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THE POSSIBILITY OF GREENHOUSE GAS EMISSIONS REDUCTION FROM THE DAIRY CATTLE FARMS

Dairy cattle have a significant share in greenhouse gas (GHG) emissions. Therefore, due to the growing demand for milk and milk products, it is worth looking for solutions to effectively reduce the environmental impact of dairy farming. The article reviews the literature on the reduction of greenhouse gas emissions from dairy farms through dietary interventions. Significant reduction in greenhouse gas emissions from dairy farms can be achieved by optimizing dairy cattle and the use of various feed additives. Silvo-pastoralism systems are also important for their ecosystem services, including climate change mitigation.

Keywords: dairy cattle; greenhouse gases; emissions; reduction

I. INTRODUCTION

The European Commission, in July 2016, published a document [Factsheet on the Commission's proposal on binding greenhouse gas (GHG) emission reductions for Member States (2021-2030)] concerning obligatory reduction of greenhouse gas emission in member states. This obligation applies to the agricultural sector, with a recommended reduction in greenhouse gas emission by approximately 30% by 2030 (Regulation (EU) 2018/842).

The agricultural sector still produces almost 20% of the total global GHG emissions, although GHG emissions resulting from agriculture, forestry, and other land-use have almost stabilised over the past 25 years (FAO and GDP 2018). Food production systems are attributable to 25-30% of total GHG emissions, of which 10–12% is a result of livestock activities (FAO and GDP 2018). Total GHG emissions from agriculture were 6.2 ± 1.9 Gt CO_2eq year-1 in 2010-2016, increasing to 11.0 ± 3.1 Gt CO_2eq year-1 including relevant land use. These are likely to increase by about 30%–40% by 2050 (FAO 2018), because the UN estimates that the world population is expected to reach 8.6 billion in 2030, 9.8 billion in 2050 and exceed 11.2 billion in 2100; thus agricultural systems throughout the world will have to provide extra food [Bodirsky et al. 2015]. According to Noiret [2016], with global demand for meat and milk products projected to increase by 73% and 58%, respectively, by 2050 there is increasing concern about the impact for climate change, land degradation, biodiversity loss, and water pollution.

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Livestock farms are the main source of NH_3, CH_4, CO_2 and N_2O as well as soil and water pollution. CO_2, CH_4 and N_2O are identified as greenhouse gases that contribute to global warming [FAO and GDP 2018; Leip et al. 2015]. Methane has an effect on global warming 28 times higher than carbon dioxide, and nitrous oxide is a molecule with a global warming potential 265 times higher than carbon dioxide.

The livestock sector is responsible for anthropogenic greenhouse gas emissions and its level depends on the systems of production and regions, the species and breed of livestock, the animal's genetic potential, nutrition, the herd maintenance system and manure management [Sarteel 2016]. Livestock in low and middle-income countries contribute 70% of the emissions from ruminants and 53% from monogastrics and these can increase as demand for livestock products increases. The global cattle population amounted to about 940 million heads in 2022, up from approximately 937.7 million in 2021 [*www.statista.com*]. World milk production in 2022 is forecast at around 930 million tonnes, up by 0.6 % from 2021, principally driven by volume expansions in Asia with a small gain in Central America and the Caribbean, offset by a sizeable decline expected in Europe. Concerns over climate and dietary desires have diluted milk production and consumption in Europe, but production is growing in Asia, now the world's top milk producer, and overall global trade in dairy products is surging, according to an analysis by Trade Data Monitor [tradedatamonitor.com]. Between 2005 and 2015, the global dairy herd increased 11 % and global milk yield increased by 15 %. Emission intensities, GHG per kilogram of milk, have declined by almost 11 % over the period 2005-2015. However, there is difference in emission intensities between regions: being lowest in developed dairy regions (ranging between 1.3 to 1.4 kg CO_2 eq. kg fat-and-protein corrected milk in 2015) while developing dairy regions such as South Asia, Sub-Saharan Africa, West Asia and North Africa having higher emission intensities (ranging between 4.1 to 6.7 kg CO_2 eq. per kg fat-and-protein corrected milk in 2015) [FAO and GDP 2018]. Cattle are the main source of global livestock GHG emissions (65 - 77%). A comprehensive approach to reduce the environmental burden in the case of milk production should, according to many authors [Little et al. 2017, van Middelaar et al. 2014, Williams et al. 2014], take into account nutrition levels, types of maintenance, manure/slurry and waste management, feed production and transport as well as herd management. Opportunities to reduce emissions in the breeding sector in Europe is estimated from 12% to 61% [Bellarby et al. 2013].

The objective of this article is to show the potential of available strategies for the mitigation of greenhouse gases and ammonia that can be used in dairy cattle farms.

II. MATERIAL AND METODOLOGY

A thematic review of the literature was conducted; the introduction compiled information on the level of greenhouse gas emissions from agriculture, including animal husbandry. Commitments to reduce emissions are indicated. The literature available in the Google Scholar database was reviewed, taking into account the areas considered relevant in terms of modifications in nutrition, methanogenesis, and pasture feeding in terms of reducing greenhouse gas emissions. Keywords included were GHG emissions, methane, dairy cattle, nutrition, reduction, pasture systems, sustainability.

III. RESULTS

Possibilities of GHG and ammonia emission reduction

Feeding of dairy cows and CH_4 and NH_3 emissions

Methane production is positively correlated to feed intake level and ingested amounts of plant cell carbohydrates and fermentable OM [Dijkstra et al. 2011]. One of the basic way of reducing the burden of dairy cattle rearing for the environment is through proper feeding strategies. Despite Moraes et al. [2015] suggestion that dietary manipulation to mitigate CH_4 emissions may be expensive, rationing and balancing of nutrients / diets as well as the enhanced digestibility of feeds should be an essential component of animal production. Dietary changes provide improved production and reduced GHG emissions [Haque 2018]. The selection and proportion of forage used in the feeding of dairy cattle can significantly reduce CH_4 emissions. The production of CH4 in the rumen is influenced by the quality and type of forage [Haque 2018]. Plants in early stages of development contain higher amounts of easily fermenting carbohydrates and less of NDF, therefore they are characterized by higher digestibility. For more mature plants with an increased C:N ratio, CH_4 production is higher. Lower production of CH_4 was found when feeding maize silage to ruminants compared to grass or barley silage [Benchaar et al. 2014]. In addition, maize silage increases milk yields. As partially fermented feed, silage degrades faster in the rumen. Similarly, pre-treatment, e.g. crushing, speeds up digestion. Watt et al. [2015] demonstrated that increasing rumination time enhances feed intake and milk output. Longer ruminating times are linked to decreased methane emission, and lower methane release per milk unit in high-yielding dairy cows fed a maize silage-based partial mixed feed without access to pasture [Mikuła et al. 2022].

The positive effect of feeding with a high proportion of silages on reducing energy and nitrogen loss as well as limitations in methane emission was demonstrated by Benchaar et al. [2014]. However, considerations should be given to the optimal ratio of different silages in TMR rations, as reductions in the digestibility may result in increased CH_4 emission from the droppings during storage. Increased share of silage (alfalfa and maize) in relation to concentrate feed resulted in increased CH_4 and CO_2 emissions in studies by Aguerre et al. [2011]. This could be the result of NDF increases and decreasing share of starch in rations, while retaining protein content at a constant level of 16.2%. The aforementioned authors indicated the lowest emission with a silage level of 47%. Changes in the TMR, regarding the role of carbohydrates in reducing CH_4 emissions are suggested by Haque et al. [2014]. Pereira and Trindade [2015] indicated that besides the better feed-use and its improved digestibility, increased cow productivity in the surveyed farms significantly reduced emissions per 1 liter of milk. With capacity of 10.000 liters of milk per cow per year there was 25 percent less compared to the 6.600 liters per year. The use of high-performance animals requires concentrates. The easily fermentable carbohydrates administered in this form also contribute to lower CH_4 emissions. However, excessive doses of concentrates may disturb the rumen. The greatest potential for reducing GHG and ammonia emissions from dairy cattle husbandry can be obtained, among others, by changing the type of feed administered, increasing the proportion of concentrates, using supplements and feed additives.

According to Liu et al. [2017], recent studies on the estimation of NH_3 and CH_4 emissions due to nutrient or energy losses in the rations gave similar results. Since only 20-35% of nitrogen in feed is secreted in milk, improved digestibility and nutrient use offer the biggest opportunities to reduce emissions of NH_3 and CH_4 [Liu et al. 2012]. As reported by Moate et al. [2011] the addition of fat to feed rations for dairy cows may result in lower methane production by about 3.5%. Patra [2014] investigated the effect of fat addition on methane production, digestibility and fermentation in the sheep's rumen by means of meta-analysis, and comparing it to the results obtained from dairy cattle. The addition of up to 6% of the dry mass of ration, additionally contributed to increased efficiency (with a reduction of CH_4 emissions by 15%).
As reported by Patra [2013], fat supplementation was found to reduce the production of methane. However, excess fat in rations may, according to the author, reduce fiber digestibility. The inhibitory effects of fatty acids on the process of methanogenesis will be more efficient by feeding cattle rations with high proportions of concentrated feed [Patra 2013]. In studies conducted by Caro et al. [2016], regarding transforming traditional feeding systems in 11 regions into modern

systems (including more precise rationing of individual components) enabled factual reductions in greenhouse gas emissions. A higher fat content (6 percent) and fibre reduction (while maintaining total gross energy consumption) facilitated the reduction of CH_4 emissions from intestinal fermentation by 15.7%. Brask et al. [2013] and Bayat et al. [2018] investigated the effect of vegetable fat addition on digestion and fermentation in the rumen resulting in reduced methane production. The resulting methane contributes to significant gross energy losses in the feed. Hellwing et al. [2016] showed, that increasing starch and fat content in rations for dairy cows led to reduced methane conversion rate. Bayat et al. [2018] also demonstrated that the addition of plant oil increased the proportions of unsaturated fatty acids and conjugation of linoleic acid in milk without jeopardizing feed efficiency levels. Efficient herd nutrition, especially the optimization of protein quantity and quality, offers opportunities for optimal balancing of feed rations. Similar opinions concerning the significant role of protein limitations in rations are expressed in literature. Studies by Bougouin et al. [2016], for example, revealed that excess of raw protein in the feed for dairy cows resulted in increased NH_3 emission. However, dietary modifications may interfere with the digestive process. For example, high proportion of concentrates, excessive supply of protein or fat may cause metabolic disorders, such as rumen acidosis or laminitis [Humer et al. 2018]. It can, thus, be argued that the proposed changes in the ration to reduce emissions should not adversely affect animal health and welfare.

Knapp et al. [2014] found that diets with higher energy or greater digestibility can reduce methane output per energy-corrected milk yield. Several innovative treatments, such as dietary supplementation with algae, phytocompounds like saponins and tannins, and essential oils, may help to reduce CH_4, although further research is needed.Williams et al. [2014] demonstrated a significant reduction in methane emissions after the use of various feed additives. Probiotics and prebiotics or other substances contribute to a more efficient functioning of the digestive tract, and hence the improved digestibility and use of feed ingredients result in higher health and efficiency. However, they should be included in the LCA (Life Cycle Assessment), as their production and transport for the nutritional needs of dairy cows may also contribute to GHG emissions.

Limitations to methanogenesis

Interesting results are provided by studies concerning possibilities of reducing the ability of methanogens to stimulate methane production. Hristov et al. [2015], in their studies on using intestinal methane inhibitor (3-nitrooxypropanol), obtained 30% reduction in emissions without any negative impact on the productivity of the animals. Very interesting results in reducing GHG and ammonia emissions by using 3-nitrooxypropanol in beef cattle were also obtained by Romero-Perez et al. [2015].

Machado et al. [2014] and Roque et al. [2019] obtained very promising results regarding the possible use of macroalgae in nutrition. Roque et al. [2019] showed the red macroalgae, *Asparagopsis taxiformis*, as a promising candidate in the biotic methane mitigation strategy for dairy cattle. However, it is necessary to determine the optimal combination and participation of algae in the ration so that gas reduction does not have a negative impact on the fermentation process. The possibility of being vaccinated against methanogens in the rumen was also studied, especially in relation to pasture feeding [Wedlock et al. 2013]. Subharat et al. [2015] investigated the stability of IgA and IgG in rumen fluid *in vitro*. The presence of antibodies in saliva and the rumen was confirmed following the subcutaneous vaccination. However, to achieve the desired effect of methanogenesis, the quantum of antibodies released into the rumen must be considered stable. This also suggests the possibility of using derivatives of plant metabolites and their antimicrobial activity. The possible impacts of tannins on the reduction of CH_4 production were also confirmed.

Jayanegara et al. [2015] studied the effect of purified and hydrolysed, and condensed tannins on methane production, rumen fermentation and structure of microbial population. They found that tannins which undergo hydrolysis (obtained from chestnut and sumac) had better ability to reduce methane concentration because they inhibited the growth and / or activity of methanogens, but the condensed types (from mimosa and quebracho) led to the reduction of fiber digestion. Oskoueian et al. [2013] reported that 4.5% concentration of flavonoids in *in vitro* experimentation reduced methane production significantly without any negative effects on fermentation and rumen's microflora. Durmic et al. [2014] tested the selected feed additives, essential oils and plant extracts for their anti-methanogenic potentials in rumen by using *in vitro* batch fermentation. They obtained significant reductions in methane production (by about 40%, 75% and 14%, respectively), which opens up new perspectives in formulating more efficient feed additives. Patra and Yu [2014], on the other hand, demonstrated that the production of CH_4 and ammonia diminished proportionately with increasing addition of Vanillin, while the essential oils inhibited proteolytic bacteria, thus limiting the production of ammonia. According to Günal et al. [2017], the influence of essential oils on methane emission depends rather on their origin and content in feeds, as there is a risk that some of them may have negative impacts on the fermentation process. Zhan et al. [2017] investigated the effect of alfalfa flavonoids on efficiency, immunity and fermentation in the rumen of dairy cows. Doses of up to 60mg/kg of body weight resulted in improved digestion of protein and fiber, thus yielding enhanced productivity. It has been shown that alfalfa flavonoids can also prevent mastitis by increasing antioxidant abilities and improving non-specific resistance. Disorders in the health of dairy herds often cause a reduction in feed digestibility and in productivity, which results in increased methane emission.

Silvo-pastoralism systems

Pastoralism has been defined as extensive livestock production on rangelands [Davies et al. 2016]. Pastoralism is practised in 75% of countries by nearly 500 million people, most of them in developing countries [McGahey et al. 2014]. A number of industrialized countries promote pastoralism as a multifunctional livestock management system, which provides ecosystem services. It is also gaining acceptance in highly developed countries, such as Australia, China, Europe and the United States. Planned herding of livestock is a common practice that is vital for sustainable development and biodiversity conservation. It is gaining increased popularity, because of its benefits to rangelands and mountain ecosystems [Davies et al. 2016]. It contributes in maintaining soil fertility and soil carbon, water regulation, pest and disease regulation, biodiversity conservation and fire management. Grazing lands cover five billion hectares of land worldwide and sequester between 200-500kg of carbon per hectare per year, thus playing a leading role in curtailing climate change. As reported by Jenet et al. [2016], over half of the world's land area is grazed in various ways: in mixed farming systems, ranching, and by wildlife and through pastoralism. In terms of total emissions, cattle raised on grasslands (which covers both ranching and pastoralism) emits 314 million tonnes (Mt) CO_2 equivalent per year, thus making nomadic herders particularly vulnerable to climate change [Jayanegara et al. 2015]. However, the system has lower emissions per unit of production compared to more intensive production systems, taking into account life-cycle assessment [Appuhamy et al. 2016].

Studies by Bellarby et al. [2013] and Doltra et al. [2018] that demonstrate that dairy production undertaken with the inclusion of grasslands can contribute to reduced emissions do seem interesting. Cattle grazing can also reduce costs of production in real terms, especially in areas where cereal cultivation is impossible. Voglmeier et al. [2019] studied N_2O emissions resulting from pasture feeding and energy/protein ratio differences in two cattle herds in Switzerland. The study showed significantly lower emissions than those reported in the IPCC guidelines for cattle manure left on the pasture. Appropriate nutrient ratios in rations for cattle and appropriate use of pastures, especially in less-favoured areas, can be an alternative in many regions. According to Vasconcelos et al. [2018], improvements in grazing management technology have resulted in a reduction of approximately 29% of equivalent CO_2 emissions per kg of livestock. These authors also emphasized the importance of grazing for the conservation of biodiversity in areas of high natural value. Similarly, Nieto et al. [2018] drew attention to the significant potential of GHG emission reduction with the proper use of pastures and proper herd management. In the studies covering semi-arid regions of Argentina, the authors also indicated the need for multidimensional analyses and comprehensive studies for a reliable assessment of the effects of grazing on climate change.

Muñoz et al. [2021] have conducted an assessment of the feasibility, under grazing management, of including whole oilseeds in the diet of dairy cows as a CH_4 mitigation strategy. Cow type, diet and grazing management were broadly representative of a range of grazing systems for dairy cattle dairy cattle from temperate climates in the southern hemisphere. Diets based on grazed grass were characterised by a roughage: concentrate ratio of approximately 70:30. This feeding regime had little effect on reduction, which may have been related to the physical form of the oil (unprocessed oilseeds), and higher levels of whole oilseed supplementation may be needed to observe greater effects. Dietary supplementation with 41 g rapeseed oil/kg in dry matter reduced daily CH_4 emissions from lactating dairy cows by 22.5% [Chagas et al. 2021].

IV. CONCLUSIONS

Greenhouse gases emissions from dairy cattle remains a significant source of air pollution. However, there are lots of techniques and technologies available that can enhance their reduction. A significant reduction in greenhouse gas and ammonia emissions from dairy farms can be achieved by optimizing the feeding of dairy cattle as well as use of various feed additives. Silvo-pastoralism systems are also important for their ecosystem services, including climate change mitigation. Universal indicators covering all stages of production, e.g. carbon footprint or carbon sequestration of feed plants, and feed and fodder value chains could be used to assess the effectiveness of the reduction technologies used. Extensive research is needed to identify options for combining different practices and technologies to effectively reduce emissions and their potential impacts on animal health, production and welfare.

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MOŻLIWOŚĆ REDUKCJI EMISJI GAZÓW CIEPLARNIANYCH Z FERM BYDŁA MLECZNEGO

Streszczenie

Bydło mleczne ma znaczący udział w emisji gazów cieplarnianych (GHG). Dlatego też, w związku z rosnącym popytem na mleko i jego przetwory, warto poszukiwać rozwiązań pozwalających na skuteczne ograniczenie wpływu hodowli bydła mlecznego na środowisko. W artykule dokonano przeglądu literatury dotyczącej możliwości redukcji emisji gazów cieplarnianych z gospodarstw mlecznych. Znaczne zmniejszenie emisji gazów cieplarnianych z gospodarstw utrzymujących bydło mleczne można osiągnąć poprzez optymalizację żywienia i stosowanie różnych dodatków paszowych. Systemy sylvo-pastoralne są również ważne ze względu na ich usługi ekosystemowe, w tym łagodzenie zmian klimatu.

Słowa kluczowe: bydło mleczne; gazy cieplarniane; emisje; redukcja