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Effect of Feed Restriction on Energy Metabolism and Methane Emission in Goats

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ABSTRACT

This study examined the effect of feed restriction on methane emission and energy metabolism in goats. Fifteen female goats of about ~ 1 year old, avg. body weight (BW) 12.59±0.60 kg were randomly divided into three groups of 5 each in a completely randomized design and randomly allocated to Control, RF-I and RF-II treatments. The goats of control group were fed total mixed ration ad *libitum* as per the predicted requirement, while in group RF-I and RF-II goats were fed 12.5 and 25 percent restricted diets, respectively of predicted requirements for 90 days. The methane emission in experimental goats was measured using open circuit respiration calorimetry. Methane emission (Ld^{-1}, Lkg^{-1} $W^{0.75}$) by goats was significantly ($P<0.01$) higher in control group followed by RF-I and RF-II, respectively. The methane emission (Lkg^{-1} DMI) did not differ significantly ($P>0.05$) among various treatment groups, however, methane emission (as percent (DOMI) was significantly ($P<0.01$) lower in RF-II as compared to control group. Losses of energy methane, faecal and urine energy ($kcald^{-1}$) were significantly ($P<0.01$) higher in control group followed by RF-I and RF-II, respectively. Metabolizability was significantly ($P<0.01$) higher in RF-II group as compared to RF-I and control. The heat production (kcal d^{-1}) was significantly ($P<0.01$) lower in goats fed 12.5 and 25 percent restricted diets as compared to *ad libitum*. It may be concluded that feed restriction considerably reduced methane emission and improved the energy utilization efficiency in goats.

Keywords: Energy utilization, feed restriction, goats, methane emission

It is well recognized that the increasing of green-house gases (GHG), mainly carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), in the atmosphere is contributing to an increasing earth surface temperature (Moss *et al*., 2000; Boadi *et al.,* 2004) . Intergovernmental Panel on Climate Change (IPCC) found that global warming potential weighted emissions of green house gases (GHGs) increased by approximately 70 percent from 1970 to 2004, with carbon dioxide (CO_2) being the largest source, having grown by about 80 percent, while emissions of methane (CH_4), the second most important GHG, rose by about 40 percent (IPCC, 2007). Methane is a very potent greenhouse gas (GHG) as it is twenty-one times more effective in trapping heat in the atmosphere than carbon dioxide (IPCC, 2007; EPA, 2010). The ruminant animals like cattle, buffalo, sheep and goats have significant amount of rumen fermentation which results in relatively large methane emissions per unit of feed energy consumed (Beauchemin and Mc Ginn, 2006). Meale *et al.* (2013) reported that CH_4 emission from ruminants accounts for 37 percent of total anthropogenic CH_4 emissions. Therefore, more emphasis should be given to methane emissions from ruminants and its mitigation in straw/ forage based feeding systems.

Methane is produced in the process of feed energy utilization within the animal; its reduction is usually associated with improved productivity (Lima *et al.,* 2013). Ruminant animals with poor production efficiency produce relatively high methane emissions. Animals with poor production efficiency divert large fraction of their feed intake solely for maintenance. Methane emissions associated with this maintenance level of feed intake, resulting in high level of emissions per unit product (Herd, 2002). Animal nutrition researchers have been focusing on various methods to reduce methane. Johnson and Johnson

(1995) reported that the amount of feed consumed affects the levels of CH_4 emission. Therefore, one of the strategies to optimizing energy use in ruminants is to minimize enteric methane (CH_4) emission during the fermentation process, by reducing dry matter intake (Shibata and Terada, 2010). Based on above observations, the present study was undertaken to ascertain the effect of feed restriction on methane emission and energy metabolism in goats.

MATERIALS AND METHODS

The experiment was conducted at the Animal Nutrition Research Sheds of the Indian Veterinary Research Institute (IVRI), Izatnagar in Uttar Pradesh Province of India.

Animals and diets

Fifteen female goats of about 1 year old, avg. BW 12.59 ± 0.60 were randomly divided into three groups of 5 each in a completely randomized design and randomly allocated to Control, RF-I and RF-II groups.

Table 1: Physical and chemical composition of TMR

Attributes	Composition (percent)
Physical composition (percent fresh basis)	
Maize	15
Wheat bran	11
Deoiled soybean meal	14
Molasses	08
Dried maize fodder	10
Wheat straw	40
Mineral mixture	01
Salt	01
Chemical composition (percent DM basis)	
Organic matter	90.76
Crude protein	12.39
Ether extract	2.11
Total Ash	9.24
NDF	57.34
ADF	30.00
Calcium	0.48
Phosphorus	0.40
GE (kcal kg^{-1})	3932

The goats of control group were fed a total mixed ration (TMR) *ad libitum* as per the predicted requirement (Kearl, 1982), while in RF-I and RF-II groups the goats were fed 12.5 and 25 percent restricted diets, respectively of predicted requirement. The physical and chemical composition of TMR is given in table 1. The ration schedule was adjusted fortnightly after recording the body weights of each animal. The goats were housed in a clean ventilated shed having provision for individual feeding and watering. All the animals were adapted to their respective experimental diets for a period of 15 days, during which their dry matter intake was recorded. All the animals were kept under strict hygiene and uniform management conditions during the 90 days of the experimental period.

Respiration calorimetry

Whole energy balance trials were conducted on individual goat one after the other, in an open circuit respiration chamber for small animals. Respiration calorimetry study was conducted in a simple type of open circuit calorimeter developed and described by Khan and Joshi (1983) for sheep and goat which consisted of a wooden chamber with internal dimensions (in meters) 1.5 × 0.9 × 1.75 (height). The chamber was maintained at 25°C with relative humidity about 65 percent. Concentration of oxygen, carbon dioxide and methane in sample air was recorded by an analyzer (Infra red gas analyzer; Type ZRJF4 C 25-BUKLF-GYYVYCY- AZ; Fuji Electric System Co. Ltd, Made in Japan) with the help of a flow meter having totaliser (Teledyne). Representative samples of the incoming and outgoing air from the respiration chamber were collected separately into two Douglas bags with the help of two sampling air pumps (Charles Austen Pumps, Survey, UK) with flow rate of 3 L per minute and provided with a by-pass arrangement to reduce their flow rate.

Prechamber handling of animals

The selected animal was weighed in the morning prior to feeding and watering and kept in respiration chamber for two days acclimatization, followed by recording of the respiration calorimetry data for two consecutive days. The animal was provided TMR and clean drinking water every day in the morning through feeding manger attached to metabolic crate, kept inside the respiratory chamber.

Measurement of respiratory exchange

After keeping the feed inside, the chamber was made airtight by closing the door and blower was started along with the ventilation system of the chamber. The equipment was run for an hour in order to stabilize the recorder. Observations on gaseous exchange were recorded for two consecutive days on each animal after adaptation period of two days in metabolic crate and two days in the respiration chamber. Recording the temperature of dry and weight bulb, flow rate, volume, atmospheric pressure was made manually. The sample of outgoing and incoming air from the respiration chamber was collected in Douglas bag separately with continuous sampling device at 12 hourly intervals. The chamber was opened after 24 h; the residues of feeds, faeces voided and urine excreted were collected and measured. Urine samples were collected in acidified containers and proportionate samples were preserved with 20 percent (v/v) sulphuric acid for estimation of nitrogen content in urine. Samples of feed (TMR), residue and faeces were dried at 60°C for 24 h or till content weight in a forced-draft oven for dry matter and gross energy estimation. Heat production was calculated as per Brouwer's equation (1965).

Chemical analysis

Samples of TMR, residues and faeces were milled to pass through a 1.0 mm sieve and then analyzed following the methods of AOAC (1995) to determine dry matter (DM) by the oven drying method (934.01), organic matter (OM) by muffle furnace incineration (967.05), crude protein by Kjeldahl method (984.13; N×6.25), ether extract (920.39), ash (942.05). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined following the methods of Van Soest *et al*. (1991). NDF was assayed with sodium sulphite in the NDF reagent without alpha-amylase and the results were expressed with residual ash. The calcium was estimated following the method of Talapatra *et al*. (1940) and phosphorus was estimated by photometric method (AOAC, 1995). The gross energy of feeds, feacal and urine samples was determined by Adiabatic Bomb Calorimeter (Toshniwal Microprocessor Bomb calorimeter; CAT. No. CC. 01 / M3) along with computer operated soft ware (Toshniwal Brothers Pvt. Ltd, Delhi).

Statistical analysis

The data obtained were subjected to analysis of variance using SPSS 17 software and treatment means were ranked using Duncan's multiple range test. Significance was declared at P<0.05 unless otherwise stated. All the statistical procedures were done as per Snedecor and Cochran (1994).

RESULTS AND DISCUSSION

Chemical composition of TMR

The chemical composition (percent DM basis) of TMR is presented in table 1. The proximate composition and fiber fractions of TMR offered to experimental goats were comparable with the values reported by earlier workers (Pi *et al*. 2005; Shi *et al*. 2011). The gross energy value of TMR was 3932 kcal kg^{-1}.

Intake and digestibility

Daily intake of DM and OM by goats was significantly (P<0.01) higher in control group followed by RF-I and RF-II, respectively. Present results are in conformity with the findings of Kamalzadeh and Aouladrabiei (2009), who reported significantly (P<0.01) higher intake of DM and OM in sheep fed *ad libitum* as compared to restricted (maintenance) diet. Similarly, Murphy *et al*. (1994) also found higher (P<0.01) DMI in growing lambs fed *ad libitum* followed by 90, 80 and 70 restricted diets of *ad libitum*, respectively. Helal *et al*. (2011) also reported reduced DMI in calves fed 70 and 85 percent restricted diets of the concentrate mixture as compared to fed *ad libitum*.

The digestibility coefficient of DM and OM measured during respiration study were significantly (P<0.01) higher in 25 percent restricted goats as compared to goats fed *ad libitum* and 12.5 percent restricted diets. Our results are in agreement with the findings of Murphy *et al*. (1994) who reported linearly (P<0.01) increased digestibility values of DM and OM in lambs fed 90, 80 and 70 percent restricted diets of *ad libitum*. Similarly, Ojha (2013) observed significantly (P<0.01) higher digestibility of DM and OM in calves fed 30 percent restricted diet as compared to *ad libitum*. In the present study, higher digestibility in restricted groups might be attributed to less feed intake resulted in a more efficient mastication, by longer time spent in eating and ruminating per kg ingested feed as also observed by Ulyatt *et al*. (1984), Aitchison *et al*. (1986) and Ojha (2013). Generally nutrients intake and digestibility are related inversely (ARC, 1980).

Methane emission

Methane emission by experimental goats was measured using open circuit respiration calorimeter after 60 days feeding. The data pertaining to respiration chamber study is presented in table 2. Average BW and metabolic body size of goats during respiration chamber study did not differ significantly (P>0.05) among dietary treatments. Methane emission (Ld^{-1}, $Lkg^{-1}W^{0.75}$, kcal d^{-1}) by goats was significantly (P<0.01) higher in control group followed by RF-I and RF-II, respectively. Our results are in agreement with the findings of Benchaar *et al*. (2001) Hart *et al*. (2009), Yan *et al*. (2010) and Lima *et al*. (2013), who reported a decrease in CH_4 (kcal d^{-1}) production with decreased DMI in cattle and goats, however, when CH_4 production was expressed relative to DMI or GEI, it was similar among all the treatments. Similar findings were also reported by Molano and Clark (2006), who did not found any change in CH_4 production (g kg^{-1}DMI) from lambs and ewes as intakes increased from about 0.8 to 2.0 times MEm. Lima *et al*. (2013) also reported no significant difference in CH_4 production (g kg^{-1}DMI) by goats fed *ad libitum*, 25 and 50 percent restricted diet. In present study, methane emission (Lkg^{-1}DMI) was 20.48, 19.16 and 17.89 by goats in control, RF-I and RF-II group, respectively. The results of present study are in agreement with the findings of Munger and Kreuzer (2006) and Molano and Clark (2006), who reported methane yield, between 16 to 26 Lkg^{-1} DMI in global studies. The CH_4 emission (as percent DOMI) was significantly lower in RF-II as compared to control group, however, goats in RF-I group has intermediate position between control and RF-II group (fig. 1).

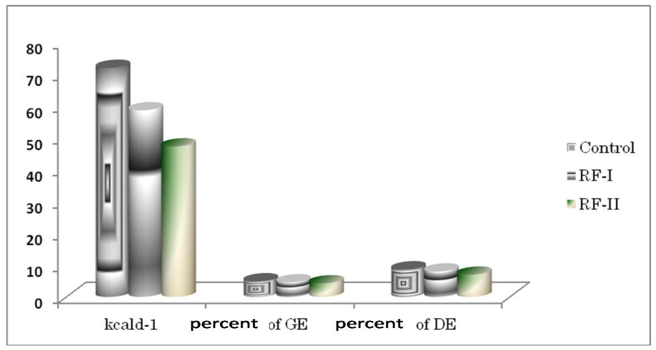

Fig. 1: Effect of feed restriction on methane emission by goats

This is probably due to an increased efficiency of feed utilization as a result of decreased rumen feed passage (Kamalzadeh and Aouladrabiei, 2009). In present study, the methane emission was reduced 18.5 and 34.25 percent at 12.5 and 25 percent dietary restriction level in goats.

Energy utilization

The intake of gross, digestible and metabolizable energy (kcal d^{-1}) by goats was significantly (P<0.01) higher in

Table 2: Effect of feed restriction on methane emission in goats

Attributes	Dietary treatments			SEM	P Value
	Control	RF-I	RF-II		
Body Wt.(kg)	15.48±0.83	15.50±1.10	14.53±0.36	0.82	0.646
Metabolic body size, (kg)	7.79±0.32	7.80±0.41	7.45±0.14	0.31	0.676
DMI (g d^{-1})	372.50±5.37^{c}	323.75±2.65^{b}	279.75±3.35^{a}	11.57	<0.001
DM digestibility	56.50±0.63^{a}	57.40±0.83^{a}	60.91±1.01^{b}	0.72	0.011
Urinary N (g d^{-1})	4.68±0.11^{b}	3.64±0.12^{a}	3.18±0.44^{a}	0.27	0.010
CH_4 emission (Ld^{-1})	7.62±0.07^{c}	6.21±0.12^{b}	5.01±0.05^{a}	0.33	<0.001
CH_4 emission (L kg^{-1} $W^{0.75}$)	0.98±0.03^{c}	0.81±0.05^{b}	0.67±0.01^{a}	0.04	0.001
CH_4 emission (L kg^{-1} DMI)	20.48±0.98	19.16±0.58	17.89±0.20	0.74	0.180

^{abc} Means with different superscripts within a row differ significantly

Table 3: Effect of feed restriction on energy partitioning in goats

Attributes	Dietary treatments			SEM	P Value
	Control	RF-I	RF-II		
GE intake (kcal d^{-1})	1473.91±21.29^{c}	1282.64±10.52^{b}	1107.81±13.27 ^{a}	45.82	<0.001
Faecal energy					
kcal d^{-1}	641.34±15.93^{c}	546.41±12.94^{b}	432.57±6.62^{a}	26.54	<0.001
percent of GE	43.50±0.63^{b}	42.59±0.83^{b}	39.08±1.01^{a}	0.72	0.011
Digestible energy					
kcal d^{-1}	832.58±11.44^{c}	736.24±10.00^{b}	675.24±19.02^{a}	20.86	<0.001
percent of GE	56.50±0.63^{a}	57.41±0.83^{a}	60.92±1.01^{b}	0.72	0.011
Urine energy					
kcal d^{-1}	71.66±1.32^{c}	60.30±0.43^{b}	48.00±0.71^{a}	2.95	<0.001
percent of GE	4.88±0.05^{c}	4.73±0.02^{b}	4.35±0.05^{a}	0.07	<0.001
Methane energy					
kcal d^{-1}	71.98±2.20^{c}	58.65±2.96^{b}	47.28±3.27^{a}	3.39	0.002
kcalkg^{-1}W$^{0.75}$	9.28±0.32^{c}	7.60±0.50^{b}	6.36±0.13^{a}	0.40	0.001
percent of GE	4.89±0.15	4.57±0.21	4.26±0.26	0.13	0.171
percent of DE	8.66±0.34^{b}	7.99±0.48 ^{ab}	6.99±0.36^{a}	0.29	0.046
Metabolizable energy					
kcal d^{-1}	688.94±12.44^{c}	617.29±11.82^{b}	579.97±16.67^{a}	15.43	0.001
Metabolizability (ME/GE)	0.47±0.01^{a}	0.48±0.01^{a}	0.53±0.01^{b}	0.01	0.004
percent of DE	82.74±0.46^{a}	83.83±0.56^{a}	85.89±0.41^{b}	0.47	0.004
Heat production					
kcal d^{-1}	544.31±9.49^{b}	485.88±8.44^{a}	456.65±14.89^{a}	12.47	0.001
kcal kg^{-1}W$^{0.75}$	70.26±3.26	62.73±2.67	61.42±2.55	1.89	0.112
Energy Retention					
kcal d^{-1}	144.63±4.23^{c}	131.41±4.77^{b}	123.32±2.58^{a}	3.36	0.013
percent of GE	9.82±0.33^{a}	10.25±0.43^{ab}	11.13±0.14^{b}	0.24	0.049

^{abc} Means with different superscripts within a row differ significantly

control group followed by RF-I and RF-II, respectively. Similarly, losses of methane, faecal and urine energy (kcal d^{-1}) were significantly (P<0.01) higher in control group followed by RF-I and RF-II groups, respectively (Table 3). The results of present study are in agreement with the earlier findings (Kamalzadeh and Aouladrabiei, 2009; Kamalzadeh *et al*., 2009), they found that energy losses through faeces, urine and methane were significantly reduced in feed restricted (below maintenance) animals as compared to control. Digestible energy intake (percent GE) was significantly (P<0.01) higher in RF-II by goats as compared to control and RF-I groups, which might be attributed to higher dry matter digestibility.

Metabolizability (ME/GE) was significantly (P<0.01) higher in RF-II (25 percent restricted diet) group as compared to RF-I and control, which might be attributed to less methane and urine energy losses, implying an increased efficiency in ME utilization (Kamalzadeh and Aouladrabiei, 2009). Similar to our findings, Thomson *et al*. (1982) and Kamalzadeh and Aouladrabiei (2009) also reported an improvement in metabolizability in feed restricted animals as compared to control. The metabolizability values obtained in this study were between 0.47 to 0.52 and these were in the normal range (0.40 to 0.64) proposed in several reports (ARC, 1980; Thomson *et al*., 1982; Oosting *et al*., 1995; Kamalzadeh, 2004). The metabolizable energy was 0.84 and 0.86 of the DE for goats in RF-I and RF-II, respectively. These values were above the generalized value of 0.82, suggested by Blaxter (1962) and ARC (1965). However, Gingins (1978) and Koenig *et al*. (1980) reported similar results, which were attributed to low methane and urine energy losses in feed restricted goats.

The heat production (kcal d^{-1}) was significantly (P<0.01) lower in goats fed 12.5 and 25 percent restricted diets as compared to fed *ad libitum*. The lower heat production (kcal d^{-1}) in restricted goats was mainly consequence of lower DMI and heat increment of feeding and fermentation (El-Meccawi *et al*., 2008) as well as lower maintenance requirement. It has been observed that animals on restricted planes of nutrition have lower maintenance energy requirement (Kamalzadeh *et al*., 2009; Ferrell *et al*., 1986) because of decrease in the weight of metabolic active organs such as liver, gastrointestinal tissues, kidney etc (Mora *et al*., 1996; Dashitzadeh *et al.,* 2008). Also, it has been shown that mild feed restriction resulted in appreciable changes in the metabolism of the liver and gastrointestinal tissues (Tovar-Luna *et al.,* 2007).

In the present study, energy retention was significantly (P<0.05) higher in control group followed by RF-I and RF-II, respectively. Although RF-II had significantly (P<0.05) higher energy retention as compared to control when it was expressed as percent of GE intake. The RF-I group has an intermediate position between control and RF-II.

On the basis of results, it is concluded that feed restriction significantly reduced the methane emission (18.5-34.25 percent) in goats. Feed restriction at 12.5 and 25 percent levels considerably increased the efficiency of energy utilization with concomitant reduction in excretory energy losses.

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