Reducing the Impact of Livestock Farming on the Environment in Morocco: A Case of Enteric Methane

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ABSTRACT

The study aimed to test the effect of natural additives on enteric methane emissions and animal performances. facial mask system was used to measure the methane emissions before and after adding additives to the animals feed.

The results showed a small but significant ($p<5\%$) effect on methane emission when using sunflower oil, with a reduction of 8.1 per cent. A product rich in thyme essential oils resulted in an average reduction of 21 per cent in the amount of enteric methane emitted, showed highly significant results ($p< 0.01$) on live weight gain in fattening bulls, with means of 1.55 ± 0.058 kg for the control group vs 1.88 ± 0.177 kg for the group that received the additive. The same additive showed an increase in daily milk production in all cows receiving the additive compared to the control cows. The results of the average amounts of milk produced per litre per day were statistically significant ($p< 0.05$), with averages of 15.38 ± 1.32 l/d for the control group and 19.17 ± 1.96 l/d for the group with the additive.

The trials undertaken during this study allowed us to verify the interest and the relevance of using the tested natural feed additives, not only for the decrease of enteric methane emission and the preservation of the environment but also for its beneficial effects on cattle production.

More research should be conducted on natural feed additives to assess their effects on reducing enteric methane emissions, while improving animals performances.

Keywords : Greenhouse gasses, Methane, Livestock Farming, Cattle, Morroco.

INTRODUCTION

Methane (CH_4) is a Green House Gas (GHG) contributing to global warming through its ability to trap heat in the atmosphere. Its global warming potential is 25 times stronger than that of carbon dioxide (1). On a global scale, livestock farming contributes 9 per cent to 11 per cent of total anthropogenic GHG emissions (2)(3). Among many GHGs, methane (CH_4) is the most incriminated agricultural contributor to global warming, with enteric fermentation as the main source of emissions (4). Enteric methane (CH_4) in ruminants results from the anaerobic degradation of ingested plants by the microorganisms present in the digestive tract (5), estimated in 2010 at

2.1 Gt of CO_2 equivalent and 4.3 per cent of global anthropogenic GHG emissions (6). Enteric methane emissions also represent an energy loss of 2 to 12 per cent of the energy contained in the feed ingested by ruminants (7), representing a loss in animal performance.

For these reasons, the development of strategies to mitigate the quantities of enteric methane emitted by animals is the best solution for increasing production efficiency, while reducing the environmental impact of livestock farming. This paper reviewed mitigation measures that Morocco put in place to reduce the impact of livestock farming on the environment using a case of Methane emissions from cattle.

Mechanism of Enteric Methane Production

1.1 Production Mechanism

Bacteria, protozoa and fungi in the rumen hydrolyze plant polysaccharides into monomeric sugars, which are then fermented to produce various products, such as the Volatile Fatty Acids (VFAs) acetate, propionate and butyrate, as well as CO_2 and CH_4 (8). During glycolysis, carbohydrates are oxidized, resulting in the reduction of the electron carrier nicotinamide adenine dinucleotide (NAD+) to NADH, which must then be reoxidized to NAD+ for fermentation to continue (9). Excessive dihydrogen (H_2) in the rumen can inhibit the activity of hydrogenase enzymes, thus limiting sugar oxidation in the absence of other H_2 elimination routes (10). Methanogenesis contributes to rumen efficiency by preventing an increase in H_2 partial pressure, thereby promoting the function of microbial enzymes involved in electron transfer reactions, such as NADH dehydrogenase (11). During the methanogenesis pathway (hydrogenotrophic methanogenesis) carried out by rumen methanogens, H_2 is oxidized to H+, and CO_2 is reduced to form CH_4 (12). However, CH_4 can also be produced by the reduction of methyl compounds and acetate via methylotrophic and acetoclastic methanogenesis, respectively. After its synthesis in the rumen, most enteric CH_4 is expelled from the rumen by eructation (13).

1.2 Methanogenic Archaea

Methane is produced by methanogenic archaea, a phylogenetically diverse group of microorganisms (14). There are two main pathways for methanogenesis in the rumen, and both carried out by archaea depending on species and substrate availability. The hydrogenotrophic pathway converts H_2 and CO_2 produced by protozoa, bacteria and fungi during the degradation and fermentation of ingested feed into CH_4 (15)(16). Formate, a natural product of fermentation, can also be used by all ruminal archaea ; it is equivalent to H_2 + CO_2, and is included in the hydrogenotrophic category (17, 18). A second substrate category for methanogenesis are methyl groups, such as those in methyl amines and methanol (19). Acetic methanogenesis (with acetate) does not appear to be an important source of methane in the rumen and has only been observed in exceptional cases (20). In the metabolic pathway in ruminants, acetate and butyrate production release pure hydrogen, while propionate formation creates a competitive pathway for H+ utilisation in the rumen (21).

In the rumen, methanogenic Archaea occupy four different niches: free in ruminal fluid, attached to solid feed particles, attached to rumen epithelium or in ecto-or endo-symbiosis with protozoa (22). Methanogen populations are highly diverse, with an increasing number of new methanogens being discovered thanks to the advent of molecular techniques (23). Methanogen diversity can be affected by inter-animal variation, diet, geographic region, rumen sampling and methodology (24)(25).

Mitigation Strategies

Feed supplements and additives have been extensively studied for their potential to reduce enteric CH_4 emissions in ruminants (26)(27). Diet modification can be a good strategy for methane reduction in ruminants.

1.1 Methane inhibitors

Various methane inhibitors are added to the feed ration to prevent energy losses in the form of methane emissions in ruminants, thus achieving economic and ecological gains. One such agent, bromomethane, inhibits methane production by reacting with coenzyme M, which is involved in the final stage of methane formation (28). (29) stated that 3-nitrooxypropanol is a potential candidate as a feed additive due to its methane mitigation effects, without negative effects on animal performance. Nitrate, nitrite and 2-bromoethanesulfonic acid have also been shown to reduce methane production in vitro and in vivo (30)(31). Other inhibitors were tested for their effect on enteric methane production. The inhibitors synthesised proved highly effective in inhibiting methanogenesis in the rumen when added to the diet as additives (32). However, many of these compounds are highly toxic, cause undesirable side effects or only transiently reduce methanogenesis. When choosing a feed additive, in addition to effectiveness and efficiency, possible toxicity to the ruminant and potential environmental impacts or undesirable side effects must be considered.

1.2 Plant Extracts

Recently, plant and herb extracts have been successfully used to replace antibiotics and feed additives in the livestock industry. Among them, materials extracted from plants (33), essential oils (34), saponins (35), tannins (36) and organosulfides (37) have shown promising results in improving rumen microbial population and nitrogen metabolism, reducing methane production and improving overall animal health and performance.

In Morocco, many experiments have been conducted to test the effects of plant extracts on enteric methane production. The energy metabolism laboratory in Agronomic and Veterinary Institute Hassan II is the only laboratory to perform measurements on animals using a face mask methane collection system. The studies were financially supported by the Moroccan Ministry of Environment. The production of methane was measured by indirect calorimetry (an open circuit) using a collecting gas mask, put on the face of the animal for several hours, after the morning feeding. Details on the methane measurement system are shown in Figure 1. The calibration of the system consists of the injection of nitrogen in the methane analyser to adjust for the zero methane gas, followed by the injection of gas containing methane with a known concentration to adjust for span gas.

The results of the study showed that sunflower oil had a small but significant ($p<5\%$) effect on methane emission, with a reduction of 8.1 per cent (38). The affordable cost of this additive makes it a promising component for reducing emissions of enteric methane in the atmosphere. Another study showed more interesting methane reduction results and improved animal production performances (39). In this study, the addition of a product rich in thyme essential oils to the cows' diet resulted in an average reduction of 21 per cent in the amount of enteric methane emitted. The same product was used to test its effect on live weight gain in fattening bulls and showed highly significant results ($p < 0.01$), with means of 1.55 ± 0.058 kg for the control group vs 1.88 ± 0.177 kg for the group that received the additive. A third trial was conducted to test the effect of the same additive on milk production. An increase in daily milk production was noted in all cows receiving the additive compared to the control cows. The results of the average amounts of milk produced per litre per day were statistically significant ($p < 0.05$), with averages of 15.38±1.32 l/d for the control group and 19.17±1.96 l/d for the group with the additive. Milk fat was also improved in the cows that were supplemented with the additive, with an average of 3.54±0.26 g/100 g in the control group vs 3.66±0.34 g/100 g of milk in the group with the additive. However, the results obtained for the milk fat showed no statistical significance ($p > 0.05$) (40). The trials undertaken during this study, allowed the researchers to verify the interest and the relevance of using the tested natural feed additives, not only for the decrease of enteric methane emission and the preservation of the environment but also for its beneficial effects on cattle production.

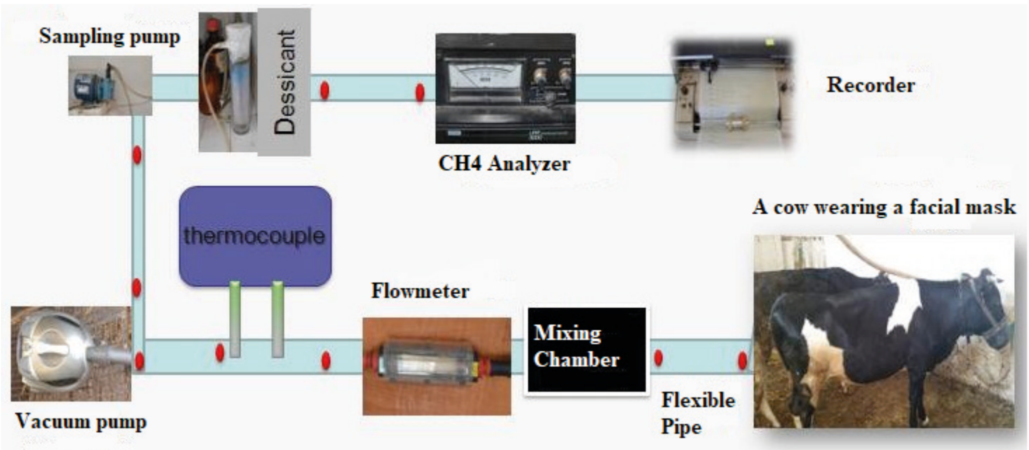

Figure 1 : Methane measurement system (Energy metabolism lab. IAV Hassan II).

1.3 Algae

Microalgae and macroalgae have been successfully tested as feed additives (41, 42). (43) were the first to identify red algae with methanogenesis-reducing properties.

CONCLUSION

The methane emitted by ruminants is a major contributor to greenhouse gas (GHG) emissions and represents a loss of energy for the animals. Global demand for meat and milk continues to rise, driven by a growing population, increased economic development and a concomitant rise in demand. Nevertheless, we can expect increasing pressure on the livestock industry to reduce its impact on the climate through land-use change and enteric fermentation, where the greatest leverage for action lies. Strategies have been developed and studied to reduce its production while maintaining herd productivity and health. These strategies have the potential to reduce methane production effectively; however, the question of the «best» approach has yet to be answered. This is a challenge that requires further research and attention.

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