Indian Journal of Animal Sciences **90** (4): 636–642, April 2020/Article

Gas and methane production *vis-à-vis* loss of energy as methane from *in vitro* fermentation of dry and green forages in sheep and goat inoculums

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Received: 23 July 2019; Accepted: 2 September 2019

ABSTRACT

Gas production, methane and energy loss from 10 dry and 12 green fodders were evaluated *in vitro* using sheep and goat inocula. Dry matter intake and digestible DM (DDM) were higher for green (2.45% and 62.28%) than dry fodders (1.72% and 52.88%), respectively. Mean *in vitro* dry matter digestibility was higher for green than dry fodders in rumen inocula of sheep (63.51 vs 45.34%) and goat (61.36 vs 41.36%), respectively. After 12 h, gas production was higher for green than dry fodders in sheep (69.70 mL/g vs 64.40) and goat inocula (61.73 vs 55.53 mL/g). Gas production was higher for dry and green fodders in sheep inoculums vs goat at 12, 24 and 48 h. At 12 h, methane production was higher for green than dry fodders both in sheep (12.96 vs 9.69 mL/g) and goat (13.34 vs 9.14 mL/g). Total CH_4 production was higher for green than dry fodders with both sheep (40.92 vs 33.83 mL/g) and goat inocula (33.34 vs 30.47 mL/g), respectively. Methane production was higher from fermentation of green fodders than dry fodders in rumen inocula from goat (19.27 vs 14.16) and sheep (18.57 vs 14.76 g/kg DM), respectively. Green fodders produced higher CH_4 with goat (33.75 g/kg DDM) vs sheep inocula (29.65 g/kg DDM). Methane production (g/kg DDM) and energy loss as methane (CH_4 % GE) was similar for dry and green fodders fermented in sheep and goat inocula. Overall, results showed that green forages produced more CH_4 compared with dry forages so this piece of information should be put into consideration for sustainable and environmentally friendly production system.

Keywords: Energy loss, Forages, Gas, Methane, Ruminants, Sustainability

Sheep and goat contribute 185 and 284 Gg, respectively to 10.82 Tg of Indian livestock enteric methane emissions (MOEFCC 2018). Methane production in ruminants is influenced by several factors such as animal species and size, animal physiological stage, feed intake, digestibility, diet composition etc (Mi *et al*. 2017, Singh *et al*. 2018, Kidane *et al.* 2018, Alvarez-Hess *et al*. 2019). Many *in vitro* and *in vivo* studies have revealed differences in methane emission between ruminant species on the same diet. *In vitro* methane production of corn silage, grass silage and wheat straw diets fermented with buffalo inoculum were lower (75.1) as compared to cattle inoculum (97.1 ml/g; Calabro *et al*. 2013). Nielsen *et al.* (2014) tested the digestive and metabolic characteristics of pseudo ruminants and true ruminants on high and low quality diets and observed that Llamas had lower daily energy expenditure (324) than sheep (416) and goats (404 $KJ/kg^{-0.75}$) on the low quality diet. Llamas in comparison with sheep and goats had lower methane emission (0.83 vs 1.34 and 1.24 $l/d/kg^{0.75}$), respectively. Studies on comparative methane emission of ruminant species are limited in Indian context and to improve the GHG inventories efforts should be made to estimate the amount of methane from different classes of ruminants on a larger number of feed resources and diets. It was hypothesized that the ruminant species differ in their rumen fermentation efficiency and had differences in methane production. With this background, the present study was carried out to determine the *in vitro* methane production from fermentation of dry and green fodders in rumen inocula of sheep and goat.

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MATERIALS AND METHODS

Collection and processing of fodder samples: Representative samples of green forages (*Hordeum vulgare*, *Avena sativa*, *Trifolium alaxendrinum*, *Medicago sativa*, *Pennisetum purpureum*, *Panicum maximum*, *Saccharum officinarum*, *Arachis hypogeal* leaves, *Grewia optiva* leaves, *Leucaena leucocephala* leaves and *Sorghum bicolour*) and dry forages, viz. *Pennisetum glaucum* stover, *Hordeum vulgare* straw, *Cicer arietinum* straw, *Grass, Zea maize* stover, *Lens culiranis* straw, *Avena* sativa straw, *Oryza sativa* straw, *Sorghum* bicolour stover *and Triticum aestivum* straw were collected from 2 locations (Institute experimental farm or nearby villages). *Saccharum officinarum* tops, *Arachis hypogea* leaves, *Medicago sativa* B, *Lens culiranis* straw and *Oryza sativa* straw were collected from nearby villages while the rest were collected from the experimental farm. Samples were collected from

3–4 trees for *Grewia optiva leaves, Leucaena leucocephala* leaves while the other green forages and dry forages were sampled from three random places. Samples were dried in hot air oven at 55°C for 48 h and then ground using a Wiley mill through a1mm sieve.

Gross energy and calculations for DDM and DMI: The gross energy values of dry and green fodder samples used in present study were measured with a bomb calorimeter (Toshniwal Brothers CLOI/M2, Bengaluru, Karnataka, India) using benzoic acid as the standard and had been reported earlier (Singh *et al*. 2011, Singh *et al*. 2012). Fodders DM intake (DMI) and digestible DM (DDM) were calculated by using the equations (DMI = 120/NDF (%); DDM =88.9–0.779×ADF (%)) of Undersander *et al.* (1993).

In vitro incubation: In vitro gas production was determined according to the pressure transducer technique (Theodorou *et al.* 1994) as described by Singh *et al.* (2017). Gas measurements were taken at 12, 24 and 48 h.

Methane measurements: Methane in total gas was measured from three bottles incubated for each of the dry and green fodders at 12, 24 and 48 h using a gas chromatography (Nucon 5765 Microprocessor controlled gas chromatograph, Okhla, New Delhi, India) equipped with a stainless steel column packed with Porapak-Q and a Flame Ionization Detector. Gas flows of air/zero gas, nitrogen and hydrogen were 400 ml/m, 30 ml/m and 40 ml/m, respectively. Running oven, detector, injector and methanizer temperatures were 100°C, 150°C, 120°C and 320°C respectively.

Gas (1 ml) was sampled using a Hamilton syringe and injected manually (pull and push method of sample injection) into a gas chromatography, which was calibrated with standard methane and CO_2. Methane was also measured from blanks at different fermentation periods and used to correct methane produced from the sheep and goat inocula. Methane measured was related to total gas to estimate its concentration (Tavendale *et al.* 2005) and converted to energy and mass values using 39.54 kJ/l CH_4 and 0.716 mg/ml CH_4 factors, respectively (Santoso *et al*. 2007). *In vitro* dry matter digestibility of dry and green fodders was estimated using Tilley and Terry (1963) method wherein 0.5 g of sample was incubated at 39°C for 48 h and then digested with 0.1 g of pepsin (1: 3000 Sisco Research Laboratories, Mumbai, India) and 2 ml of 6N HCl at 39°C for 24 h. Samples were incubated in triplicate along with blank in ruminal inocula from 4 adult sheep and goats as described by Singh *et al*. (2017). Digestibility was estimated as the difference between DM incubated and residual DM at the end of the second stage of digestion.

Statistical analysis: Data were analysed using the PROC GLM procedure of SAS (version 9.0; SAS Inst. Inc. Cary, NC). The model included the effect of treatment, inocula, and the treatment × inocula interaction. Means were then compared by applying the probability of difference option of the least squares means statement. Additionally, means were also separated by using Fisher's LSD and differences among means with P<0.05 were accepted as statistically significant. Probability values less than 0.001 were expressed as P<0.001.

RESULTS AND DISCUSSION

DMI, DDM and in vitro dry matter digestibility: Mean DMI and DDM values were greater (P<0.012 and P<0.001) for green fodders (2.45 and 62.3%) in comparison to dry fodders (1.72 and 52.9%, Table 1), respectively. Greater calculated DMI value for green forages (2.45%) compared with dry forages (1.72%) may be due to lower fiber content (NDF 53.82%) of green *versus* dry forages (70.67%). The NDF of forages has been negatively correlated with DMI, which is always not consistent, although the NDF is positively related with resistance to comminution (Romney and Gill 2000). Among the green fodders, DMI and DDM values were greater for *Trifolium alaxendrinum*, *Medicago sativa*, *Arachis hypogea* leaves, *L. leucocephala* leaves and *G. optiva* leaves as compared to *Saccharum officinarum* tops,

Table 1. Dry matter intake (DMI), digestible dry matter (DDM), gross energy (GE) and *in vitro* dry matter digestibility (*IVDMD*) of dry and green fodders

Fodder	DMI (%)	DDM (%)	GE (KJ/g DM)	IVDMD (%)	
				Sheep	Goat
Dry fodder					
Pennisetum glaucum stover	1.66	52.9	18.8	42.5	47.0
Hordeum vulgare straw	1.91	51.5	18.8	55.3	48.3
Cicer arietinum straw	1.53	45.5	17.2	37.1	34.9
Grass	1.74	59.8	17.6	52.4	54.8
Zea maize stover	2.23	58.9	18.8	52.6	49.9
Lens culiranis straw	1.52	50.3	18.5	42.3	33.2
Avena sativa straw	1.54	48.2	17.1	43.7	41.0
Oryza sativa straw	1.83	57.3	17.3	40.7	41.4
Sorghum bicolour stover	1.61	52.6	17.7	40.3	25.0
Triticum aestivum straw	1.59	51.9	18.2	46.5	37.9
SEM	0.194	1.71	0.26	0.86	0.86
Green fodder					
Hordeum vulgare green	1.95	60.9	19.7	73.1	68.3
Trifolium alaxendrinum	2.93	64.9	18.3	76.5	73.9
Sorghum bicolour	1.71	58.3	18.1	52.4	56.9
Grewia optiva	3.19	70.0	17.1	74.4	76.4
Arachis hypogea leaves	3.10	63.9	16.9	76.1	66.4
Panicum maximum	1.63	54.0	16.6	44.4	39.2
Leucaena leucocephala	3.98	74.3	18.7	54.6	58.7
Medicago sativa-A	2.82	63.4	17.2	70.1	63.9
Medicago sativa-B	2.95	64.7	19.1	70.9	65.0
Pennisetum purpureum	1.62	57.3	16.7	61.4	61.5
Avena stativa	1.89	61.0	18.4	74.1	67.4
Saccharum officinarum top	1.61	54.6	16.7	33.9	38.7
SEM	0.177	1.56	0.25	0.77	0.77
LSD at P<0.05	–	–	0.70	11.95	11.95
P value (Treatment, T)	0.012	<0.001	<0.001	<0.001	<0.001
P value (Inoculum, I)	–	–	0.995	<0.001	<0.001
P value (T × I)	–	–	1.000	<0.001	<0.001

SEM, standard error of means.

Pennisetum purpureum grass and *Panicum maximum* grass. Among dry fodders, the highest values were noted for *Lens culiranis* straw (DMI), and *Zea maize* stover and *Lens culiranis* straw (DDM). Mean *IVDMD* of green fodders was higher (P<0.001) than dry fodders in rumen inocula of both sheep (63.5 vs 45.3%) and goat (61.4 vs 41.4%), respectively. The *IVDMD* values of fodders (dry and green) differed (P<0.001) in sheep and goat inocula. Differences among gross energy (GE KJ/kg DM) contents of dry fodders were less than 2. Among the green fodders, the GE values of cereals and leguminous green fodder were more than grasses and *Saccharum officinarum* tops. Higher *IVDMD* and DDM of green fodders may be attributed to their lower cell wall contents. Observed differences in the present study are consistent with previous reports (Issac *et al*. 1994, Molina *et al*. 1997, Molina *et al*. 2000) that differences between sheep and goat in total tract digestibility and rumen degradability are small for medium to high quality forages. Contrary to our study, Ammar *et al.* (2008) and Aderinboye *et al*. (2016) observed no differences in *IVDMD* of some browse plants fermented in sheep and goat inocula probably because of high quality of browsing species.

In vitro gas production from dry and green fodders in sheep and goat inocula: Mean *in vitro* gas production was higher (P<0.001) for green fodders than dry forages in rumen inocula of sheep (69.9 vs 64.5 ml/g) and goat (61.7 vs 55.5 ml/g), respectively at 12 h post fermentation incubation (Table 2). Similar trends were noted at 24 and 48 h of fermentation. Fermentation of dry and green fodders resulted in higher (P<0.001) gas production in rumen inoculum of sheep than goat. Greater gas production from green fodders at 12 h may be attributed to their higher soluble carbohydrate contents compared with green fodders. Additionally, greater *IVDMD* values noted for green forages than dry fodders could have contributed to higher gas in these green forages. Pal *et al.* (2015) reported higher gas production from green forages (26.68) than straws and shrubs (23.77 ml/200 mg DM) supports our findings that gas production is more from green forages than straws. Ammar *et al*. (2008) reported that overall gas production (ml/g) at 24 h from five browse plants was higher in sheep than goat inocula is consistent with our observations. Cone *et al.* (2002) observed similar total gas production between inocula collected from cattle and sheep, but gas production

Table 2. Gas production (ml/g DM) of dry and green fodders incubated in sheep and goat inocula

Fodder	Sheep			Goat		
	12 h	24 h	48 h	12 h	24 h	48 h
Dry fodder						
Pennisetum glaucum stover	65.9	118	171	52.9	108	153
Hordeum vulgare straw	62.3	118	176	60.0	116	170
Cicer arietinum straw	63.4	116	168	62.5	117	166
Grass	61.3	111	164	45.9	100	149
Zea maize stover	71.3	125	180	53.3	113	158
Lens culiranis straw	71.4	123	173	61.8	116	164
Avena sativa straw	62.4	117	174	60.3	115	168
Oryza sativa straw	62.3	115	172	48.8	106	156
Sorghum bicolour stover	62.3	113	166	50.4	97.0	141
Triticum aestivum straw	62.1	117	175	59.3	115	164
SEM	0.35	0.8	1.3	0.35	0.77	1.3
Green fodder						
Hordeum vulgare green	68.9	127	185	64.6	120	172
Trifolium alaxendrinum	74.1	129	182	65.0	121	169
Sorghum bicolour	74.0	130	186	60.0	118	167
Grewia optiva	75.0	126	174	60.6	120	166
Arachis hypogea leaves	77.4	134	183	64.5	123	171
Panicum maximum	62.0	116	173	62.0	116	165
Leucaena leucocephala	72.9	123	171	62.0	121	170
Medicago sativa-A	70.1	126	208	64.8	119	167
Medicago sativa-B	69.0	123	170	62.4	119	166
Pennisetum purpureum	63.0	121	180	61.8	122	176
Avena stativa	67.3	124	181	61.5	120	172
Saccharum officinarum top	64.9	115	165.3	52.0	107	153
SEM	0.56	1.06	1.54	0.56	1.1	1.5
LSD at P<0.05	6.90	7.77	7.40	6.90	7.77	7.40
P value (Treatment, T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
P value (Inoculum, I)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
P value (T × I)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

SEM, standard error of means.

dynamics between two species differed (P<0.05).

In vitro methane production from dry and green fodders in sheep and goat inocula: In vitro methane production of forages followed the same trend observed in the *in vitro* gas production. Greater (P<0.001) methane production values were recorded for green forages both in sheep (12.9 vs 9.69 ml/g DM) and goat (13.3 vs 9.15 ml/g DM) inocula at 12 h of fermentation (Table 3). Among dry forages, methane production was lowest for mixed grass (sheep inoculum) and *Sorghum bicolour* stover (goat inoculum). Fermentation of *Saccharum officinarum* top and *L. leucocephala* leaves had the lowest methane production for sheep and goat inocula, respectively. Greater methane production from *Cicer arietinum* straw*, Lens culiranis* straw and *Zea maize* stover among dry forages and *Hordeum vulgare* fodder, *Medicago sativa*, *Arachis hypogea* groundnut leaves, *G. optiva* leaves except *Pennisetum purpureum* grass may be attributed to their higher *IVDMD* values in sheep and goat inocula. Consistent with the present results, previous studies reported that feedstuffs with higher gas production and *IVDMD* tended to have higher methane production per gram DM incubated (Durmic *et al*. 2010, Njidda and Nasiru 2010, Jayanegara *et al*. 2011). Variation in methane emission between green and dry forages and within forages may be attributed to the differences in their chemical constituents as reported earlier (Singh *et al.* 2011, Singh *et al*. 2012). Pal *et al.* (2015) reported higher methane production for legumes (berseem and cowpea) *versus* cereals (grasses, maize, bajra) which is similar to our results. Chaves *et al.* (2006) reported that *in vitro* methane production (g/kg DM) was higher (P<0.05) from alfalfa (16.7) than grass (13.5) collected from different sites substantiates our findings.

Methane production (*g/kg DDM*) *and methane as a proportion* (*%*) *of gross energy:* Greater (*P*<0.001) methane production in inocula of goat (19.2 vs 14.1 g/kg DM) and sheep (18.5 vs 14.7 g/kg DM) were observed for green and dry forages, respectively (Table 4). Methane production (g/kg DDM) and energy loss as methane (CH_4 % GE) differed (P<0.001) both for the type of fodder and the source of animal inoculum. Loss of energy as methane was lowest for *Avena sativa* green and *L. leucocephala* both for sheep (7.47 and 7.71%) and goat (7.67 and 7.33%) inocula, respectively. One of the options to improve the feed

Table 3. Methane gas production (ml/g DM) of dry and green fodders incubated in sheep and goat inocula

Fodder	Sheep			Goat		
	12 h	24 h	48 h	12 h	24 h	48 h
Dry fodder						
Pennisetum glaucum stover	8.64	17.7	30.5	8.75	19.7	26.3
Hordeum vulgare straw	6.22	16.8	32.6	10.7	24.7	42.8
Cicer arietinum straw	9.58	20.9	33.0	15.2	29.6	45.0
Grass	6.33	14.4	25.9	4.16	10.3	20.2
Zea maize stover	15.7	30.2	46.8	9.06	21.4	31.8
Lens culiranis straw	18.8	32.3	45.2	14.2	26.5	37.2
Avena sativa straw	6.70	16.3	29.9	10.8	23.6	39.8
Oryza sativa straw	7.86	18.8	33.6	5.37	14.8	24.5
Sorghum bicolour stover	9.18	19.0	31.7	4.43	8.12	10.2
Triticum aestivum straw	7.91	18.8	34.7	8.85	19.0	27.4
SEM	0.248	0.62	1.19	0.248	0.62	1.19
Green fodder						
Hordeum vulgare green	12.5	27.7	45.0	14.6	30.9	49.9
Trifolium alaxendrinum	16.9	30.9	45.4	15.7	28.5	35.4
Sorghum bicolour	14.8	29.0	46.4	13.8	28.0	37.9
Grewia optiva	20.6	35.3	48.9	11.2	26.4	38.2
Arachis hypogea leaves	15.6	30.5	45.7	18.7	33.8	43.6
Panicum maximum	6.44	16.4	31.6	9.68	19.6	29.4
Leucaena leucocephala	12.5	20.3	28.2	10.9	20.7	26.6
Medicago sativa-A	12.5	26.4	40.2	18.4	34.5	50.4
Medicago sativa-B	14.3	28.2	41.4	14.4	26.9	34.6
Pennisetum purpureum	7.70	21.7	41.0	13.9	32.8	53.8
Avena stativa	12.1	26.3	44.2	12.0	24.5	36.6
Saccharum officinarum top	9.22	17.3	26.9	6.11	15.0	22.4
SEM	0.408	0.75	1.18	0.408	0.75	1.18
LSD at P<0.05	6.35	5.25	6.76	6.35	5.25	6.76
P value (Treatment, T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
P value (Inoculum, I)	0.031	<0.001	<0.001	<0.001	<0.001	<0.001
P value (T × I)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

SEM, standard error of means.

Table 4. *In vitro* methane (CH_4) production (g/kg DDM) and methane % gross energy (GE) of dry and green fodders incubated (24 h) in sheep and goat inoculums

	Sheep			Goat		
	CH_4 (g/kg DDM)	CH_4 (g/kg DM)	CH_4 (% GE)	CH_4 (g/kg DDM)	CH_4 (g/kg DM)	CH_4 (% GE)
Dry fodder						
Pennisetum glaucum stover	31.2	12.7	9.72	34.6	14.2	10.7
Hordeum vulgare straw	28.3	12.0	8.14	37.7	17.7	10.8
Cicer arietinum straw	27.2	15.1	7.83	43.7	21.1	12.6
Grass	27.9	10.3	8.75	20.9	7.35	6.59
Zea maize stover	41.1	21.6	12.6	27.9	15.3	8.56
Lens culiranis straw	44.1	23.2	12.6	37.9	19.0	10.9
Avena sativa straw	27.7	11.7	8.06	51.4	16.9	14.9
Oryza sativa straw	31.1	13.6	9.85	26.2	10.6	8.26
Sorghum bicolour stover	33.7	13.6	10.3	23.1	5.78	7.05
Triticum aestivum straw	28.8	13.4	8.55	35.9	13.5	10.7
SEM	1.50	0.46	0.499	1.50	0.463	0.499
Green fodder						
Hordeum vulgare green	27.2	19.9	7.44	32.5	22.1	8.89
Trifolium alaxendrinum	29.0	22.2	8.55	27.8	20.5	8.18
Sorghum bicolour	39.8	20.8	11.9	35.3	20.1	10.5
Grewia optiva	34.0	25.3	10.7	24.8	19.0	7.85
Arachis hypogea leaves	28.9	21.9	9.23	36.6	24.3	11.7
Panicum maximum	26.6	11.8	8.66	35.9	13.9	11.7
Leucaena leucocephala	26.7	14.5	7.71	25.4	14.9	7.33
Medicago sativa-A	27.0	18.9	8.51	38.6	24.7	12.1
Medicago sativa-B	28.6	20.3	8.06	29.7	19.3	8.38
Pennisetum purpureum	25.4	15.6	8.2	38.3	23.6	12.4
Avena stativa	25.4	18.9	7.47	26.1	17.6	7.67
Saccharum officinarum top	36.9	12.4	11.9	27.7	10.7	8.95
SEM	1.22	0.49	0.396	1.22	0.49	0.396
LSD at P<0.05	19.04	7.68	6.15	19.04	7.68	6.15
P value (Treatment, T)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
P value (Inoculum, I)	<0.001	0.001	<0.001	<0.001	0.001	<0.001
P value (T × I)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

DDM, digestible dry matter; SEM, standard error of means.

efficiency through efficient rumen fermentation is that dry matter conversion to methane is less and utilization by animal is more (Waghorn and Hegarty 2011). Methane an end-product of rumen fermentation causes 2% to 12% loss of dietary energy (Lan and Yang 2019). This loss of feed energy as methane varies with its quality (Mirzaei-Aghsaghali and Maheri-Sis 2011, Singh *et al.* 2011, Singh *et al.* 2012) and animal species. In the present study, overall *in vitro* methane production (g/kg DM) from green fodders was relatively higher than dry roughages, which was partly supported by Pal *et al.* (2015) who observed relatively higher methane production from green forages (17.6 ml/g DM) than straws and shrubs (16.3 ml/g DM). Overall methane production (ml/kg truly degraded dry matter) between forages (27.3) and straws and shrubs (27.8) reported by these workers was on the pattern of our findings. Observed differences in methane production (g/kg DM and g/kg DDM) between ruminant species were also reported earlier by Singh *et al.* (2018) and Calabro *et al.* (2013). The mean energy loss of fodders as methane from dry and green forages in sheep (9.64 and 9.04%) and goat (10.11 and 9.70%) inocula was more or less similar to a range of values (5.2–9.6%) reported by Bhatta *et al.* (2008) who evaluated 19 diets using *in vitro* gas production technique.

Furthermore, the proportion of methane relative to GE of the 22 fodders evaluated in the present study is within the range of Bhatt *et al.* (2008) with the exception of *Zea maize* stover, *Saccharum officinarum* tops and mixed grass for sheep, and *Cicer arietinum* straw, *Pennisetum purpureum* grass, *Panicum maximum* grass, *Medicago sativa*-A and mixed grass for goat. Contrary to our results, Boadi and Wittenberg (2002) reported that percentage of gross energy intake lost as methane was similar for high-, medium- and low-quality diets. Using a modelling approach, Benchaar *et al.* (2001) demonstrated that methane losses expressed as M cal/day or as % of GEI were higher (+7% and +28%, respectively) for alfalfa hay than for grass hay.

Results revealed that intake and digestible dry matter values of green fodders was more than for dry fodders. *In vitro* dry matter digestibility, gas production, CH_4

production (g/kg DDM) and loss of energy as CH_4 differed greatly between dry versus green fodders and sheep versus goat inocula. These findings indicate that incorporation of a particular fodder in diet of a particular species may result in lower gas and CH_4 production to benefit environment and to provide more dietary energy to animal for improved production.

ACKNOWLEDGEMENTS

The Ministry of Environment, Forest and Climate Change, Government of India, New Delhi provided funds for this work. Authors are thankful to Director, Indian Grassland and Fodder Research Institute for providing animal and laboratory facilities.

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