Short Review of Global Methane Situation and of Facilities to Reduce in Ruminants in Third World Countries

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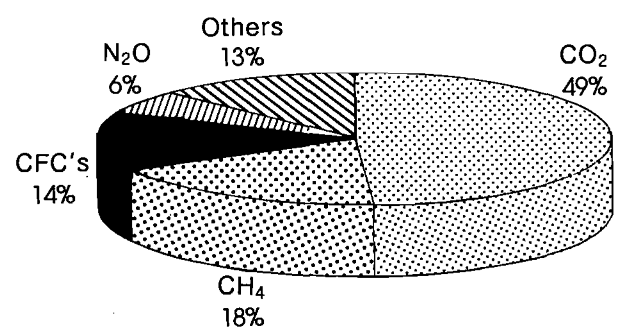
ABSTRACT : This paper analyses a number of important areas relating to methane production in ruminants, consequent hazards and different methods of reducing this gas. Clearly methane not only affects on the environment but also on the economy of animal production. Several factors including feed, species, microbes, rumen environment, etc. are responsible for methane production in animals. Although methane production can be reduced by chemical manipulation, defaunation and strategic feeding, the latter was found to be effective because the method is easier to follow than the others. Furthermore, feeding technology could play an important role in reducing methane production particularly in developing countries because of its relative cost effectiveness. However, it needs to compare to what extent it could reduce methane production as well as cost of animal production. Therefore, research program needs to be concentrated on the appropriate feeding system to reduce methane production, consequently pollution and cost of production particularly in developing countries.
(**Key Words:** Methane, Ruminants, Pollution, Feeding Strategy)

INTRODUCTION

The greenhouse effect is mainly caused by carbon dioxide, chlorofluorocarbons (CFC_{11} and CFC_{12}), hydrochlorofluorocarbons, methane and nitrous oxide (figure 1).



Source : Singh, 1993

Figure 1. Relative contribution of greenhouse gases to global warming (%).

It causes depletion of stratospheric ozone layer, global warming followed by rising of sea levels as well as health hazards (IAEA, 1992; Singh, 1993; White and McGovern, 1993). Carbon dioxide is the greatest proportion of greenhouse gases that produces mainly as a result of burning fossil fuel. Methane is the second largest source of anthropogenic greenhouse gases produces mostly from agricultural activities (from paddy fields and ruminants). Likewise, nitrous oxides are mostly the results of agricultural activities but CFC's are being produced from the industrial activities. A comprehensive description of different aspects of greenhouse gases is given in table 1.

About 300 million ton of methane is producing annually in the atmosphere, 30% (about 80 million ton) of which is from ruminants (Leng, 1991; Singh, 1993). It is a matter of concern that methane is increasing in the atmosphere at about 1% per year. Although the rate is only 1/100 that of carbon dioxide, its relative effectiveness is 21% higher for global warming potential than carbon dioxide (IAEA, 1992; White and McGovern, 1993; Huque and Stem, 1994). As livestock being the major anthropogenic source of methane, controlling its emission are, therefore, has become an important component of the world-wide campaign to prevent global warmimg. Controlling methane emission is also important for economical issues. Methane production in animals during the process of fermentative digestion and metabolism represents a loss of food energy. It was estimated that methane account for 15% of the loss of DE intake of feed (Singh, 1993). This is a major loss because

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two-thirds of the production cost of animals represents cost of food (Rahman et al., 1990). It was observed that methanogenic energy loss is high particularly on low quality roughages such as straw based diet. Straw is the principal feed for vast majority of ruminants in developing countries. Evidently methane emission and thereby loss of food is also higher in developing countries. Appropriate technology can reduce its emission as well as feed cost. Chalupa (1980) stated that complete or partial reduction of this loss increases both liveweight and feed conversion efficiency. Therefore, research needs to be concentrated in understanding the mechanisms to reduce methane production not only for environmental sake but also vital for economic reason.

Table 1. Contribution of greenhouse gases to climate change

Gases	Sources	Emissions (1990, MT)	Concentration in atmosphere (ppm)	Cut in emissions needed to stabilise concentration (%)	Annual increase in concentration (%)	Global warming potential*
Carbon dioxide	Burning fossil fuels and forests, cement making	26,000	354	60-80	0.5	1
Methane	Rubbish dumps, paddy fields, cattle, tarmac, coal mining, gas leaks	300	1.72	15-20	0.9	21
CFCs, HCFCs	Coolants for fridges, air conditioners, foam blowing agents, electronics, solvents, aerosols	1	0.001	70-85	4	6,000
Nitrous oxide	Burning fossil fuels and forests, fertilisers	6	0.31	70-80	0.25	290

Source: White and McGovern, 1993.

MT, metric ton: ppm, parts per million;

* A measure of how much warming one tonne of the gas causes over a century, relative to one tonne of carbon dioxide.

METHANE PRODUCTION IN RUMINANTS AND RELATED FACTORS

To control methane production in ruminants, it is very important to know the factors associated and the mechanisms of methane production. A brief description of the factors responsible and the mechanisms of methane production in ruminants are given below.

Gaseous products in the rumen

The end products of fermentation of all diets in ruminants are volatile fatty acids (acetate, propionate and butyrate) and different gases. The composition of the gases produced in the rumen are carbon dioxide (40%), methane (30-40%), hydrogen (5%) together with small and varying proportions of oxygen and nitrogen (McDonald et al., 1983). Rate of gas production varied greatly and the rate is very high immediately after feeding which may go beyond 30 liter(*l*) h^{-1} (McDonald et al., 1983).

Methanogenesis

The process by which methane is formed is called methanogenesis. Methane is an electron sink product that produces in the rumen in strictly anaerobic condition. The basic reaction by which methane is formed in the rumen is the reduction of carbon dioxide and hydrogen, some of which may derive from the formate. Methane is produced by a highly specialized biochemical process done by bacteria called methanogenic bacteria. Methanogenesis is a complicated process that involves folic acid and vitamin B_{12}, coenzyme M, fatty acid, 2-methyl butyrate (Taylor et al., 1974).

As the product of the fermentation is volatile fatty acids, formate and hydrogen, the methanogens use the formate and hydrogen plus carbon dioxide to form methane. Molecular hydrogen produced in a recycled oxidative process during ATP generation. The hydrogen is vital for methane production because methanogenic bacteria gained energy from methane by combining hydrogen and CO_2. Methane and CO_2 produced are expelled through eructation. However, methanogenesis can be restricted by favoring the conditions to produce propionate as propionate uses that hydrogen that to be used by the methanogenic bacteria. On the other hand, if roughage proportion is higher in the diet, it favors acetate production which immediately favors methanogenesis (Preston and Leng, 1987; Ørskov and Ryle, 1990). So, methanogenesis can be manipulated by changing the feeding pattern. The mechanism of methane production can simply depict as follows:

$CO_2 + 4H_2 = CH_4 + 2H_2O$

$CH_3 + H^+ = CH_4$

$HCOOH = CO_2 + H_2$

Types of animal and feed

Methane production varies according to the types of animal. Large animals like cattle and buffaloes produce more methane than smaller animals like sheep and goats. While methane production in sheep varied from 16-30 l d^{-1}, in cattle it varied from 150-170 l d^{-1} at maintenance level and 280-300 l d^{-1} on production ration (Singh, 1993). However, it is apparent that methane generation would be similar in both types of animals which are converted to their metabolic body weight.

Moss and Givens (1993) in sheep found that methane production could vary in the same type of animal depending on the type of feed. They studied sheep and found that methane production varied from 36-44 l d^{-1} which was lower in high (1.00) and higher in low (0.26) forage-concentrate ratio. They also found that methane production increased with the increased fermentable organic matter (FOM) and varied from 57 l to 81 l kg^{-1} FOM from high (1.00) to low (0.26) forage-concentrate ratio respectively.

Microbes in methane formation

Archaebacteria are mainly responsible for methane production that involves a specialized biochemical function (IAEA, 1992). Some eubacteria may also produce small amounts of methane. Archaebacteria those responsible for methane production in the rumen include methanogens, sulphate reducers, thermophiles and halophiles. Of them, methanogens are very different from other rumen microorganisms because of their specialized energy metabolism. Only methanogenic bacteria derive energy from methanogenesis (Jones et al., 1987). Some of the major methanogenic bacteria involve in methane production are given in table 2.

Table 2. Some methanogenic bacteria responsible for methane production in ruminants (after Arora, 1988; Yokoyama and Johnson, 1988)

Bacteria	Substrates	Products
Methanobacterium ruminantum	CO_2, H_2 and HCOOH	CH_4, CO_2 and H_2O
Methanobacterium fomicicum	HCOOH	CH_4, CO_2 and H_2O
Methanobrevivactor ruminantum	HCOOH	CH_4, CO_2 and H_2O
Methanomicrobium mobile	HCOOH	CH_4, CO_2 and H_2O
Methanosarcina barkerii	Methanol, Methylamine and Acetate	CH_4, CO_2 and NH_4

EFFECT OF METHANE PRODUCTION

Reducing methane production is important for at least two reasons. Methane, as one of the potential greenhouse gases responsible for pollution and health hazards. Furthermore, it affects the economy of animal production. Consequences of these effects are briefly described below.

Effect on environment

Methane gas and even other greenhouse gases are almost transparent and their wavelength is approximately equivalent to the infrared wavelength of sunlight. So, it can absorb and re-emit a large fraction of the longer infrared radiation emitted by the earth and thereby entraps heat. As a result of this heat trapping, the atmosphere radiates a large amount of long wavelength energy to the earth surface. In this way, long wavelength radiated energy received on earth is nearly doubled that received from the sun (IAEA, 1992). Consequently, it causes depletion of stratospheric ozone layer. The ozone layer usually absorb the harmful solar rays like ultraviolet β rays, cosmic rays etc. so that these harmful rays can not come to the earth. However, due to the gradual depletion of ozone layer, these rays come directly to the earth and causing several consequences. For example, people suffer from health hazards like skin cancer, cataracts, impaired immune system etc., and natural hazards like flood, draught, crop damage, rising sea level etc (White and McGovern, 1993).

Methane is a potent greenhouse gas in terms of global warming potential as it is 21times more global warming potential relative to CO_2. So, every effort should be made to combat this gas.

Effect on economy

It is also worth considering the importance of welfare production in ruminants. It was estimated that methane produces during fermentation of feed represents a loss of 7-10% gross energy intake (Moss and Givens, 1994) or 5-16% of digestible energy (Leng, 1985; Singh, 1993) depending on the type of feed. Preston and Leng (1987) reported that up to 20% of the metabolizable energy intake is being lost as heat and methane in ruminants. Table 3 gives losses of energy of some feedstuffs due to the formation of methane.

Table 3. Metabolisable energy (MJ KG^{-1} DM) of some foods

Animal	Food	Gross energy	Energy lost in Faeces	Energy lost in Urine	Energy lost in Methane	ME
Cattle	Maize	18.9	2.8	0.8	1.3	14.0
	Barley	18.3	4.1	0.8	1.1	12.3
	Wheat bran	19.0	6.0	1.0	1.4	10.6
	Lucerne hay	18.3	8.2	1.0	1.3	7.8
Sheep	Barley	18.5	3.0	0.6	2.0	12.9
	Dried ryegrass (young)	19.5	3.4	1.5	1.6	13.0
	Dried ryegrass (mature)	19.0	7.1	0.6	1.4	9.9
	Grass hay (young)	18.0	5.4	0.9	1.5	10.2
	Grass hay (mature)	17.9	7.6	0.5	1.4	8.4
	Grass silage	19.0	5.0	0.9	1.5	11.6

Source: McDonald et al., 1983.

This loss is significant in the field of animal production because feed cost represents 60-70% of the cost of animal production (Rahman et al., 1990) as stated earlier. Chalupa (1980) reported that complete or partial reduction of this loss increases liveweight by 48% of animals. However, there are no data on to what extent methane affect on the economy of animal production. As there are no data on to what extent methane production affects the economy of animal production, it deserves investigation.

REDUCING METHANE PRODUCTION

As stated earlier, reducing methane production from ruminants is important for at least two reasons. Firstly, it would reduce the amount of methane in the atmosphere and consequently reduce the greenhouse effect. Then, it would reduce the feed cost that is a major cost in animal production. Therefore, this is important to evolve different ways to reduce methane production from ruminants as well as from agricultural practices.

Different methods of reducing methane produdtion in the rumen have been proposed. One of them is the ionophore antibiotic feed additives that increase propionate and thereby reduce methane. Defaunation has also been suggested as a means of reducing methane production. Supplementation of readily available carbohydrate (i.e. molasses) to fibrous diets has also been suggested to reduce methane production.

Chemical techniques

Methane production is reverse with propionate production, i.e. if propionate increases there is a decrease in methane production and *vice versa* (Hungate, 1961). Certain ionophore feed additives like monensin and rumensin (monensin sodium) are able to increase propionate production at the expense of methane production. These compounds inhibit the enzyme system in the final methyl transfer reaction that leads to decrease in methane (Rowe et al., 1992). Thronton and Owens (1981) reported that methane production can be decreased by 16-24% in steers with the addition of monensin in feed. Dramatic result was found in sheep where methane production was decreased by 30-40% with monensin (Allen, 1981). Joyner et al. (1979) reported that monensim not only reduces the methane production but also increases the feed conversion efficiency in ruminants.

Practically these additives increase the efficiency of feed utilization by modifying rumen fermentation. The cause of increase in propionate production with monensin is associated with the inhibition of growth of acetate and hydrogen producing rumen microorganisms such as *Bacteroides fibrisolvens,* therefore favoring the growth of propionate producers such as *Bacteroides ruminicola* (Ørskov and Ryle, 1990).

Experiments suggest that it is possible to inhibit methane production without seriously affecting the efficiency of rumen fermentation by adding long chain unsaturated fatty acids to the ration (Czerkawaski, 1986).

Defaunation

It was observed that the hydrogen utilizing bacteria are easy to isolate and consequently it would be possible for defaunation after isolation. Another method would be the isolation and defaunation of protozoa from the rumen because methanogenic bacteria were found attached with the protozoa (Hungate, 1996; Coleman, 1975). However, this subject needs corroborative i.e. more supporting research to implement in practical situation.

Feeding strategy

Chemical manipulation or defaunation may be possible in specialized production system. However, in developing country where most of the livestock exists (table 4) and managed in villages in small herd, may not be possible to follow the above methods. In that case, feeding locally available quality feedstuffs may hold promise in combating methane production.

Evidently the largest proportion of methane is produced from the poor quality roughage feeds because acetic acid is the principal fermented product of poor quality feed. Saadullah (1992) stated that the methane emission per unit of product can be reduced by 25% to 75% allowing urea molasses block, fish meal, oil cakes etc. to ruminants especially to cattle and buffaloes that feed mostly on straws and thereby global methane emission could be cut by approximately 12%. The main theory behind the offsetting of global methane emissions through the application of feed supplements is that when animal productivity increases, there is a substantial decreases in the amount of methane emitted per unit of the production (Huque and Stem, 1994). Therefore, through strategic feeding, milk, meat and power can be increased providing additional food and income that is a direct benefit to the farmers.

Table 4. Methane production from ruminants in Asian countries and the world (after Leng, 1991)

Country	Cattle equivalent (× 1,000)	Ruminant distribution (%)	Total methane production (Tg*)	Methane production (%)
Bangladesh	47,756	2.64	1.61 - 2.11	0.40
India	3,440,001	19.04	12.37 - 16.18	2.86
Pakistan	47,877	2.65	1.72 - 2.28	0.40
China	128,204	7.10	4.61 - 6.31	1.07
Asia-Pacific	736,234	40.74	26.48 - 34.63	6.11
Other countries	1,070,680	59.26	38.52 - 63.60	8.89
World	1,806,914	100.00	65.00 - 85.00	15.00

* 1Tg = 10^{12}metric ton.

Feeding concentrates and straw based diet

Preston and Leng (1987) reported that 2 kg methane produced per kg meat when ruminants fed mainly with straw. However, methane can be reduced to 0.36 kg to produce per kg meat by offering straw with urea, minerals and by-pass protein (table 5) which may be due to the efficient fermentative digestion. Therefore, methane production can be reduced significantly by manipulating the fermentative pattern in the rumen and thereby growth rate can be induced at a faster rate.

Table 5. Effect of supplementation of straw based diet on methane: Meat production ratio in growing cattle (after Preston and Leng, 1987)

Attributes	Unsupplemented	Supplemented
Digested energy fermented to methane (%)	15	8*
Ratio methane/meat (kg/kg)	2.4	0.36**

* With urea and minerals.
** With urea, minerals and bypass protein.

It is also reported that the methane production is comparatively less in urea treated straw than untreated straw. Whilst 0.126 kg methane produced per kg liveweight gain with urea treated straw, it was 0.84 kg per kg liveweight gain with untreated straw (Saadullah et al., 1981). Crutzen et al. (1986) stated that 15% of the digestible energy is channelled for methane production in fibrous diet that become less than half with quality feed. So, there is a possibility of reducing methane production and consequently increased animal production through efficient utilization of feedstuffs with appropriate feeding technology.

Methane production can also be changed by changing forage-concentrate ratio and the type of concentrate. Moss and Givens (1993) reported that the type of concentrate and forage-concentrate ratio can substantially influence on methane production. They offered iso-energetic forage (grass silage): concentrate (rolled barley or soyabean meal) rations of 1.0, 0.75, 0.50 and 0.25 (DM basis) to wether sheep at maintenance level. They found that the methane production (l kg^{-1} FOM) increased significantly and linearly with decreasing forage-concentrate ratios for rolled barley diets but was non-linear for soyabean meal diets with low levels at forage-concentrate ratios of 0.76 and 0.51 (table 6). They suggested that rumen stoichiometry is unable to explain non-liearity of methane production for soyabean diet. Moss and Givens (1994) further reported that methane stoichiometry does not relate well to rumen VFA stoichiometry. However, it evident from their result that forage-concentrate ratio influence methane production significantly.

Table 6. Methane production from barley and soyabean meal fed with grass silage at different forage-concentrate ratios to sheep at maintenance (after Moss and Givens, 1993)

Feed / components	Actural forage-concentrate ratio (DM basis)				SED
	1.00	0.76	0.51	0.26	
Barley					
Intake (g OMD[1] d^{-1})	679	689	700	697	10.6
Organic matter digestibility coefficient	0.743	0.788	0.834	0.883	0.0030***
Methane production (l d^{-1})	37.2	41.5	41.9	43.9	1.56***
Methane production ((l kg^{-1} FOM[2])	58.4	61.1	67.3	80.6	2.72***
Soyabean meal					
Intake (g OMD[1] d^{-1})	700	719	723	689	13.1*
Organic matter digestibility coefficient	0.753	0.814	0.861	0.863	0.0129***
Methane production (l d^{-1})	35.8	36.4	35.8	33.7	0.44**
Methane production (l kg^{-1} FOM[2])	56.9	50.5	56.6	63.6	0.73**

[1]Organic matter apparently digeststed; 2, Fermentable organtc matter, *, $P<0.05$, **, $P<0.01$; ***, $P < 0.001$.

Feeding urea molasses block (UMB)

Mainpulation of methanogenesis in the rumen is also possible through UMB feeding where poor quality roughages are used. Reasearch in Bangladesh and India demonstrate that milk production in cows doubled when UMB offered with straw based diet (Kibria et al., 1991; Huque and Stem, 1994) which may be an indicative of reduced methane production. Leng (1991) stated that strategic supplementation with UMB could promote efficient fermentative digestion and thereby decrease methane generation per unit of digestive feed by 30 to 50% of digestible energy. Moreover, fermentation of soluble carbohydrates like molasses in the rumen leads to narrower acetate-propionate ratio (Ørskov et al., 1968) which implies lower methane production feeding UMB with fibrous diet.

CONCLUSION

From the discussion evidently the key to reduce methane emission from ruminants is to improve nutritional management particularly supplementation for both milk and meat production. The feeding technology holds promise in the fact that it would reduce methane production and can be practiced by the farmers of developing countries where majority of the domestic ruminants exists and where ruminant production system based heavily on straw based ration. Therefore, it may be worth to concentrate research and understanding the mechanisms by which different feed supplements reduce methane production with straw based diet.

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