academicJournals

Vol. 10(25), pp. 2501-2505, 18 June, 2015
DOI: 10.5897/AJAR2014.8686
Article Number: E5057BB53510
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Review

Synergistic effect of methane emission through ruminant production

T. O. Ososanya* and T. O. Faniyi

Department of Animal Science, University of Ibadan, Ibadan, Nigeria.

Received 14 March, 2014; Accepted 19 May, 2015

The world we live in is not in isolation, therefore every action undertaken by humans and animals have a direct effect on humans. Some sort of boomerang effect. Methane is produced mostly by anaerobic microbial metabolism in the rumen and sent out through eructation into the environment. Methane and other gases such as carbon dioxide and nitrous oxide (CO_2 and N_2O) have been giving great concern worldwide as they represent greenhouse gases (GHG). Though produced as a result of the actions of methanogens (bacteria) within the rumen, methane gas portend grave consequences through global warming and other negative effects as it relates to interaction between the environment and living things. Hence, this paper discusses the effects of methane, the producers and action of production and mitigation strategies are all reviewed in this study.

Key words: Methanogens, rumen, livestock production, environment, mitigation strategies.

INTRODUCTION

Livestock producers are confronted with a lot of challenges culminating into pressure through public interactions or complaints about maintaining a healthy, balance atmosphere and adoption of welfare friendly environments Aluwong et al. (2011). Similarly, Steinfield et al. (2006) identified ruminants as a major contributor to greenhouse gases. It is a well-known fact that livestock especially ruminants play a leading role in methane emissions. Enteric fermentation and manure production represents about 80% of agricultural methane emissions and about 35 to 40% of the total anthropogenic methane emissions (Gerber et al., 2007). Furthermore, Hegarty et al. (2010) reported that the release of methane from livestock production is produced by anaerobic microbial metabolism in the digestive tract and in manure, also, the release of nitrous oxide from agricultural soils are both greenhouse gases (GHG).

Cole et al. (1997) reported that methane production through enteric fermentation is of great concern worldwide due to its contribution to the accumulation of greenhouse gases (GHG), mainly carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in the atmosphere. This contribution has increased the temperature of the earth surface. Wang and Chen (2009) opined that accumulation of these greenhouse gases are known to be increasing at the rate of 0.3 to 0.9% per annum due to natural (wetland, termites, oceans and fresh water, e.t.c.) and anthropogenic effects (that is, landfills, ruminants, wasteland, energy, biomass burning, e.t.c.) on the carbon and nitrogen cycles.

Ruminants have been widely reported to be one of the major contributors to these GHG and almost 50 to 80%

*Corresponding author. E-mail: tosossanya85@gmail.com

of all the methane emission comes from the agricultural sector especially ruminants (NRC, 2002; Steinfield et al., 2006). Ruminant animals with low levels of production efficiency have relatively high methane emissions per unit of product. This situation results because these animals use a large fraction of their feed intake solely for maintenance (that is, for the basic metabolic processes required to stay alive). Methane emissions associated with this “maintenance” feed intake are spread over a relatively small level of production, resulting in a high level of emissions per unit product. In animals with higher levels of production efficiency, the “maintenance emissions” are spread out over a larger amount of production, thereby reducing methane emissions per unit product (although emissions per individual animal may be higher).

UNFCCC (2007) and Aluwong et al. (2011) reported that methane has a radioactive effect on the climate; its potential on global warming for over a decade is 21 times above that of CO_2 while CO_2 has a serious effect on ozone formation. Forster et al. (2007) and Hook et al. (2010) reported that methane is a potent trace gas due to its effect on global warming. It is the second largest anthropogenic greenhouse gas, behind CO_2, it is estimated to have a total concentration of 1774 ± 1.8 parts per billion (ppb). Methane is a colourless and odourless gas. Its production in the rumen occurs as a by-product of microbial (anaerobic) fermentation of feed through the presence of a group of microorganisms referred to as methane producing bacteria known as methanogens. Methanogens reside in gastrointestinal tract of ruminants. These organisms play an important role in converting organic matter to methane (that is, use the hydrogen and carbon dioxide produced as end products of microbial digestion to generate energy for growth producing CH_4 as an end product). Kimberly et al. (2004) reported that the microbial activity (bacteria, protozoa and fungi) in rumen hydrolyses, the dietary organic matter to amino acid and sugars and these will now be fermented anaerobically to volatile fatty acids (VFAs), hydrogen; CO_2 and other end products. Methanogens then reduces carbon dioxide to methane, preventing the accumulation of hydrogen. When hydrogen ions accumulate in the rumen environment, it results in the decline of pH, and subsequent inhibition of many organisms that are essential for fibre digestion.

$$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$$

In this reaction, CO_2 combines with H_2 to produce CH_4. The methane from ruminants is produced by methanogens. These microbes are responsible for between 0.25 to 0.37% of the total methane produced O’Mara (2004). Methanogens work at their optimal level in anaerobic conditions and most of the microbes in the rumen are anaerobes. Factors such as the type of carbohydrate in the diet, level of feed intake, digester passage rate, presence of ionophores, lipids in the diet and ambient temperature influence the emission of methane from ruminants (McAllister et al., 1996).

In order to decrease the methane production, these vital factors must be taken into consideration: Acetate and butyrate are the principal fermentation products of protozoa. Removal of protozoa population will cause shift in fermentation of the substrate from acetate and butyrate to propionate and decrease the formation of methane (McAllister et al., 1996).

Bell and Eckard (2012) summarised the process of methanogenesis thus:

1. Glucose equivalents from plant polymers or starch are hydrolysed by extracellular microbial enzymes to form pyruvate in the presence of protozoa and fungi in the digestive tract:

$$\text{Glucose} \longrightarrow 2\ \text{Pyruvate} + 4H$$

(Embden-Meyerhof-Parnas pathway);

2. According to Moss et al. (2000), the fermentation of Pyruvate involves oxidation reactions under anaerobic conditions producing reduced co-factors such as NADH. Reduced co-factors such as NADH are then re-oxidised to NAD to complete the synthesis of volatile fatty acids (VFAs) with the main products being acetate, butyrate and propionate:

2H producing reactions:

$$\text{Pyruvate} + H_2O \longrightarrow \text{acetate (C2)} + CO_2 + 2H$$

2H using reactions:

$$\text{Pyruvate} + 4H \longrightarrow \text{Propionate (C3)} + \text{H2O}$$

$$2C_2 + 4H \longrightarrow \text{butyrate (C4)} + 2H_2O$$

$$CO_2 + 8H \longrightarrow \text{methane } (CH_4) + 2H_2O$$

3. The VFAs are then available for absorption through the digestive mucosa into the animal’s blood stream. The production of acetate and butyrate provides a net source of hydrogen available for utilization by propionate. Thereafter, methanogens eliminate the available hydrogen by combining with carbon dioxide (CO_2) to produce methane:

$$4H_2 + CO_2 \longrightarrow CH_4 + 2H_2O$$

The molar percentage of the different volatile fatty acids produced during fermentation influences the production of methane in the rumen. Acetate and butyrate promote methane production while propionate formation can be considered as a competitive pathway for hydrogen use in the rumen.

Bell and Eckard (2012) reported an inverse relationship between the production of methane in the rumen and the presence of propionate. If the ratio of acetate to propionate was greater than 0.5, then hydrogen would become available to form methane. If the hydrogen produced is not correctly used by methanogens, such as when large amounts of fermentable carbohydrate are fed, ethanol or lactate can form, which inhibits microbial growth, forage digestion and any further production of VFAs. In practice, ethanol or lactate may form, but any excess hydrogen is simply eructated.

Zhou et al. (2011) reported that rumen methanogenesis result in the loss of 6 to 10% of gross energy intake or 8 to 14% of the digestible energy intake of ruminants. This losses varies based on the species, geographical location, feed quality, feed intake, feed composition and processing of the feed (Okine et al., 2004; Cottle et al., 2011).

Methanogens are unique and a distinct group of microorganisms. They are nutritionally fastidious anaerobes that grows in an environment with a redox potential and at neutral pH between 6 and 8 while some grow under extreme pH 3 to 9.2 (Jones et al., 1987; Stewart and Bryant, 1988). Methanogens belongs to group Archea and phylum Euryarchaeota and unlike bacteria; they lack peptidoglycan in their cell wall which is replaced by pseudomurein, heteropolysaccharide and protein. They possess three co - enzymes which have not been found in other microorganism. Methanogens use the process of formation of CH_4 to generate energy for growth and the substrate used in the process include H_2, CO_2, formate, acetate, methanol, methylamines, dimethyl sulfide and some alcohol (Boadi et al., 2004).

In ruminants, 87 to 93% of methane production occurs in the foregut, with the highest rate of production coming after eating. In sheep, almost 90% of the methane produced in the hindgut has been found to be absorbed and expired through the lungs, with the remainder being excreted through the rectum (Murray et al., 1976). Rectum enteric methane losses have been estimated to be 7% by Grainge et al. (2007) and 8% by Tamminga et al. (2007) of methane output in dairy cows compared to 1% found in sheep (Murray et al., 1976).

If the quantity of methane produced by the livestock can be decreased, it may also decrease carbon footprint; consequently, it may increase the efficiency of feed utilization and decrease production costs. One area of decreasing ruminal methane production is to increase the production of volatile fatty acid, that is, increasing the propionate proportion by the ruminal microbial population. Propionate is used more efficiently by ruminants than other volatile fatty acids, increase in propionate production can decrease the quantity of feed required per unit of weight gain. Kobayashi (2010) summarised that methane emitted from ruminants is regarded as a loss of feed energy and a contributor to global warming. Methane is the most prominent sink for hydrogen synthesized in the rumen. Methane contains gross energy therefore, its emission during rumen fermentation is considered to be a loss of energy equivalent to 2 to 12% of the gross energy of animal feed Kobayashi (2010).

Another negative aspect of methane emission from ruminants is the possible contribution to global warming. Annual methane production from cattle accounts for 15 to 20% of global methane production. This level of production corresponds to 3 to 5% of global CO_2 production when converted to CO_2 based on the global warming effect of methane (IPCC, 2001).

The main health hazard associated with methane is that it is highly combustible. Mixtures of 5 to 15% methane in air can be explosive. Also, large concentrations of methane in enclosed areas can lead to suffocation; as large amounts of methane will decrease the amount of available oxygen in the air. The effects of oxygen deficiency are nausea, headaches, dizziness and unconsciousness. Utility companies that use natural gas add a small amount of smelly, sulfur-containing compounds so that gas leaks can be detected before methane concentrations are large enough to cause suffocation or explosions.

By far the most important non - CO_2 greenhouse gas is methane, and the number one source of methane worldwide is animal agriculture. It is responsible for nearly as much global warming as all other non-CO_2 greenhouse gases put together. Methane is 21 times more powerful as greenhouse gas than CO_2. While atmospheric concentrations of CO_2 have risen by about 31% since pre-industrial times, methane concentrations have more than doubled. Whereas human sources of CO_2 amount to just 3% of natural emissions, human sources produce one and a half times as much methane as all natural sources. In fact, the effect of methane emissions may be compounded as methane-induced warming in turn stimulates microbial decay of organic matter in wetlands.

With methane emissions causing nearly half of the planet's human-induced warming, methane reduction must be a priority. Methane is produced by a number of sources, including coal mining and landfills; however, the number one source worldwide is animal agriculture.

Mitigation strategies

Many reviews are available and many researches are still ongoing on how to mitigate methane emission especially in ruminant production area (Moss et al., 2000; Boadi et al., 2004; O'Mara, 2004; Aluwong et al., 2011) with respect to nutrition and influence on the rumen microbes in the rumen. To provide solution to this issue and hitherto to nutrition, successful mitigation practices must account for the rumen micro biota / a proper understanding of the rumen ecology must be well grasped (Martin et al., 2010). Zhou et al. (2011) reported that various methane mitigation methods have been applied (McAllister et al., 1996; Martin et al., 2010), such as defaunation (Ushida et al., 1997), dietary inclusion of monensin (Van Nevel and Demeyer, 1977), redirection of reducing equivalents to alternate acceptors (Johnson and Johnson, 1995) and stimulation of methanogens competitors such as acetogens (Leedle and Greening, 1988). However from their conclusion, it was observed that many of these approaches were not authenticated through microbial adaptation shortly after the application of all these methods, and to this regard long-term effect of methane mitigation methods needs to be sourced.

Conclusion

However, the following mitigation strategies are to be considered: The feeding of highly digestible forages for grazing and confined cattle, inclusion of legumes in forage mixtures, supplemental fats in diets and dietary additives that manipulate rumen function and On-farm practices.

On farm practices include: Improvements in efficiency through application of best practice in 'on-farm' management, the application of animal genetics and improved feed quality (that is, Genetic selection for production traits, feed testing and ration balancing, pregnancy testing will reduce enteric CH_4 emissions by reducing feed costs associated with animal maintenance).

In a bid to mitigate against methane emission, use of probiotics should be explored for their mitigation potentials. Biotechnological solutions based on the introduction of new or modified microorganisms to the animals, immunological and hormonal control of gut function, or the use of genetically modified crops and/or animals.

Areas that require long term research support include: The potential for selection of low methane emitting animals and the development of products to inhibit methanogenesis, provide alternate electron acceptors, or reduce rumen protozoa populations.

Conflict of Interest

The author(s) have not declared any conflict of interest.

REFERENCES

Aluwong T, Wuyep PA, Allam L (2011). Livestock - enviroment interactions: Methane emissions from ruminants. Afr. J. Biotechnol. 10(8):1265–1269.

Boadi D, Benchaar C, Chiquette J, Masse D (2004). Mitigation strategies to reduce enteric methane emissions from dairy cows: Update review. Can. J. Anim. Sci. 84(3):319-335.

Cole CV, Duxbury J, Freney J, Heinemeyer O, Minami K, Moseir A, Paustian K, Rosenberg N, Sampson N, Sauerbeck D, Zhao Q (1997). Global estimates of potential mitigation of greenhouse gas emissions by agriculture. Nutrient Cycling in Agroecosystems 49:221–228.

Cottle DJ, Nolan JV, Wiedemann SG (2011). Ruminant enteric methane mitigation: A review. Anim. Prod. Sci. 51:491–514.

Forster P, Ramaswamy V, Artaxo P (2007). "Changes in atmospheric constituents and radiative forcing" in Climate change 2007: The physical science basis. Contribution of working group 1 to the fourth assessment report of Intergovernmental Panel on Climate Change, S. Solomon, D. Qin, M. Manning et al., Eds., Cambridge University Press, Cambridge, UK.

Gerber P, Wassenaar T, Rosales M, Castel V, Steinfield H (2007). Environmental impacts of a changing livestock production: overview and discussion for a comparative assessment with other food production sectors. In D. M. Bartley, C. Brugere, D. Soto, P. Gerber and B. Harvey (eds). Comparative assessment of the environmental costs of aquaculture and other food production sectors: methods for meaningful comparisons. FAO/WFT Expert Workshop, 24 – 28 April, 2006. Vancouver, Canada. FAO Fisheries Proceeding, No. 10. Rome, FAO 2007. pp. 37–54.

Grainge C, Clarke T, McGinn SM, Auldist MJ, Beauchemin KA, Hannah MC, Waghorn GC, Clark H, Eckard RJ (2007). Methane emissions from dairy cows measured using the sulphur hexafluoride (SF6) tracer and chamber techniques, J. Dairy Sci. 90:2755-2766.

O'Mara F (2004). Greenhouse gas production from dairying: Reducing methane production. Adv. Dairy Technol. 16:295–309.

Hegarty RS, Alcock D, Robinson DL, Goopy JP, Vercoe PE (2010). Nutritional and flock management options to reduce methane output and methane per unit product from sheep enterprises. Anim. Prod. Sci. 50:1026–1033.

Hook SE, Wright AG, Mcbride B W (2010). Methanogens: Methane producers of the rumen and mitigation strategies. Hindawi Publishing Corporation, doi:10.1155/2010/945785.

Intergovernmental Panel on Climate Change (2001). "Intergovernmental Panel on Climate Change'' in Climate Change 2001: A Scientific Basis, J. T. Houghton, Y. Ding and D. J. Griggs, Eds., Cambridge University Press, Cambridge, UK.

Johnson KA, Johnson DE (1995). Methane emissions from cattle. J. Anim. Sci. 73:2483–2492.

Jones WJ, Nagle DP, Whitman WP (1987). Methanogens and the diversity of archaebacteria. Microbiol. Rev. 53:135–177.

Kobayashi Y (2010). Abatement of methane production from ruminants: Trends in manipulation of rumen fermentation. Asian – Australian J. Anim. Sci. 23(3):410–416.

Leedle JA, Greening RC (1988). Postprandial changes in methanogenic and acidogenic bacteria in the rumens of steers fed high or low forage diets once daily. Appl. Environ. Microbiol. 54:502- 506.

Martin C, Morgavi DP, Doreau M (2010). Methane mitigation in ruminants: from microbe to the farm scale. Animal 4:351–365.

McAllister TA, Okine EK, Mathison GW, Cheng KJ (1996). Dietary, environmental and microbiological aspects of methane production in ruminants. Can. J. Anim. Sci. 76:231–243.

Moss AR, Jouany JP, Newbold J (2000). Methane production by ruminants: its contribution to global warming. Ann. Zootech. 49:231–253.

Murray RM, Bryant AM, Leng RA (1976). Rates of production of methane in the rumen and large intestine of sheep. British J. Nutr. 36: 1-14.

NRC (National Research Council). Committee on Animal Nutrition (2002). The Scientific Basis for Estimating Air Emissions from Animal Feeding Operations: Interim Report. Available: http://www.nap.edu/catalog/10391.html?se_side. [Accessed 25 January 2006].

Okine EK, Basarab JA, Laki A, Goonewardene LA, Mir P (2004). Residual feed intake and feed efficiency: differences and implications. Florida Ruminant Nutrition Symposium. University of Florida. Available at http://dairy.ifas.ufl.edu/files/rns/2004/Okine.pdf[verified 4 August

2010]

Steinfield H, Gerber P, Wassenaar T, Castel V, Rosales M, De Haan C (2006). Livestock's Long Shadow: Environmental Issues and Options. Food and Agriculture Organization of the United Nations, Rome, Italy Stewart CS, Bryant MP (1988). The rumen bacteria in: Hobson P.N. (Ed.), The Rumen Microbial Ecosystem, Elsevier Applied Science, New York, pp. 21–75.

Tamminga S, Bannink A, Dijkstra J, Zom R (2007). Feeding strategies to reduce methane loss in cattle. Report 34, Animal Science Group. http://edepot.wur.nl/28209.

UNFCCC (2007). United Nations Framework Convention on Climate Change .http:unfccc.int/ghg_emissions_data/information_on_data_sources/global_warming_potentials/items/3825.phpForster *et al.* 2007

Ushida K, Tokura M, Takenaka A, Itabashi H (1997). Ciliate protozoa and ruminal methanogenesis. In: Rumen Microbes and Digestive Physiology in Ruminants ed. Onodera, R., Itabashi, H., Yano, H. and Sasaki, Y. Tokyo: Japan Scientific Society Press. pp. 209–220.

Van Never CJ, Demeyer DI (1977). Effect of monensin on rumen metabolism in vitro. Appl. Environ. Microbiol. 34: 251–257.

Wang ZW, Chen S (2009). Potential oil - based biofuels production. Appl. Microbiol. Biotechnol. 83:1-18.

Zhou M, Chung YH, Beauchemin KA, Holtshausen L, Oba M, McAllister TA, Guan LL (2011). Relationship between rumen methanogens and methane production in dairy cows fed diets supplemented with a feed enzyme additive. J. Appl. Microbiol. 111:1148–1158.