Greenhouse gas emissions from ruminant production – mitigation strategies

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Food production results in greenhouse gas (GHG) emissions including carbon dioxide (CO_2) from organic matter decomposition and fossil fuel use, methane (CH_4) from enteric fermentation in ruminants and manure decomposition, and nitrous oxide (N_2O) from manure and artificial fertilizers. On the other hand, agricultural soils also have a potential to sequester carbon, and thus mitigate CO_2 emission. The world's population is increasing, and in many regions of the globe climate change is predicted to reduce food production. Thus, the main challenges will be to optimize food production and find methods to minimize the net GHG emissions. Finding ways to minimize emissions is, however, complicated by interactions and feedbacks among the various agricultural practices. Agriculture is estimated to account for about 13% of total global GHG emissions, In western Europe agriculture, calculated on CO_2-equivalent basis, CH_4 and N_2O each account for about 45% of emissions, whereas CO_2 only accounts for about 10%. Moreover, methane from enteric fermentation in ruminants is estimated to account for as much as 80-85% of the total CH_4 emissions from the agricultural sector. This means that mitigation strategies in ruminant production must focus on the reduction of CH_4 and N_2O.

The aim of this presentation is to discuss the possibilities to reduce GHG emissions from ruminant production.

Nitrous oxide (N_2O)

Nitrogen oxide emissions account for ~10% of GHG, and ~90% is derived from agriculture (IPCC, 2007). Emissions of N_2O are largely a result of two soil microbial processes: nitrification and denitrification. Nitrification is an aerobic process that oxidizes ammonium to nitrate with N_2O as a by-product. Denitrification is an anaerobic process that reduces NO_3^- into N_2, with N_2O as an obligatory intermediate. Model calculations suggest that denitrification is the main source of N_2O in intensive animal agriculture. The largest source of N_2O in animal agriculture is from animal excreta (faeces and urine), recycling of N from fertilizer and biological nitrogen fixation (Clark et al., 2005). Urea is the main N component in urine which is rapidly hydrolyzed in soil to ammonia and subsequently converted to NO_3^-. The main N source in faeces is organic N, which is not as readily available for N_2O production as urine N. This is because the mineralization to ammonia from organic N is a much slower process. Therefore, N in urine is a more potent N_2O source, and thus strategies to reduce N_2O production originating from animal excreta should focus on reduction of N content in the urine. As described, the major portion of N_2O emissions in dairy farming originates from fields with the major sources being N-fertilizers, land applied animal manure, and urine deposited by grazing animals. Increased N-efficiency by the animal is a key to minimizing N_2O-emissions. This means that strategies to reduce N_2O emission must be focused at two levels: 1) at animal level by reducing the content of N in urine and faeces and 2) at the field level by a direct reduction in the N_2O emission or by a higher efficiency in converting soil N into plant biomass. Based on a review article of de Klein and Eckard (2008) Table 1 describes reduction potentials of targeted N_2O abatement strategies from animal agriculture. Based on the technology available today, managing animal diets, fertilizer management and nitrification inhibitors show the best potential for reducing emissions in the short term. The NorFor feed evaluation system is an important tool to optimize protein feeding in cattle. By optimising the PBV and AAT level in the diet it is possible to improve the efficiency in converting dietary protein into milk and meat thus reduce the amount of N that ends up in faeces and urine.

Table1. Estimated reduction potentials of targeted N_2O abatement strategies from animal agriculture (modified after de Klein and Eckard, 2008)

	Reduction potentials, %	
Strategy	N_2O	Urinary N
Animal interventions		
Improved dietary protein to energy ratio		10-45
Diuretic (e.g. salt)	5-10	
Condensed tannins		9-59
Nitrification inhibitor bolus	30-60	
Animal breeding		3
Soil/management interventions		
Fertilizer management	2-13	
Effluent management	50	
Wet season grazing management	7-11	
Soil water management	57-59	
Nitrification inhibitors	61-86	

Methane (CH_4)

Globaly, ruminant livestock annually account for ~28% of the anthropomorphic CH_4 emissions (IPCC, 2007). This represents a production of ~80 million tones. Ruminal CH_4 production is a natural byproduct of anaerobic fermentation, and its production serves as the principal hydrogen (H_2) sink within the rumen. If H_2 is accumulated in the rumen it will inhibit the rumen fermentation. Methane is formed in the rumen by the specialized group of microorganisms called metanogenes by converting H_2 and CO_2 to CH_4. Moreover, ruminal production of CH_4 represents a significant loss of dietary energy (2-12% of the gross energy), thus reducing enteric CH_4 production may also improve feed efficiency. The amount of CH_4 released from the rumen is dependent on the amount of H_2 produced and the supply of alternative electron acceptors which serve as sinks. The rumen fermentation pattern has great influence on the balance between H_2 produced and the amount of available H_2 sinks. Acetate and butyrate production promotes H_2 formation and consequently CH_4 production, whereas propionate is a net sink of H_2. Therefore, the molar percentage of the various volatile fatty acids produced in the rumen, which is dependent on diet composition, affects the CH_4 production. Important nutritional strategies to reduce enteric CH_4 production are presented in Table 2. It is well known that increased concentrate level in the diet reduces the proportion of dietary energy converted to CH_4. This is explained by changes in ruminal pH, fermentation substrate (fibre vs. starch) and microbial populations. Moreover, increased concentrate level will increase animal performance, and thus reduce the amount of CH_4 per unit of animal product. Increased dietary lipid level will reduce enteric CH_4 emission. However, it is important to stress that dietary lipid levels higher than 6-7% in the total diet will reduce fibre digestibility and dry matter intake, and thus reduce feed efficiency. In addition to level of lipid supplementation, fat source and fatty acid profile will affect the CH_4 emission. Refined oils that are high in medium-chain fatty acids (C12:0 – C14:0), such as coconut oil, palm kernel oil, high-laurate rape oil, or pure myristic acid are particularly effective in reducing CH4. However, it is important to stress that a higher content of these acids in the diet will increase the milk fat proportion of medium-chain fatty acids, and thus reduce the milk fat quality for human consumption. Roughage based milk and meat production will probably be even more important in the future. Although not clearly verified, increased forage or pasture quality will reduce the CH_4 emission either by changing ruminal fermenmtation or by increasing animal performance. Use of ionophores, e.g, monensin has shown to reduce CH_4 remission both in vivo and in vitro. However, long term inhibitory effects of ionophores are not well documented and needs to be verified. Furthermore, monensin is prohibited to use in Europe. During the last years, extensive research has been performed to identify the effects of feed enzymes, feed additives and plant secondary compounds on CH_4 production. However, more research is needed before these products can be used in practice.

Table 2. Estimated reduction potentials of targeted CH_4 abatement strategies from animal agriculture (modified from Boadi et al, 2005; Beauchemin et al., 2008)

Strategy	Reduction potentials, %
Increased dietary concentrate level	25
Increased dietary fat level	25-30
Increased forage and pasture digestibility	20-25
Increased proportion of maize silage in grass silage based diets	15
Improved animal productivity	25-30
Ionophore supplementation (e.g. monensin)	11-30
Protozoa inhibitors	20
Plant secondary compounds (e.g., condensed tannins and saponins	2-12
Animal breeding/increased feed efficiency	21

Conclusion

Several strategies can be used to reduce the GHG emission from animal agriculture. Each individual strategy presented in Table 1 and 2 seems rather efficient in reducing GHG emissions. However, several of the treatment comparisons and levels are of no practical relevance. Within today's narrow range in animal performance levels the possibilities to reduce the GHG emissions are much smaller. For example, an increase in dietary concentrate proportion from 0 to 60 % might reduce the CH_4 production by 20-25 %. In a practical feeding situation an increase from 30 to 40 % concentrate in the diet is more realistic, and this will only reduce the CH_4 emission by 3-4%. Nevertheless, strategies to reduce the GHG emissions need to be assessed on a whole farm basis. Reduction strategies should always consider associated emissions, to ensure that reductions in one part of the system do not stimulate higher emissions in another part of the system. It is important to identify the strategies that have the largest reduction in emission for a given production level. When the levels continue to increase, the reduction in GHG per unit of product needs to be greater than the increase in production to ensure that the net effect on GHG emissions is reduced. Supplementation of diets with plant extracts, yeast cultures, or feed enzymes may have a role in future strategies of N_2O and CH_4 mitigation. More research and verification is needed before it can be introduced into practice.

References

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