos et al. (2013) suggest that experiments to estimate emission factors should be performed under real field conditions, with continuous measurements at the day and year, and indicates the use of robust statistical analyzes and models that may include uncertainties.

Micro meteorological measures techniques are indicated by many researchers because they do not interfere in the behavior of the animals and in the characteristics of the physical environment, such as flux-gradient measurement from the animal feedlot, integrated horizontal flux measurements from animals in pasture, micrometeorological mass difference measurements from animal pens, inverse-dispersion calculations of whole farm emissions and the relaxed eddy accumulation technique for feedlots (GAO et al., 2010). It is important to establish micrometeorological analyzes not only as a way of analyzing the production of GHG from different sources, and thus to obtain the total quantities of gases produced by a property.

The model recommended by the United States Environmental Protection Agency (USEPA), in which it relates gas production and local temperature presents approximate values when compared to the values obtained in situations of low temperatures, by micrometeorological mass balance, but for high temperatures, the model overestimates the values (KARIYAPPERUMA et al., 2010). The authors suggest experimental tests over a year in which the hysteretic patterns of such measurements can be verified for the correction of the model in situations of high temperatures.

Ammonia emissions are also present in livestock containment systems and the importance of quantifying them is not only related to the fact that it is a GHG but also because it is a precursor to aerosols and particles that are harmful to human health (KILLI et al. al., 2017). In countries where livestock farming is economically and socially important, the reduction of ammonia emissions is also necessary, but it is known that there are uncertainties regarding the quantification of this gas, being an obstacle in the face of reduction targets. Due to the numerous uncertainties related to the quantification of this gas, it is necessary to standardize methodologies for the search of an emission factor.

Some researchers have suggested infrared photoacoustic spectroscopy, used for decades, because of its selectivity, reduced calibration deviation, ease of use, and reduced measurement cost, but there are risks of overestimation of the emission of gases (HASSOUNA et al., 2013). The authors emphasize that each site should have measures for the construction of local models.

An alternative may be the solar concentration flux (SOF) method, which uses sunlight to determine the concentrations of gases in a vertical direction in the atmosphere. The method was used to measure ethene, propane, alkanes, and ammonia and is considered complementary to other in situ quantification techniques, as it assists in the verification of total emission quantities remotely and can also perform nitrous oxide measurements (KILLE et al., 217) but the methodologies should be standardized to be applied as a GHG quantification reference.

Non-invasive methodologies have the potential of not altering the physical environment and need to be better analyzed. Isolated experiments, in systems that inhibit the feeding or behavior of animals, compromise the results of the research.

Enteric methane emissions are often analyzed by methods that compromise animal behavior. The methane emission is an indication that the diet is not used in terms of losses of 2 to 12% of the energy value, which generates expenses for the production (HINDRICHSEN et al., 2006) and the use of micrometeorological analyzes can help to obtain emission factors that correspond to the real condition of animal husbandry.

In addition to this, one should also consider the production of waste gases, which are often destined for anaerobic composting systems generating large quantities of methane, which could be stored for use as fuel or electric power for a rural property. In this way, a sustainable property would be the one that destines the waste to the production of biofuel and organic fertilizers and that control of diets to the animals.

Different studies suggest that the amount of methane emitted by the waste depends on the number of fibers in the diet of the animals and other physical and chemical properties of the diet, which are not simple to obtain because it is not a routine among rural properties, of great importance for gas estimation (HINDRICHSEN et al., 2006).

Regarding the diets, there are studies that indicate that there is no clear relation between fiber amounts in diets and enteric methanogenesis and waste. In the same study, in relation to nitrous oxide emissions, the authors indicate that slurry methanogenesis depends on temperature and storage duration, but there is no effect on nitrogen emissions (KLEVENHUSEN et al., 2011). Lee et al. (2012) found no relationship between the diet offered to the animals and the emission of nitrous oxide from the slurry, contrary to what they observed in relation to the ammonia that was shown to correlate with the type of diet.

The reduction in the crude protein content of the diets does not affect the ingestion of the animals or even the performance and therefore some authors suggest the use of 10% of crude protein in bovine diets so that there is a reduction of the nitrogen excreted by the animals, however, this change did not affect the emission of methane and the authors indicate the need for further studies on these relationships (MENEZES et al., 2012).

On nitrous oxide emission at confinement sites, Ngwabie et al. (2009) cite that if the production system presents daily removal of waste in storage tanks, there are no considerable emissions of this gas. Bedding materials from containment systems should also be considered. Spiehs et al. (2016) report that wood-based beds reduce ammonia concentrations in the air from 20 to 21% when compared to corn straw. Green or dry cedar bed increases CH_4 concentrations. There is a lack of studies that can analyze the concentration of N_2O in these coverage systems.

Nitrous oxide may still be related to enteric fermentation. It is known that this process is the main production means of methane, which varies according to the age of the animal, digestibility among other parameters. Generally, N_2O is found at low concentrations in the enteric fermentation process, however, Stackhouse et al. (2011) in gas quantification experiments in and out of calorimetric chambers with gas sensors, report that in closed chambers the animals emitted a higher amount of N_2O in relation to emission outside the chamber. These emissions were from enteric eructation because in the chamber the wastes were immediate removal.

It is observed that integrated studies, in relation to the different sources of emission, can indicate relations that need to be analyzed through the local specific conditions. There are many controversies about diet modification and changes in enteric methane emissions and other gases from slurry or manure.

Noninvasive gas quantification methodologies may be more appropriate means of not interfering with the production environment and obtaining measures that reflect the conditions of animal breeding and production. However, in order to obtain GHG measurements in an integral form of a confinement system, it is not enough to use non-invasive means, such as micrometeorological analysis systems, but also to verify strategic locations that may represent situations of local confinement and standard methodologies obtained by studies of several researchers, in different places, under different conditions.

In a study using a photoelectric analyzer for quantification of concentrations of CH_4, N_2O, NH_3, and CO_2 in a dairy confinement system, it was observed that the emissions of these gases vary considerably throughout the day, because the environment is naturally ventilated. Thus, it is necessary to perform samplings in several places, with short-term measures and several replicates (NGWABIE et al., 2009). It should also be considered that different types of waste disposal result in different emission standards for the containment systems. Such variability must be scaled so that there is indeed a way to establish a standard methodology.

In a study using a Multi-Gas monitor and photo-acoustic spectrometer, it was observed the experimental emission factors differ from those recommended in models used as a reference for the inventories. The calculated emission factors were 20% lower for CH_4, 21% higher for NO_2, and 67% lower for CO_2 (RZEŹNIK et al.2016). This shows the need for *in situ* verification under production conditions.

Wu et al. (2016), through the use of portable gas sensors (INNOVA gas monitor), developed a methodology for individual quantification of enteric methane in dairy cattle. In systems of individual bays, during the rest period, measurements were made during winter and summer. It was possible to verify in this experiment the animals produced a greater amount of enteric methane in the winter when compared with the summer, but this can be related to the time of permanence inside the bays. The methodology can be useful, but it needs to be validated in order to be able to obtain quantification that represents the animal individual emissions in relation to the day and not only in the period of inactivity.

Thus, there are innovations in terms of technologies and methodologies that can answer the various questions regarding the gas quantification, but it is necessary the researches have continuity to answer the open questions and obtain a standard method useful in several locations.

CONCLUSIONS

The articles selected for the meta-synthesis indicated the following aspects: I - There is a need for supplementation of cattle diets to reduce energy loss and decrease methane emissions, but there is a lack of fundamental knowledge about some aspects that involve herd characteristics, type of management and facilities, as well as the local climate, these variables can camouflage the information related to diet change; II - Genetic selection can be considered an innovation for mitigation processes in the long term; III - Proper management of waste is a form of mitigation and avoids soil denitrification and gas release into the atmosphere, and the anaerobic digestion process is a promising strategy; IV - There are many difficulties associated with experimental planning that can alter the environment and animal behavior, generating inaccurate information about emission factors; V - Ammonia emitted from bovine manure is responsible for negative impacts on human health and environmental problems such as eutrophication of surface waters, acidification of ecosystems, and global warming, and studies are needed to analyze the relationship between ammonia and nitrous oxide emissions under controlled conditions; VI - The diversity of agricultural practices is associated with the variability of livestock production systems, such as race, diet, manure management, and other factors that potentially lead to large differences in GHG emissions; VII - Rural facilities should be prepared for the appropriate treatment of waste and quantification of gases, but there is no routine for producers to quantify emissions. The research should be applied in real conditions, in systems of commercial dimensions for a better emission estimation, so the association of the research with the producers is fundamental for systemic estimates, on a micrometeorological scale, of sources of greenhouse gases from cattle.

Quantifying greenhouse gases and pursuing mitigation strategies are still challenges to science. Mitigation strategies require studies that result in confirmation. In the short term, it can be stated that the management of manure through anaerobic digestion is the most likely efficient strategy to mitigate gas from livestock.

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