DAIRY FARMING AND GREENHOUSE GAS EMISSIONS IN LATVIA: SOME METHODOLOGICAL ASPECTS OF GREENHOUSE GAS INVENTORY

Ritvars Sudars, Laima Berzina, Juris Priekulis
Latvia University of Agriculture
ritvars.sudars@llu.lv, laima.berzina@llu.lv, juris.priekulis@llu.lv

Abstract. The paper examines the effects on greenhouse gas (GHG) emissions accounting methodology by introduction of the Intergovernmental Panel on Climate Change (IPCC) 2006 guidelines with respect to methane and nitrous oxide emission quantification in the dairy sector. Typical systems for dairy management in Latvia are compared with the aim to highlight methods available to calculate and report agricultural GHG emissions in national inventories and outcome differences among greenhouse gas emission contributing sources with the reference to the most important agriculture branch in Latvia. The study results show that the emission origin in the country for dairy farming is most accurately characterized by using Tier 2 methodology for emission calculations, however, the best results are available only if country specific parameters are available. Methane emissions are significantly affected by the dairy cow feeding system, while nitrogen oxide emissions are directly related with nitrogen excretion from the animal. Different manure management technologies show slighter effect on GHG emissions per dairy cow.

Keywords: Dairy cattle, greenhouse gas, methane, nitrous oxide, inventory.

Introduction

According to The Food and Agriculture Organization of the United Nations (FAO) report livestock production is contributing about 18 % of the global anthropogenic greenhouse gas (GHG) emissions [1]. FAO also highlights that the dairy sector globally releases 4 % of the total anthropocentric GHG emissions [2]. In some developed countries, the contribution of dairy production to GHG emissions is considered to be lower due to higher productivity of livestock, dilution by emissions from other sectors, and lack of significant land use change [3]. Mitigation methods to reduce emissions from this sector are possible to detect with identification of the most important emission sources; therefore, international legislation requires the submission of annual reports quantifying GHG emissions amounts. According to the United Nations Framework Convention on Climate Change (UNFCCC) GHG emissions reporting requirements, the Intergovernmental Panel on Climate Change (IPCC) developed general guidelines for compiling and reporting national GHG inventories in a transparent framework. In national inventories according to the IPCC methodology emissions are accounted by the regionalized (Tier 1) or national (Tier 2) approach, but accounting for mitigation measures requires the Tier 3 approach that has dynamic nature and higher complexity than the Tier 2 approach and at the same time reduces uncertainty of outcome. Tier 3 models account for more specific farm level parameters [4].

The EU as a party of UNFCCC prepares annual reports on GHG inventories for 1990 to t-2 for emissions within the area of the Member States. For agriculture, the inventory includes the emissions of CH_4 (methane) from enteric fermentation, manure management and emissions of N_2O (nitrous oxide) from manure management and agricultural soils. According to the latest report, total GHG emissions in the EU-28 decreased by 19.2 % between 1990 and 2012 (-1082 million tones CO_2 equivalents (eq.)) as a result of the significant decline in livestock numbers, more efficient application of fertilizers and improved manure management [5]. The EU has set a target to reduce its emissions to 20 % below 2005 levels by 2020. For Latvia it is allowed to increase emissions by 17 % in that time period, however, the overall goal is to meet 10 % reduction of emissions from the non-ETS (Emissions Trading System) sectors, including agriculture in EU-28. For 2030, the EU has committed the reduction of its GHG emissions by at least 40 % compared with 1990 leading to cut emissions by 80 % to 95 % by 2050. Emissions from non-ETS sectors are expected to be reduced by 30 % below the 2005 level [6].

At the same time Latvia sets plans of intensification of the currently extensive agricultural production and for encouraging of abandoned agricultural land return for production, which may significantly increase GHG emissions. Taking into account that the agro-climatic conditions and agricultural land in Latvia are suitable for dairy farming the sectoral policy strategy document of the

Ministry of Agriculture "Development trends of Latvia dairy sector till 2020" shows a goal to increase milk production and reach 30 % growth of the average milk yield.

The objective of this research is to examine the GHG emission calculation methodology outcome in Latvian dairy sector according to the IPCC 2006 Guidelines. One of the most important tasks includes highlighting the most important substances of methodology influencing the national inventory outputs, and the problems and challenges this can cause.

Materials and methods

Activity data for calculation of emissions describe the magnitude of a human activity resulting in emissions. In the dairy sector the main activity data for CH_4 and N_2O emissions consist of numbers of dairy cows. Regardless of the Tier approach chosen, GHG emissions can always be expressed as the multiplication of the activity data with an emission factor, that quantify the emissions of gas per unit of activity data. The value of the emission factor depends on the Tier level. The input data for Latvian GHG inventory were obtained from different sources: data on dairy cow numbers, milk production and composition are provided by the Central Statistical Bureau of Latvia (CSB). Other information on dairy cow basic characterization of ration, manure management systems, length of the grazing period and animal weights is determined by the experts in relevant fields. Emissions of CH_4 and N_2O emissions in Latvia dairy sector are estimated by using Tier 2 levels based on the IPCC guidelines [4]. Exception is N_2O emissions from pastures and manure application on fields where Tier 1 level is selected for calculations.

CH_4 and N_2O inventories from dairy cattle were compiled following the 2006 IPCC guidelines at Tier 2 level. According to the 2006 IPCC guidelines for calculation of methane emissions from enteric fermentation equation (1) is used:

$$EF = \left(GE \cdot \left(\frac{Y_m}{100} \right) \cdot 365 \right) / 55.65 \ , \tag{1}$$

where EF – emission factor, kg CH_4 head^{-1} yr^{-1};

GE – gross energy intake, MJ head^{-1} day^{-1};

Y_m – methane conversion factor, per cent of gross energy in feed converted to methane (6.5 %).

For estimating CH_4 emissions from manure management systems, the equation determined in the 2006 IPCC (2) Guidelines are used:

$$EF_{(T)} = \left(VS_{(T)} \cdot 365 \right) \cdot \left[Bo_{(T)} \cdot 0.67 \frac{\text{kg}}{\text{m}^3} \cdot \sum\nolimits_{(S,k)} \frac{MCF_{(S,k)}}{100} \cdot MS_{(T,S,k)} \right], \tag{2}$$

where $EF_{(T)}$ – annual CH_4 emission factor for livestock category T, kg $CH_4 \cdot$animal$^{-1} \cdot$yr^{-1};

$VS_{(T)}$ – daily volatile solid excreted for livestock category T, kg dry matter$\cdot$animal$^{-1} \cdot$day^{-1};

$Bo_{(T)}$ – maximum methane producing capacity for manure produced by livestock category T, m$^3 \cdot CH_4 \cdot$kg^{-1}of VS excreted (0.24);

$MCF_{(S,k)}$ – methane conversion factors for each manure management system by climate region k, % (Solid Storage – 2 %, Liquid Storage (with crust) – 10 %, Pasture – 1 %; Anaerobic Digester – 0 %);

$MS_{(T,S,k)}$ – fraction of livestock category manure handled using the manure management system in climate region k, dimensionless.

Direct N_2O emissions (kg N_2O yr^{-1}) from manure management have been calculated by using the 2006 IPCC Guidelines equation:

$$N_2O_{D(mm)} = \left[\sum\nolimits_{(S)} \left[\sum\nolimits_{(T)} \left(N_{(T)} \cdot Nex_{(T)} \cdot MS_{(T,S)} \right) \right] \cdot EF_{3(S)} \right], \tag{3}$$

where $N_2O_{D(mm)}$ – direct N_2O emissions from manure management in the country, kg $N_2O \cdot$yr^{-1};

$N_{(T)}$ – number of heads of livestock category T in the country;

$Nex_{(T)}$ – annual average N excretion per head of category T in the country, kg N$\cdot$animal$^{-1} \cdot$yr^{-1};

$MS_{(T,S)}$ – fraction of total annual nitrogen excretion for each livestock category T that is managed in the manure management system in the country, dimensionless;
$EF_{3(S)}$ – emission factor for direct N_2O emissions from manure management system S, kg N_2O-N·kg^{-1} N;
S – manure management system.

The manure management systems (S) reported in the Latvian GHG inventory 2013 were: liquid system (27 %); solid storage; (49 %) pasture range and paddock (20 %) and anaerobic digester (3.4 %). The global warming potential (GWP) index was used to determine the contribution to GHG is set 25 and 298 for CH_4 and N_2O, respectively.

Results and discussion

1. Dairy sector in Latvia

Dairy farming is one of the most important branches of agriculture in Latvia. After the World War II till 1990 Latvia became a major supplier of dairy products to the Soviet Union. After the centralized Soviet system collapse and privatization and restructuring of collective farms during 1992–1994, dairy farming activities sharply drop – also the output of milk and its quantity processed decreased. In 2013, the number of dairy cattle decreased to 69 %, comparing to 1990. The number of dairy cows in Latvia is relatively stable, with a tendency to slightly increase in recent years. In 2013, 165 thousand dairy cows were registered and average milk yield per cow reached 5508 kg, showing the highest value since 1990. From 2009, the number of large farms has increased, while small farms have closed, however, dairy farms in Latvia countryside are characterized by a low herd size in comparison with other European countries. The average number of cows in the herd was 7 animals in 2013. Small farms with 1-5 cows account for 79.5 % of all dairy farms. By contrast, 42.4 % of cows were kept in farms with at least 50 cows; however, such size of dairy farms represents only 2.3 % of the total number of dairy farms [7].

According to the GHG emissions inventory for the year 2013, the agriculture sector in Latvia contributed for 2314.9 Gg CO_2 eq, and represented the second largest source of GHG emissions. Dairy farming alone accounted for 30.4 % of total agriculture emissions, shared between enteric fermentation (515.4 Gg CO_2 eq. or 73.3 % of total dairy emissions) and manure management (114.6 Gg CO_2 eq. or 16.3 % of total dairy emissions). 10.4 % of total dairy emissions refer to N_2O emissions from nitrogen deposited by grazing animals on pasture and animal manure applied to soils, which totals to respectively 36.4 Gg and 37.1 Gg CO_2 eq.

Total emissions of GHG from agriculture decreased by 58.4 % in the period from 1990 to 2013, mainly due to reduced amounts of nitrogen applied per hectare, which has a significant effect on nitrous oxide emissions, and reductions in the number of cattle, which resulted in methane emissions decrease at 65 % rate. In recent years, dairy farming turns to the liquid slurry management system according to closing of small farms and reflection to the trend to this management system in developed countries, however, liquid slurry produces more methane and promotes increase of this kind of emissions. The distribution of dairy cattle number, milk yields and dairy farming GHG emissions per cow (excluding emissions related to soils) over 1990-2013 is presented in Fig. 1.

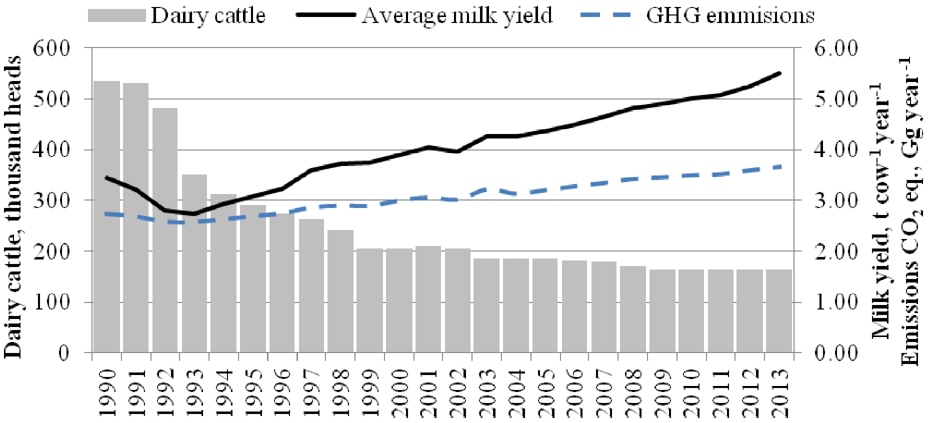

Fig. 1. **Characteristics of dairy sector in Latvia, 1990-2013**

2. Enteric fermentation

Methane emissions. Methane is mainly produced by anaerobic bacterial decomposition of organic compounds in feed, which is emitted as a product of enteric fermentation, and from decomposition of manure under anaerobic conditions [8]. In ruminant livestock systems, methane is the predominant source of GHG emissions with enteric fermentation. Methane from manure management can also include a relevant share of livestock emissions when liquid manure storage systems dominate. The 2006 IPCC methodology sets default Tier 1 emission factor for CH_4 emissions from enteric fermentation for Western Europe as 117 CH_4 $kg \cdot head^{-1} \cdot yr^{-1}$. The IPCC methodology for generating CH_4 emission factors is generally based on daily feed intake values and nutritional quality of the diet. Enteric fermentation emissions quantification with Tier 2 is based on average daily feed intake as gross energy (GE) $MJ \cdot day^{-1}$ generated from national values of animal body weight, average daily weight gain, diet digestibility, pregnancy status, feeding level and milk production. For dairy cattle fed forage based diets, it is assumed that 6.5 ± 1 % of GE intake is converted to $CH_{4,}$ while for feedlot cattle a 3 ± 1 % conversation rate is suggested.

In 2013, according to the Tier 2 approach estimated emission factor for enteric fermentation in dairy cow population for Latvia was 125 CH_4 $kg \cdot head^{-1} \cdot yr^{-1}$. At the aggregated data for EU-15 for 2012 GHG inventory showed that the implied emission factor for dairy cattle is close to that estimated value. GE contents and especially DE is very a important substance that influences the total amount of GHG emissions from an animal. As the results of calculation of GHG emissions for dairy cow based on solid manure management with weight 550 kg and utilizing pastures 145 days show, increasing DE from 45 % to 85 % would cause a triple reduction of total emissions (Fig. 2). According to several scientific research results [9], the use of high energy concentrate feeds results in relatively higher animal production and less CH_4 emissions.

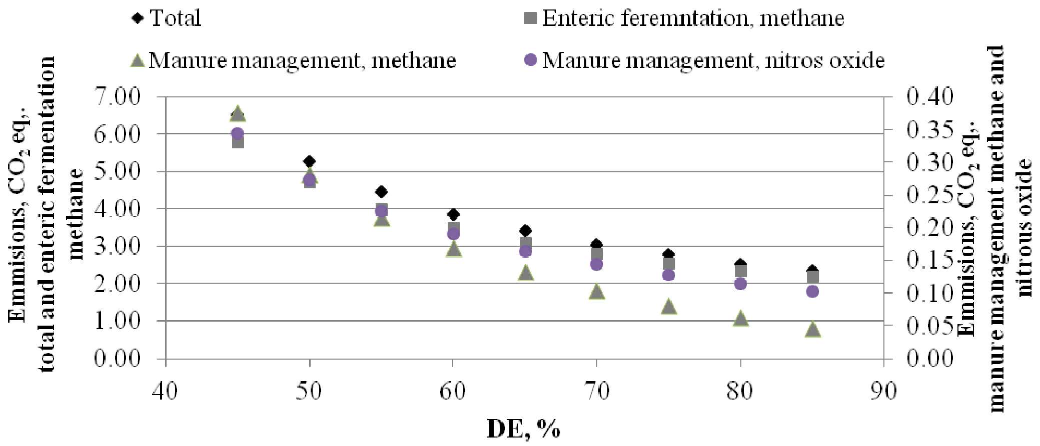

Fig. 2. **Influence of GE on total dairy cow emissions**

3. Manure management

Methane emissions. Amount of GHG emissions from handling and storage of manure depends on the amount of manure produced, its nitrogen content and the proportion that decomposes anaerobically, also temperature, duration and the type of storage are significant parameters for evaluation of emissions [4]. The selection of the Tier 1 emission factor is based on the average annual temperature for the region and its predominant manure management system. The 2006 IPCC guidelines for dairy cows in Western Europe region cool climate zone set the emission factor as 21-29 CH_4 $kg \cdot head^{-1} \cdot year^{-1}$, depending on the assumption that liquid/slurry systems are prevailing and limited cropland is available for manure spreading. The Tier 2 approach for determination of the CH_4 emission coefficient from manure management leads to quantifying of volatile solids produced by livestock, the maximum amount of methane (Bo) that can be produced from manure and the methane conversion factor (MCF). The MCF values vary according to different manure management systems and climate conditions during manure storing.

According to the Tier 2 approach estimated emission coefficient for Latvia in 2013 was 13.2 CH_4 $kg \cdot head^{-1} \cdot yr^{-1}$. The manure CH_4 emission coefficient calculated by Tier 2 was lower than those from Tier 1, because the dominated manure management system for dairy cows in Latvia refers to solid manure.

Nitrous oxide emissions. N_2O emissions occur due to nitrification of ammonium to nitrate, or incomplete denitrification of nitrate under conditions of low oxygen. N_2O emissions are estimated as direct emissions from manure storage, deposited urine and dung on pastures by grazing animals or animal manure applied to soils. In addition, indirect N_2O emissions associated with volatilization of nitrogen in NH_3 and NO_x forms that is considered to be re-emitted as N_2O of stored or land applied manure and nitrogen losses via runoff and leaching from manure storages and agricultural soils are quantified in GHG inventory. For inventory purposes, N_2O emitted directly and indirectly from stored manure is classified under the manure, while remaining emissions are classified under the agricultural soils category.

N_2O emissions from manure management are principally based on the amount of nitrogen excreted from an animal. Total manure management emissions are the product of the amount of nitrogen excreted multiplied by the associated emission factor for each manure management system and animal population. According to the 2006 IPCC methodology, default N_2O emissions factors tend to have lower N_2O emissions for anaerobic systems. Currently IPCC assumes the N_2O emission factor of 0.005 kg $N_2O\text{-}N\cdot(\text{kgN excreted})^{-1}$ for slurry stores with a crust and solid manure storages. N_2O emissions on pasture are evaluated as 0.02 kg $N_2O\text{-}N\cdot(\text{kg N})^{-1}$.

Generally aerobic conditions in manure storage could increase N_2O losses. Apart from manure storage, an important parameter in the calculation of N_2O emissions from manure management is the nitrogen excretion rate per head and year. For example, revision of 2012 national inventory reports of EU-15 shows for dairy cattle nitrogen excretion range of about 40 kg $N\cdot head^{-1}\cdot y^{-1}$ from 100 (Ireland) to 138 kg $N\cdot head^{-1}\cdot y^{-1}$ (Denmark) [5]. National studies data of nitrogen excretion during the year per dairy cow in Latvia reach 118 kg $N\cdot head^{-1}\cdot y^{-1}$.

In contrast to pasture-based systems, confinement of dairy cows and well balanced feeding is characterized as prior to achieve high milk production rates [10]. However, the study of [11], 2012 shows that a general conclusion cannot be made in comparing the carbon footprint of milk produced by pasture-based and confinement feeding strategies. This further illustrates that the use of grazing may not have much impact on the carbon footprint of milk production when compared to confinement feeding. Research results from Georgia also confirm that the carbon footprint of milk production was similar for the pasture based and confinement based dairy [11].

The study of Ross [12] found that improving milk production through livestock feeding and genetics is the most promising approach for reducing GHG from dairy production systems. Also other review made by Knapp [13] of enteric emissions in dairy cattle production expressed priorities of genetic selection for feed efficiency, heat tolerance, disease resistance, and fertility promoting to reduce enteric CH_4 emissions with the potential of 9 to 19 %.

Knapp found that feeding and nutrition have modest (2.5 to 15 %) potential to mitigate enteric emissions due to intensive dairy operations. However, all improvement in animal productivity was found to positively correlate with GHG emissions per animal because higher productivity is usually associated with larger animals and higher feed intake. Looking at single gases CH_4 emissions significantly and positively correlated with output per cow, while N_2O emissions increased with the yield, but not significantly [14].

Figure 3 shows effects on slurry based and solid manure management system emissions involving different pasture lengths for a dairy cow derived according to the 2006 guidelines methodology. The results approve that higher manure CH_4 emissions are applicable to slurry based manure management systems, while enteric fermentation emissions tend to increase by a longer pasture period. Different manure management systems and pasture length lead to emission reduction around 14 % (Fig. 3).

The impact of anaerobic digestion in reducing GHG emissions from dairy cattle slurries and manures has been studied comprehensively and found as the most efficient way to reduce GHG emissions arising from manure management [15; 16]

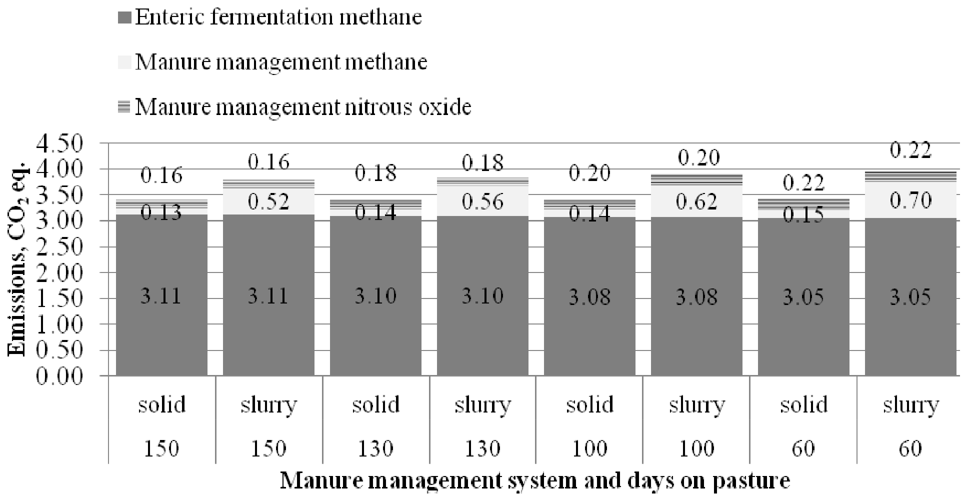

Fig. 3. **Effects on manure management system and pasture length on total dairy cow emissions**

Conclusions

1. Dairy farming is one of the most important contributors of greenhouse gas emissions in the agriculture sector in Latvia responsible for 30.4 % of total agriculture emissions in 2013.
2. The biggest share of GHG emissions from dairy cows is relevant to methane emissions from enteric fermentation. High quality and digestibility of forage is resulting in significant amounts of emissions reduction from dairy farming.
3. Different manure management technologies lead to a slight decrease in GHG emissions per dairy cow. Most valuable reduction of methane and nitrous oxide emissions should be extended to anaerobic digestation.

References

1. “Livestock long shadow: environmental issues and options”, FAO: Rome, 2006. [online] [03.03.2015]. Available at: http://www.fao.org/docrep/010/a0701e/a0701e00.HTM
2. Greenhouse Gas Emissions from the Dairy Sector – A Life Cycle Assessment. FAO: Rome, 2010. [05.03.2015]. Available at: http://www.fao.org/docrep/012/k7930e/k7930e00.pdf
3. Hagemann M., Hemme T., Ndambi A., Alqaisi O., Sultana M. N. Benchmarking of greenhouse gas emissions of bovine milk production systems for 38 countries. Animal Feed Science and Technology. 2011, vol. 166-167, pp. 46-58.
4. IPCC (2006). Agriculture, Forestry and Other Land Use: Emissions from Livestock and Manure Management. In: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, H.S. Eggleston et al. (eds) IGES, IGES, Hayama, Kanagawa, Japan, pp. 10.1-10.87.
5. Technical report No 09/2014 Annual European Union greenhouse gas inventory 1990-2012 and inventory report 2014 Submission to the UNFCCC Secretariat European Commission, DG Climate Action European Environment Agency, 2014. 1294 p.
6. 2030 framework for climate and energy policies. [online] [03.03.2015]. Available at: http://ec.europa.eu/clima/policies/2030/index_en.htm
7. Lauksaimniecības ziņojums 2013 (Agricultural report 1013). [online] [03.02.2015]. Available at: https://www.zm.gov.lv/lauksaimnieciba/statiskas-lapas/lauksaimniecibas-gada-zinojumi?nid=531#jump (In Latvian)
8. Moss A.R., Jounay J.P., Newbold J. Methane production by ruminants: its contribution to global warming. 2000, Ann. Zootech. vol.49, pp. 231-253.
9. Johnson K.A., Johnson D.E. Methane emissions from cattle. 1995, Animal Science Journal, vol. 73, pp. 2483–2492.
10. Winsten J.R., Petrucci B.T. Seasonal Dairy Grazing: A Viable Alternative for the 21st Century. 2003, American Farmland Trust, Washington, DC. 26 p.
11. Belflower J., et al. A case study of the potential environmental impacts of different dairy production systems in Georgia. 2012, Agricultural Systems, vol. 108, pp. 84-93.

12. Ross S.A et al. Effect of cattle genotype and feeding regime on greenhouse gas emissions intensity in high producing dairy cows. 2014, Livestock Science, vol.170, pp. 158-171.
13. Knapp J. R., Laur G. L.,Vadas P. A.,Weiss W. P., Tricarico J. M. Invited review*:* Enteric methane in dairy cattle production: Quantifying the opportunities and impact of reducing emissions. 2014, Journal of Dairy Science, vol. 97, pp. 3231-3261.
14. Gerber P., Vellinga T., Opio C., Steinfeld H. Productivity gains and greenhouse gas emissions intensity in dairy systems. 2011, Livestock Science, vol. 139, pp. 100-108.
15. Amon B., Kryvoruchko V., Amon T., Zechmeister-Boltenstern S. Methane, nitrous oxide and ammonia emissions during storage and after application of dairy cattle slurry and influence of slurry treatment
16. Agriculture, Ecosystems and Environment. 2006, vol. 112, pp. 153-162.
17. Marañón E., Salter A.M., Castrillón L., Heaven S., Fernández-Nava Y. Reducing the environmental impact of methane emissions from dairy farms by anaerobic digestion of cattle waste. 2011, Waste Management, vol. 31, pp. 1745-1751.