Effect of greenhouse gases on climate change and Indian ruminant livestock

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All countries are concerned about environmental pollution causing depletion of the ozone layer. Global warming is an international problem. But health hazards due to toxic gases in air differ from country to country and also from city to city, depending on their industrial status. This article discusses the emission of greenhouse gases and the role of Indian ruminants in respect of methane production.

Methane production by ruminant livestock

METHANE emission in atmosphere as greenhouse gas is estimated to be 255 (ref. 1), 423 (ref. 2) and 550 (ref. 3) million tonnes per year from all sources. According to the World Resource Institute (WRI) estimate, Indian contribution from all sources is 12.1% of the total production. Rice field and ruminants contribute 27.3% and 13.2%, respectively (Table 1). Therefore, measures may be taken to reduce methane production from rice field and ruminants. According to Bolls *et al.*[4], global methane production comes from non-biological material (32%), rice field (18%), ruminants (18%), marshes (13%) and other sources (6%).

Reaction of methane in atmosphere

The most important reaction of methane in atmosphere is the conversion of ozone (O_3) to O_2 and O.

$$OH + CH_4 \rightarrow H_2O + CH_3$$

$$O_3 + h\nu \rightarrow O + O_2$$

$$O + H_2O \rightarrow OH + OH.$$

The reaction of methane in atmosphere is a complex one as: (i) Methane has absorption band in infrared region. (ii) It is oxidized in troposphere by free radical OH. (iii) It is a sizeable source of CO through its oxidation by OH. (iv) It is a source of water vapour in the stratosphere owing to its oxidation to CO_2 and H_2O. (v) Stratospheric methane can react with Cl radicals, forming HCl which slow the rate at which Cl and ClO destroy stratospheric ozone.

Methane plays different roles under different spheres of O_3.

Stratospheric O_3

$$O_2 + h\nu \rightarrow O^*$$

$$O^* + O_2 \rightarrow O_3$$

$$CFC \rightarrow Cl$$

$$Cl + O_3 \rightarrow ClO + O_2.$$

Tropospheric O_3

$$O_2 + h\nu \rightarrow O^*$$

$$H_2O + O^* \rightarrow OH + OH.$$

Methane

$$OH + CH_4 \rightarrow CH_3O + H_2$$

$$NO_2 + h\nu \rightarrow NO + O$$

$$O + O_2 \rightarrow O_3$$

$$NO + O_3 \rightarrow NO_2 + O.$$

Looking into stoichiometry of hexose fermentation, it is clear that:

$$C_6H_{12}O_6 \rightarrow 2CH_3COOH + 2CO_2 + 8[H]$$
(Methanogenic)

$$C_6H_{12}O_6 \rightarrow 2CH_3CH_2COOH + 2H_2O + 4[H]$$
(Glucogenic)

Table 1. Total methane emission in atmosphere and methane emitted in India by different sources (million tonnes)

Source	World	India	Contribution of India as of world
Solid waste	44.0	1.80	4.1
Livestock	76.0	10.00	13.2
Hard coal	16.0	0.83	5.2
Rice field	66.0	18.00	27.3
Pipeline leakage	53.0	0.18	0.3
Total	155.0	30.80	12.1

Based on WRI 1990 data.

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$C_6H_{12}O_6 \rightarrow CH_3CH_2CH_2COOH + 2CO_2 + 4[H]$ (Methanogenic).

Twelve [H] are produced; however, 4[H] are utilized for propionate formation and 8[H] are converted to methane.

$4H_2 + O_2 \rightarrow CH_4 + 2H_2O.$

This is a theoretical calculation and may vary from feed to feed. The molar proportion of volatile fatty acids (VFA) plays a key role because fibrous feed results in higher methanogenic VFA[5]. Formate, methanol, methylamine, dimethylamine, acetate, etc. are also formed in the rumen owing to primary fermentation of carbohydrate, which are converted to methane to some extent by methanogens. Therefore, methane production control is possible at the rumen level by manipulation of the diet, or managemental practices and by modifying the microbial activity in rumen.

Supplementation of nutrients to straw-based diet

In India and in most of the developing countries, cereal straws are the major feed for ruminants. These are poor sources of nitrogen and minerals and energy, because of being present in the form of cellulose/hemicellulose, which on fermentation give rise to higher methanogenic VFA, and produce more methane[6]. Supplementation of straw diet with deficient nutrients however optimizes the rumen fermentation leading to reduced methane and carbon dioxide production[7] and increases the efficiency of growth and milk production.

Supplementation of UMM lick to crop residue diet

Percentage of methane in greenhouse gas decreased from 41.3 to 38.2 in untreated wheat straw and from 38.6 to 35.4 in urea-treated wheat straw owing to supplementation of urea–molasses–mineral (UMM) lick. Thus methane in greenhouse gas reduced by 5.8% to 7.5% and 6.0% to 8.0% on untreated and urea-treated straw, respectively. However, the percentage reduction of methane in greenhouse gas was 12–15 due to both supplementation of UMM lick and urea treatment[8]. Molar percentage of acetate decreased significantly due to supplementation of UMM lick to straw-based diet. The percentage increase of molar propionate decreased the methanogenic VFA[5]. Changes in molar proportion of acetate, propionate and butyrate due to supplementation of UMM lick are described as the shift in the fermentation process[9].

Percentage of methane in gas decreased from 42.2 to 36.5 due to supplementation of UMM lick to paddy straw-based diet, resulting in about 9% decrease of methane in greenhouse gas on untreated paddy straw, and from 39.7 to 35.5% on urea-treated paddy straw, the reduction being to the extent of 11%. Methane production decreased from 2.76 moles/kg digestible dry matter (DDM) to 2.30 moles/kg DDM due to supplementation of UMM lick and urea treatment of paddy straw, resulting in 16.7% reduction of methane[8]. Increase in propionate due to supplementation affects the methane in gas (Figure 1) because propionate acts as a hydrogen sink[8,10].

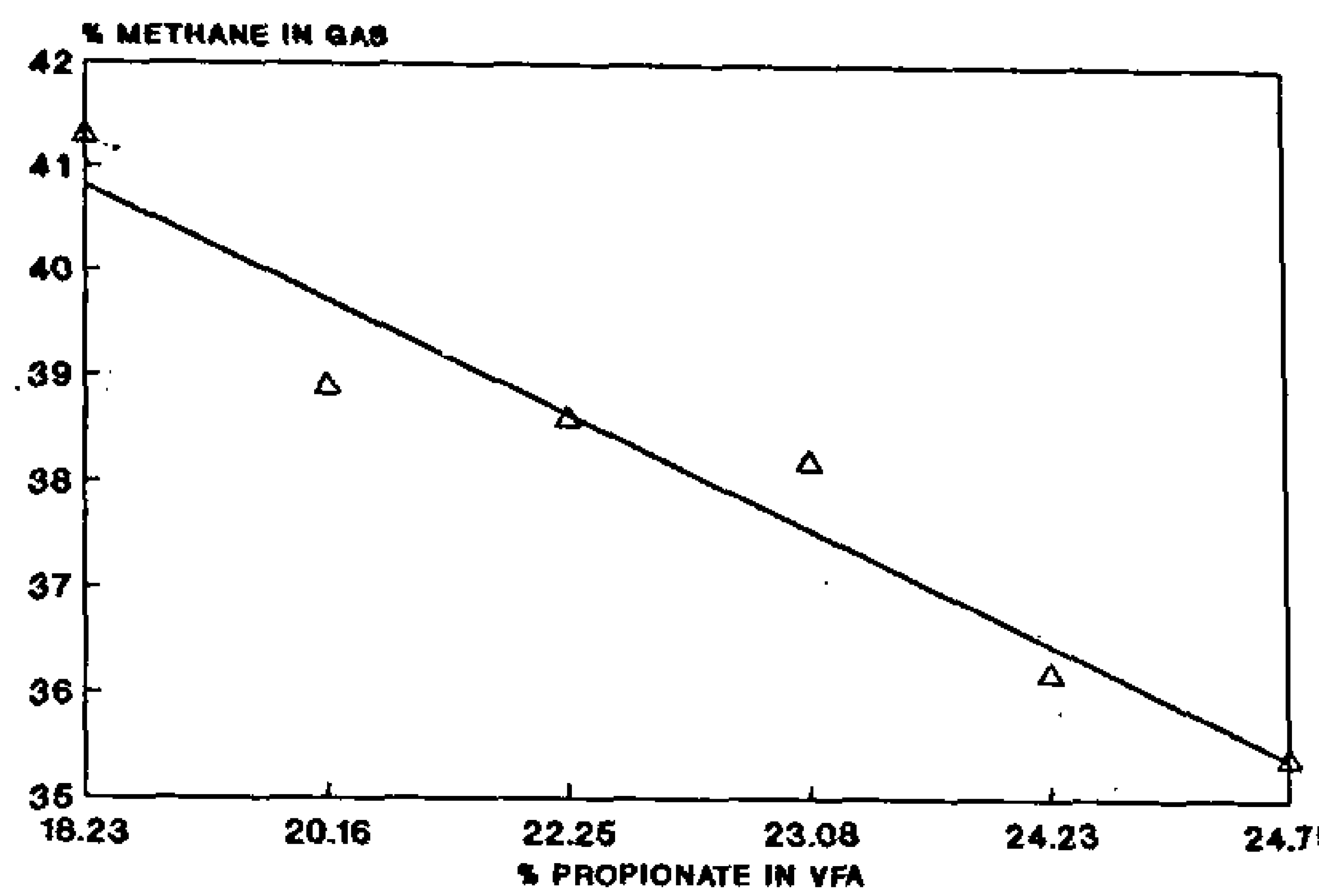

Figure 1. Relation between percentage of propionate in volatile fatty acids and percentage of methane in gas.

Supplementation of urea, mineral and by-pass protein

For the ruminants fed mainly on straw, the methane generated per kg meat is estimated about 2 kg methane per kg meat produced. However, by supplementing with urea, minerals and by-pass protein, methane production is 0.36 kg per kg meat due to increased efficiency of fermentation, digestion and faster growth[11].

Concentrate roughage ratio in ruminant diet and methane production

Sicilliano-Jones and Murphy[12] reported significant decrease in acetate and increase in propionate when steers diet was changed from alfalfa hay : concentrate feed of 4 : 1 to 1 : 4. On the other hand, Davies[13] reported 67%, 21% and 12% acetate, propionate and butyrate in VFA, respectively on alfalfa : grain (1 : 1.3) diet and 49%, 40% and 11% acetate, propionate and butyrate on alfalfa : grain (1 : 6.6) diet. Beever *et al.*[14] calculated the VFA and methane production on different types of diets:

(i) *High forage diet*

1 mol CHO $\rightarrow$ 1.34 mol CH_3COOH + 0.45 mol

$CH_3CH_2COOH + 0.11$ mol $CH_3CH_2CH_2COOH + 0.61$ mol CH_4 $+ 4.62$ mol ATP.

(ii) *High cereal diet*

1 mol CHO $\rightarrow$ 0.90 mol CH_3COOH + 0.70 mol CH_3CH_2COOH + 0.20 mol $CH_3CH_2CH_2COOH$ + 0.38 mol CH_4 + 4.38 mol ATP.

(iii) *High molasses diet*

1 mol CHO $\rightarrow$ 0.94 mol CH_3COOH + 0.40 mol CH_3CH_2COOH + 0.33 mol $CH_3CH_2CH_2COOH$ + 0.54 mol CH_4 + 4.50 mol ATP.

However, the above results based on good quality roughage like alfalfa and grain-based feed are not applicable for Indian ruminants because their major roughage is straw and the concentrate mixture contains agro-industrial by-product.

One of the important methods of reducing the methane production is by increasing the concentrate mixture in diet, specially when animals are fed straw-based diet. Singh and Mohini[15] reported that propionate in VFA increased from 23.33% on concentrate-25 : wheat straw-75 diet to 35.60% on concentrate-75 : wheat straw-25 and 30 on concentrate-50 : wheat straw-50. Methane production reduced from 40.9 to 28.0 lit/kg DDM due to the increase of concentrate mixture from 25% to 75% in wheat straw-based diet (Figure 2). Similar studies on three ratios of concentrate and paddy straw (25 : 75, 50 : 50 and 75 : 25) showed an increased propionate percentage in VFA acids (22.3%, 29.5% and 36.7%) and decrease in methanogenic VFA from 77.7% on concentrate-25 : paddy straw-75 to 70.5% on concentrate-50 : paddy straw-50 and 63.3% on concentrate-75 : paddy straw-25, respectively[16]. Thus, methane production was reduced by 19.5% to 31.5% due to increase of concentrate in wheat-straw-based feed. However, the reduction of methane production was between 20.4% and 26.6% when diet was on straw alone and when concentrate mixture was increased up to 75% in the feed based on paddy straw as roughage (Figure 3).

Green fodder in diet and methane production

The green fodder and grasses contain higher amounts of soluble sugars, which when fed to ruminants change their fermentation pattern towards more propionate and less methane production. *In vitro* methane production studies on different ratios of berseem and wheat/paddy straw resulted in 20–30% and 18.5–30% reduction in methane production depending on the ratio of berseem

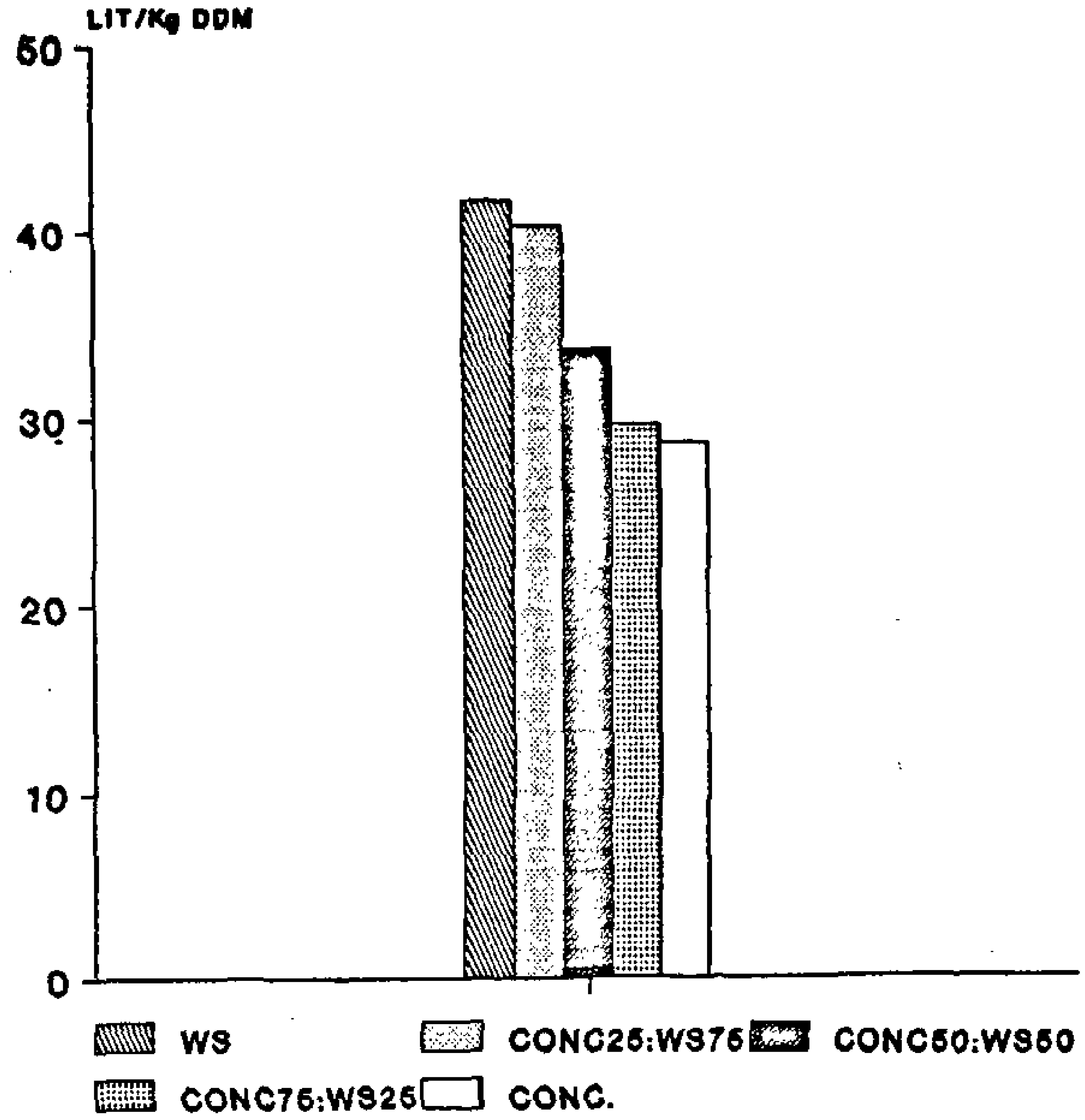

Figure 2. Effect of concentrate and straw ratio in diet on methane production.

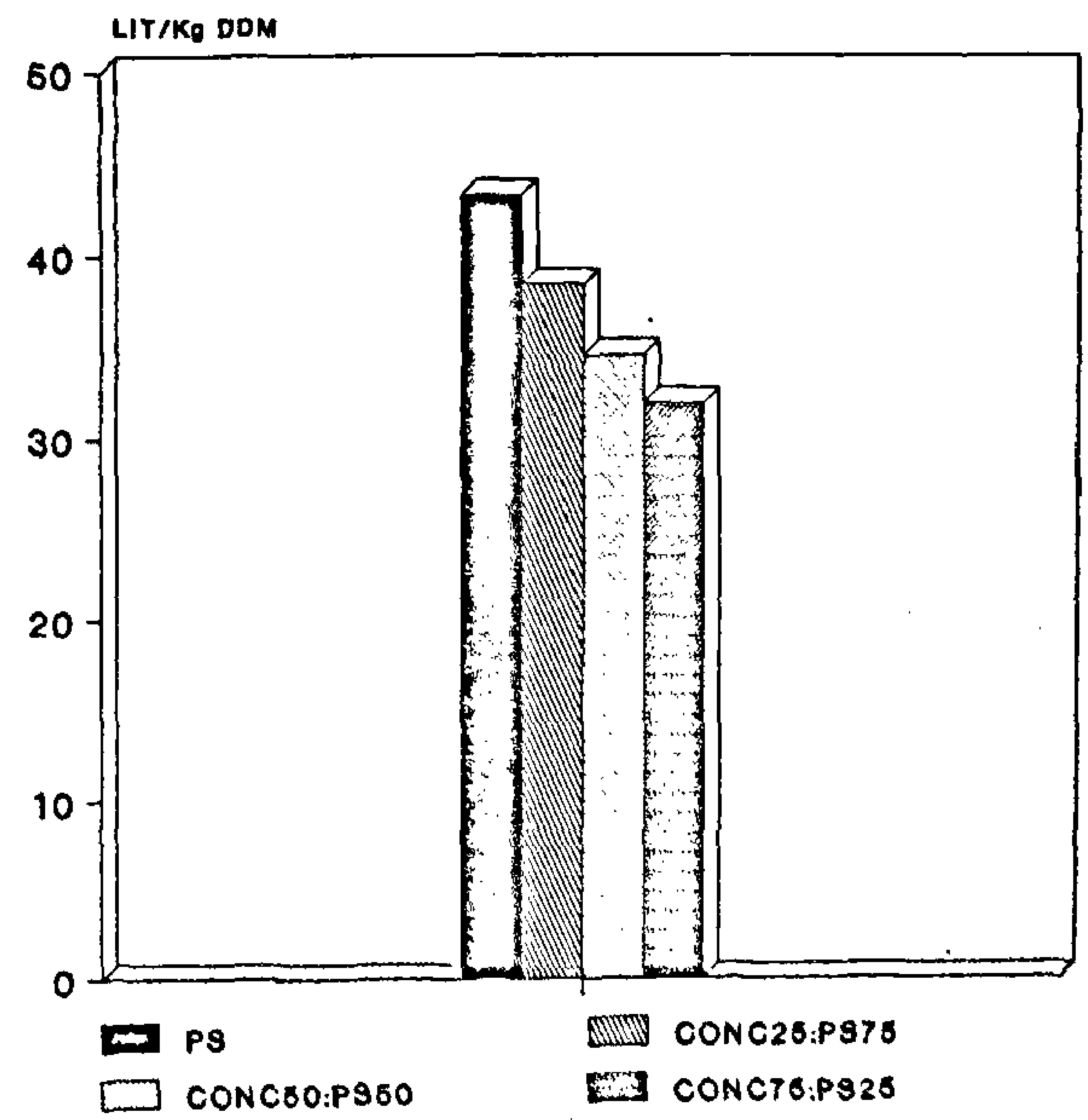

Figure 3. Effect of concentrate and paddy straw ratio on methane production.

Table 2. Effect of rumensin feeding to ruminant on the molar percentage of acetate, propionate and butyrate in volatile fatty acids

	Rumensin fed (mg/day/animal)		
	0.0	50.0	100.0
TVFA (mg/100 ml SRL)	11.16 ± 0.63	12.01 ± 0.48	11.52 ± 0.78
Molar percent of			
Acetate*	65.85 ± 1.32^a	58.81 ± 1.05^b	58.86 ± 0.27^b
Propionate**	24.33 ± 0.99^a	32.73 ± 1.81^b	32.29 ± 0.58^b
Butyrate	9.79 ± 0.86	8.46 ± 0.30	8.85 ± 0.58
Methanogenic VFA*	75.64 ± 1.86^a	67.27 ± 2.10^b	67.71 ± 2.37^b

Figures with superscripts in a row differ significantly.
*$P < 0.05$.
**$P < 0.01$.

in diet. In oat green fodder and wheat straw combinations, methane production reduced to the extent of 8–23%. Therefore, in India, methane production could be reduced to a significant extent by feeding green fodder to ruminants and thereby manipulating rumen fermentation.

Feed additive for minimizing methane production by ruminants

A large number of inorganic, organic compounds and ionophores are known to modify microbial activity to reduce methane production, for example as carbon tetrachloride, which is a very effective, methane inhibitor but toxic to animals and thus cannot be used for feeding[17,18]. The most promising and tested rumen fermentation modifier is momensin/rumensin. Ionophores are routinely used as feed additive in beef cattle feed in the US. Ionophores have little direct effect on methanogens, but they inhibit the growth of bacteria which produce hydrogen, the precursor of methane[19]. Rumensin/momensin increases the feed utilization efficiency and this effect can be mediated by a decrease in methane production, with increase in propionate and ruminal pH (ref. 20). In a rusitec experiment, it has been reported that feeding of 0, 2, 10 and 50 mg/day momensin resulted in 48, 30, 19 and 18 mol/day methane production, indicating the effectiveness of momensin for control of methanogenesis[21,22].

It has been observed that the feeding of 50 and 100 mg rumensin/day/animal increased the propionate production significantly and decreased the percentage of methane in gas as well as methane produced per unit digestible dry matter (Tables 2 and 3). The methane production was reduced by 14–23% on maintenance, 30–35% on medium milk production and 22–32% on high milk production feed consisting of concentrate and wheat straw due to rumensin feeding[23]. Similarly on three types of feed consisting of concentrate and paddy straw, propionate production increased and methane produced per unit of digestible dry matter decreased

Table 3. Gas and methane production on concentrate and wheat/paddy straw diet as affected by rumensin

Rumensin (mg/d)	Total gas (lit/kg DDM)	Methane in gas (%)	Methane production (lit/kg DDM)
Wheat straw*			
0	108.8	38.8	39.99
50	100.9	31.9	32.23
100	98.9	31.0	39.39
Concentrate*			
0	111.7	25.6	28.71
50	111.4	17.1	18.93
100	125.6	13.2	16.62
Concentrate-25 : wheat straw-75*			
0	114.1	33.2	41.48
50	124.1	28.5	35.41
100	122.1	26.1	31.83
Concentrate-50 : wheat straw-50*			
0	110.5	30.6	33.83
50	110.5	21.4	23.68
100	117.9	18.5	21.81
Concentrate-75 : wheat straw-25*			
0	108.7	26.5	28.71
50	107.2	22.5	22.25
100	105.1	18.7	19.67
Paddy straw**			
0	111.3	37.3	38.59
50	108.6	33.0	33.16
100	107.3	32.2	30.66
Concentrate-25 : paddy straw-75**			
0	109.7	34.1	42.08
50	109.3	28.8	35.84
100	111.2	25.2	32.77
Concentrate-50 : paddy straw-50**			
0	112.3	31.0	33.63
50	111.5	22.8	25.86
100	107.3	20.1	22.28
Concentrate-75 : paddy straw-25**			
0	108.7	27.3	27.50
50	108.1	23.2	23.68
100	110.3	18.1	20.55

DDM = Digestible dry matter.
*Singh and Mohini[23].
**Singh and Mohini[24].

(Table 3). Reduction in methane production was 15–22% on maintenance production, 23–32% on medium production and 14–25% on high milk production diet due to feeding of 50 and 100 mg rumensin per day[24]. On the basis of digestibility and methane production per kg DDM methane production by 400 kg cow was calculated at maintenance, medium and high production feeds and it was observed that the methane production was reduced from 153.1–162.0 to 112.8–129.0 lit/day at maintenance level of feeding (concentrate-25 : straw-75), from 178.0–183.3 to 119.0–127.9 lit/day at medium level of production ration feeding (concentrate-50 : straw-50) and from 202.8–206.8 to 146.3–157.60 lit/day on high production ration (concentrate-75 : straw-25) feeding due to rumensin in the diet (Figure 4). Thus, Table 4 shows that the methane production by Indian ruminants is

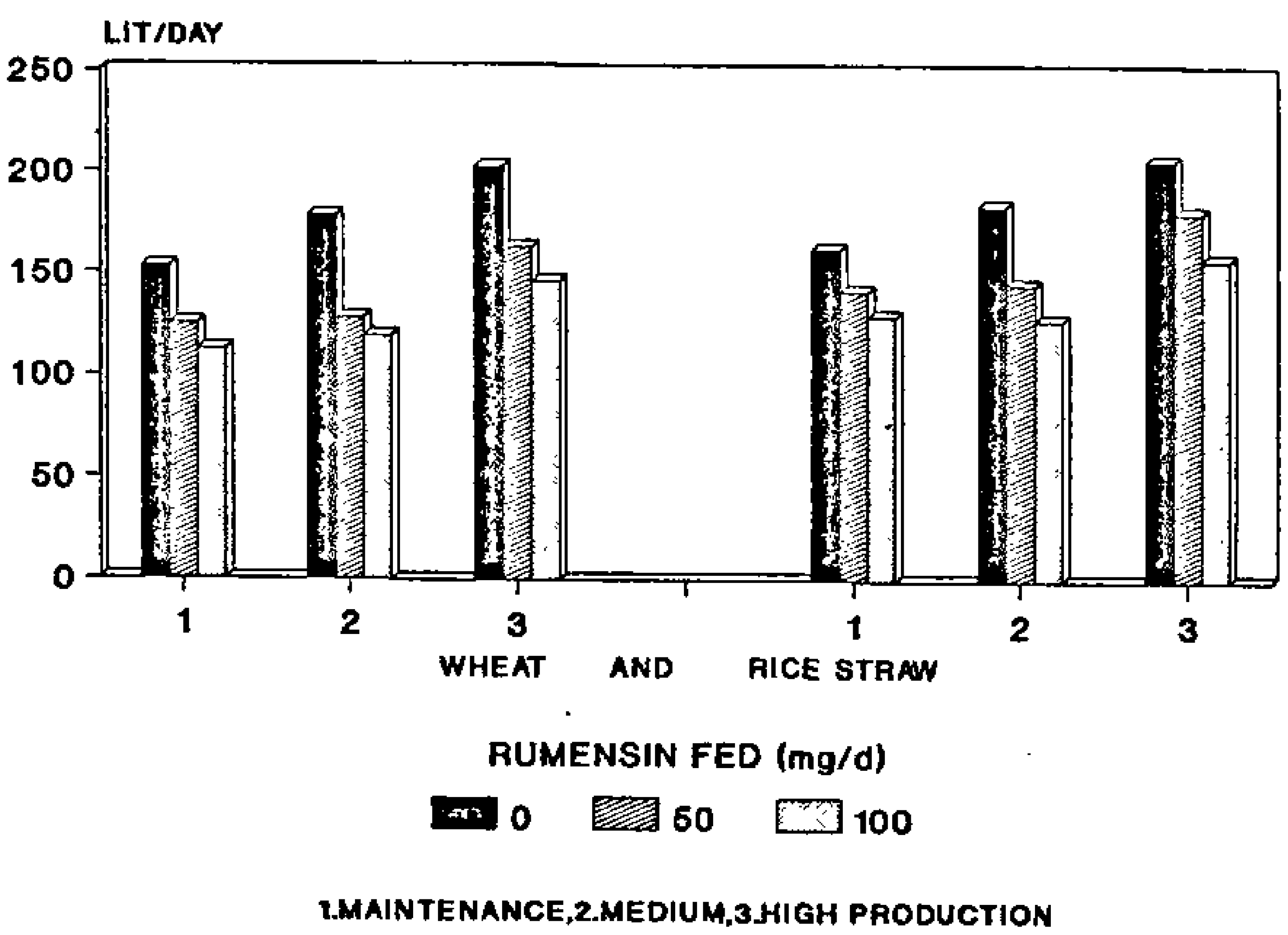

Figure 4. Methane production by a 400 kg-cow on maintenance, medium and high production.

Table 4. Methane production by a 400-kg-body wt cow and effect of rumensin in diet

Particulars	Lit/day 1	Lit/day 2
Maintenance	154.0	150–270
Medium milk production (5–10 mg/day)	175.0	–
High milk production (10–18 kg/day)	202.0	280–300
Rumensin in diet		
Maintenance	125.0	–
Medium production	127.0	–
High production	163.0	–
Sheep	14.18*	26–36

1. Singh and Mohini[16,23,24].
2. Czerkawski[17].
*Singh and Leng[28].

lower than the reported values[1,17] and the measures suggested above could reduce methane production by 20–30% or 2–3 million tonnes less per year by Indian ruminants than the WRI[1] estimate of 10 million tonnes methane per year. Therefore, Indian livestock contribution to greenhouse pool could be brought to 9.2–10.5% from 13.2% of the total methane produced by animals all over the world. This will increase the energy utilization efficiency of animals and decrease the methane level in greenhouse gases pool which is responsible for gradual depletion of ozone layer and global warming.

Total methane emission by Indian ruminants

In rural areas of India, animals are poorly fed. They are fed on crop-residue-based feed and whatever is available at the farmer's house. Feeding practices and type of feed differs from region to region. Even the body weight of animals is not same and varies to a great extent. Keeping all these factors in mind, total emission of methane from ruminant livestock has been calculated based on the 1993 level of animal population (Table 5). Total emission of methane by cattle is 5.690 Tg/year. While males contribute 3.088 Tg/year, females only contribute 2.602 Tg/year. Buffaloes contribution of methane to atmosphere is estimated to be 2.735 Tg/year[25]. Male buffalo emits only about 18% of methane and the rest is by female buffaloes. Sheep and goat contribution of methane in total methane pool was

Table 5. Methane production by Indian ruminant livestock (cattle, buffalo, sheep and goat)

		Methane production		
Species	Number (× 10^3)	Lit/day (× 10^8)	Mole/day (× 10^8)	Tg/year
Cattle crossbred				
Male	4278	5.00	0.26	0.154
Female	8513	12.48	0.56	0.322
Cattle indigenous				
Male	94407	112.60	5.00	2.934
Female	88512	87.50	3.90	2.280
Total	195867	218.50	9.72	5.690
Buffalo				
Male	16706	19.10	0.85	0.498
Female	60054	85.80	3.83	2.237
Total	76760	108.90	4.86	2.735
Sheep	44837	8.00	0.36	0.388
Goat	99405	14.90	0.66	0.388
Total				9.023

Based on:
1. Animal No.: Tech. Committee Report, Govt. of India, 1993.
2. Body weight of animal.
3. Type of feed and intake.
4. Digestibility of feed.
5. Methane per kg DDM determined.

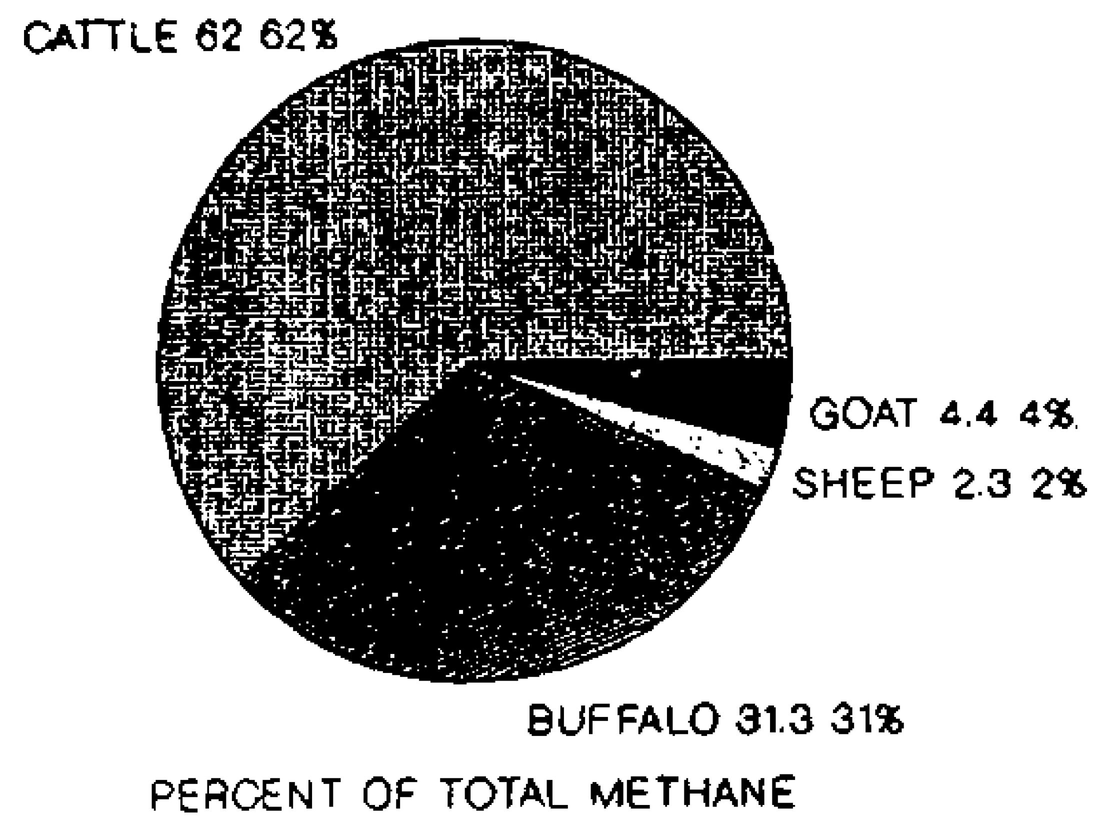

Figure 5. Contribution of methane by different ruminant livestocks.

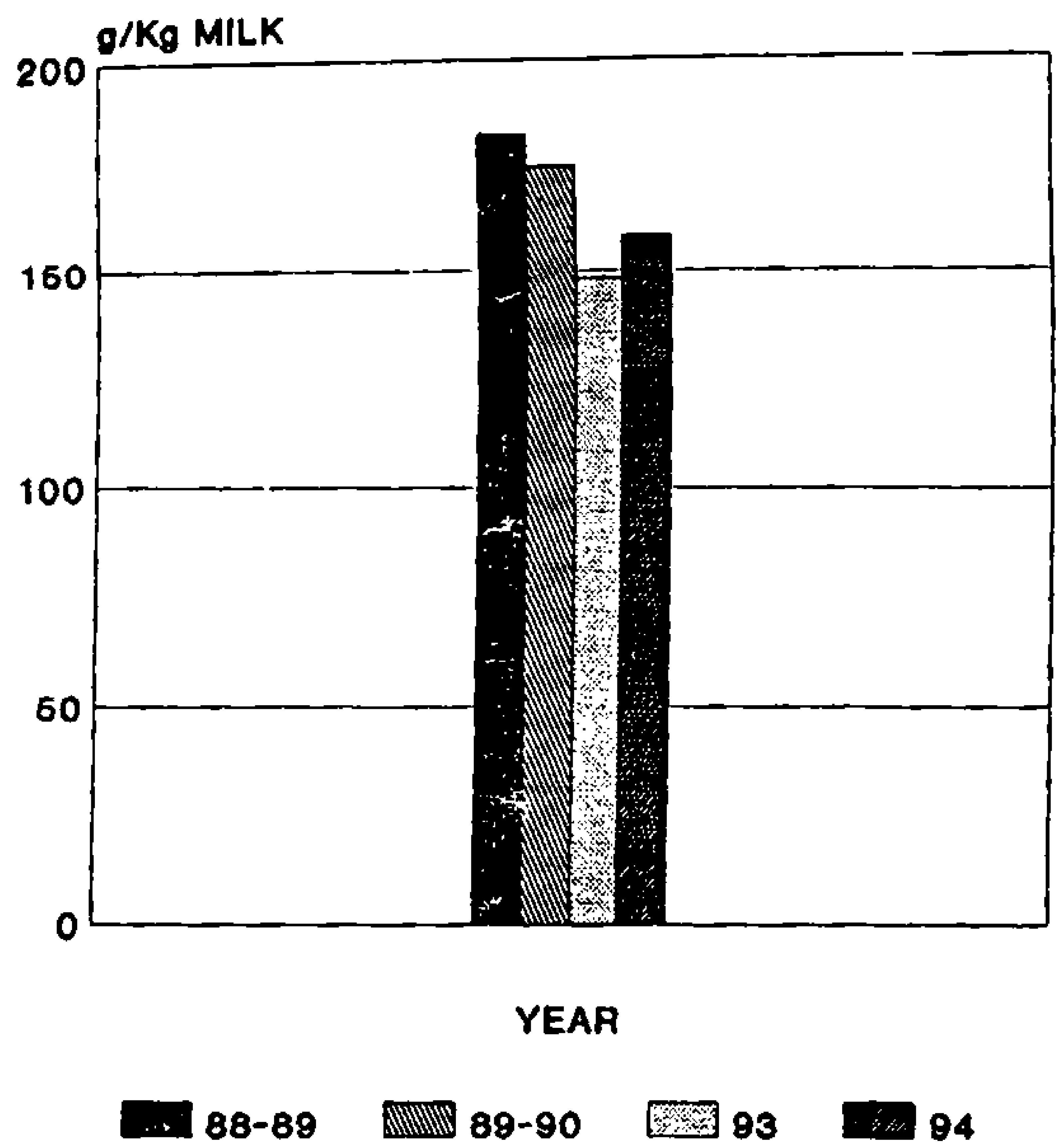

Figure 6. Methane production by Indian ruminant per kg milk production based on milk production and animal population.

0.210 and 0.388 Tg/year. While WRI[1] reported 10.00 million tonnes/year, Ahuja[26] reported 10.4 Tg/year. Both the estimates are higher even at 1990 level of animal population. Share of cattle, buffalo, sheep and goat of methane emission is 62, 31, 2 and 4% respectively (Figure 5). Methane production per kg milk varies between 148 and 183 g/kg milk (Figure 6) based on milk production and methane production estimate of the last 6–7 years. However, it cannot be 240 g/kg in any situation as reported by Aneja[27].

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