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Effect of Feeding Total Mixed Ration on Methane Emission and Energy Metabolism in Crossbred Cattle and Buffaloes

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ABSTRACT

This study evaluates the nutrients digestibility and energy metabolism of crossbred cattle and buffaloes fed different ratio of concentrate and roughage based ration. 12 adult animals were used of three groups of cattle and buffalo, the following: cattle (*Bos taurus* × *Bos indicus)* (n=6) and buffalo (*Bubalus bubalis*) (n=6). Three groups of animals, each consisting two crossbred cattle, and two buffalo were fed experimental diets and used in 3×3 switchover design. A metabolism trial was conducted with six crossbred cattle and six buffaloes fed with different ratio of concentrate and roughage. There was non-significant difference in nutrient digestibilities between cattle and buffaloes. Respiration calorimetric studies revealed that heat production was significantly ($P<0.01$) lower in buffaloes however, methane emission and net energy utilization was significantly ($P<0.05$) higher in buffaloes than cattle. It was concluded that under higher plane of nutrition and higher concentrate: roughage ratio there is significant reduction in methane emission compared to lower plane of nutrition in both species. However, efficiency of energy utilization was significantly lower in crossbred cattle than buffaloes.

Keywords: Cattle and buffalo, methane emission, energy metabolism, nutrient digestibility

In India both cattle and buffaloes play an important role in farmer's economic life, being an integral part of the farming system. There are contrary reports regarding the intake and efficiency of utilization of nutrients and energy metabolism among buffaloes and crossbred cattle. Ranjhan (1988) reported that there might be a difference between the riverine buffalo and the cattle in ability to digest poor quality roughage.

When cattle and buffalo are kept under similar conditions, buffaloes digest feed more efficiently than cattle, as reported by Wanapat (2001). Wanapat and Rowlinson (2007) observed that DM, OM, protein intake and total digestible energy intake tended to be higher for buffaloes as compared to cattle. Davendra (1983) reported that nitrogen utilization in swamp buffalo was found to be more efficient than that in Malaysian cattle. Contrary, Kennedy *et al*. (1992 a, b) reported lower digestibility for buffalo than cattle fed rice straw and tropical forages. Rodrigues *et al*. (2001) found no difference in ($P>0.05$) DM intake between Buffalo and cattle. Abdullah *et al*. (1992) observed no difference ($P>0.05$) for dry matter intake in cattle and buffaloes. Similarly, Reid *et al*. (1990) observed similar digestibility of DM and OM in crossbred cattle and water buffalo.

Generally a livestock farmer provide the limited concentrate to their dairy animals due to its high cost and straw, crop residues and green fodder like green maize, berseem, lucerne etc. and grazing and field grasses were commonly available as major feed resources for ruminants. Concentrate feeds reduce ruminal methane production but diets high in cereals reduce ruminal pH (Franzolin and Dehority 1996) which may induce acidosis thereby causing reduced feed intake and nutrient absorption as well as depressed animal performance (Owens *et al*. 1998).

Therefore, present experiment was conducted to examine the nutrient utilization, energy metabolism and methane emission in crossbred cattle and buffaloes fed TMR.

MATERIALS AND METHODS

The protocol for this experiment was approved and animals were cared according to the guidelines of the Institutional Animal Care and Use Committee of Indian Veterinary Research Institute, Izatnagar, Bareilly, (UP), India.

Animals and experimental design

Twelve adult animals (6 cattle and 6 buffaloes) of 12-18 months and body weight 257 and 319 kg, respectively, were selected and divided into three groups. Three groups of animals, each consisting two crossbred cattle, and two buffalo were fed experimental diets and used in 3×3 switchover design.

All the animals were individually provided with weighed amount of TMR diet in the ratios of 60:20:20, 40:30:30 and 20:40:40, respectively (concentrate: wheat straw: green maize) for *ad libitum* feeding regime and daily intake of TMR by each animal was determined by weighing the left over residue in the morning before offering the experimental diet. The chemical composition of various TMR is given in table 1.

Table 1: Chemical composition of various TMR (%)

Attributes	TMR-I	TMR-II	TMR-III
	60C:20W:20G	40C:30W:30G	20C:40W:40G
DM	89.92	90.43	90.56
OM	92.30	92.16	92.05
CP	14.64	11.65	8.89
EE	2.07	1.67	1.30
CF	19.20	25.37	30.91
NDF	49.59	56.31	62.48
ADF	24.34	32.01	39.06
Gross Energy (Kcal/g)	4.09	4.01	3.94

TMR = Total mixed ration; C=Concentrate; W =Wheat straw; G=Green maize

Metabolism and respiration trial

Three metabolism trials of six days duration excluding three days of adaptation period were conducted keeping the animals individually in the metabolic cages after three weeks of experimental feeding. After metabolic trial three respiration chamber study trials were conducted in an Open Circuit Respiration Chamber for all animals of each group.

Chemical analysis

The proximate principles of (feeds, faeces and urine) were determined by (AOAC, 1995). The fibre fractions were analysed as per Van Soest *et al*. *(*1991). Gross energy (GE) of the samples was estimated by Gallenkamp Ballistic bomb calorimeter (Gallenkamp, C.B.370 ME, UE and DE were calculated).

Methane energy loss was calculated from the total amount of methane produced multiplied by its calorific value (13.34 kcal/g or 9.45 kcal/L). Heat production (kcal/d) was calculated using the equation: 3.866 O_2 (litres/d) + 1.200 CO_2 (litres/d) – 0.518 CH_4 (litres/d) – 1.431 N (g/d) (Brouwer, 1965). Energy balance (kcal/d) was calculated using the equation: ME Intake - heat increment.

Statistical analysis

The data were analysed using the statistical software SPSS (version 20.0). All data were subjected to ANOVA and differences among treatments were analysed by Duncan's Multiple Range using Generalized Linear Model (Snedecor and Cochran, 1994).

RESULTS AND DISCUSSION

The partition of energy in faeces, feed, residue, urine, methane and heat production, is depicted in Table 2 and 3. GE intake (Mcal/d) and GE Intake/kg$W^{0.75}$ (kcal/d) in crossbred cattle (26.18 and 406.84 and buffaloes (28.42 and 376.70) was non-significant (P>0.05) with each other. The intakes of energy in crossbred cattle and buffaloes were comparable due to similar the total DM and OM consumption (kg/d) and DMI/kg$W^{0.75}$ in the crossbred cattle and buffaloes.

Table 2: Energy metabolism (Mcal/d) in crossbred cattle and buffaloes fed different TMR diets

60C:20W:20G	40C:30W:30G	20C:40W:40G	Mean ± SE		SEM	P-Values		
T1	T2	T3	Cattle	Buffalo		T	S	T×S
Body weight (kg)								
287.33	287.96	289.56	257.01^{q}	319.56^{p}	8.34	NS	**	NS
Dry Matter Intake (kg/d)								
6.86	6.52	6.25	6.30	6.79	0.20	NS	NS	NS
Dry Matter Intake (g/kgW$^{0.75}$)								
98.26	93.97	89.52	97.84	90.00	2.21	NS	NS	NS
Gross Energy Intake (Mcal/d)								
29.69^{b}	27.07^{ab}	25.14^{a}	26.18	28.42	0.86	**	NS	NS
Gross Energy Intake (kcal/kgW$^{0.75}$)								
425.17^{b}	390.16^{ab}	359.98^{a}	406.84	376.70	9.08	**	NS	NS
Faecal Energy Loss (Mcal/d)								
10.51^{b}	9.48^{ab}	8.51^{a}	9.04	9.96	0.40	*	NS	NS
Faecal Energy Loss (kcal/kgW$^{0.75}$)								
149.99^{b}	135.75^{ab}	121.13^{a}	139.40	131.85	4.72	*	NS	NS
Digestible Energy Intake (Mcal/d)								
19.18^{c}	17.59^{b}	16.64^{a}	17.15	18.46	0.55	*	NS	NS
Digestible Energy Intake (kcal/kgW$^{0.75}$)								
275.18^{b}	254.41^{ab}	238.85^{a}	267.45	244.85	6.26	*	NS	NS
Methane Energy Loss (Mcal/d)								
1.64^{a}	1.77^{ab}	1.98^{b}	1.59^{q}	2.00^{p}	0.06	*	**	NS
Methane Energy Loss (kcal/kgW$^{0.75}$)								
23.28^{a}	25.48^{a}	28.33^{b}	24.76^{q}	26.64^{p}	0.61	**	*	NS
Urinary Energy Loss (Mcal/d)								
0.43^{a}	0.47^{a}	0.60^{b}	0.39^{q}	0.60^{p}	0.02	**	**	NS
Urinary Energy Loss (kcal/kgW$^{0.75}$)								
6.17^{a}	6.83^{a}	8.62^{b}	6.26^{q}	8.15^{p}	0.33	**	**	NS
Metabolizable Energy Intake (Mcal/d)								
17.11^{b}	15.34^{ab}	14.05^{a}	15.16	15.84	0.51	*	NS	NS
Metabolizable Energy Intake (kcal/kgW$^{0.75}$)								
245.72^{b}	222.09^{ab}	201.89^{a}	236.42^{p}	210.05^{q}	6.27	**	*	NS
Heat Increment (Mcal/d)								
9.48	9.43	9.31	10.25^{p}	8.56^{q}	0.21	NS	**	NS

Heat Increment (kcal/kgW$^{0.75}$)								
139.17	138.23	137.82	161.37^{p}	115.45^{q}	5.19	NS	**	NS
Net Energy (Mcal/d)								
7.62^{b}	5.91^{ab}	4.74^{a}	4.91^{q}	7.27^{p}	0.53	*	*	NS
Net Energy (kcal/kgW$^{0.75}$)								
106.55^{b}	83.85^{ab}	64.06^{a}	75.05^{q}	94.60^{p}	6.77	*	*	NS

Mean bearing different superscripts in a column and row differ significantly, *P<0.05; **P<0.01
SEM, standard error of the mean (n=36); T = Dietary treatment; S = Species (Crossbred cattle and buffalo); T×S = Interaction between species and dietary treatments. C=Concentrate; W =Wheat straw; G=Green maize.

Table 3: Balance of Energy Metabolism (%) in Crossbred Cattle and Buffaloes Fed Different TMR Diets

60C:20W:20G	40C:30W:30G	20C:40W:40G	Mean ± SE		SEM	P-Values		
T1	T2	T3	Cattle	Buffalo		T	S	T×S
Faecal Energy Loss as % Gross Energy Intake								
35.12	34.92	33.82	34.17	35.07	0.78	NS	NS	NS
Digestible Energy as % Gross Energy Intake								
64.88	65.08	66.18	65.83	64.93	0.78	NS	NS	NS
Urine Energy Loss as % Gross Energy Intake								
1.49^{a}	1.79^{a}	2.44^{b}	1.58^{q}	2.23^{p}	0.11	**	**	NS
Methane Energy as % Gross Energy Intake								
5.48^{a}	6.54^{b}	7.91^{c}	6.14^{q}	7.14^{p}	0.19	**	**	NS
Metabolizable Energy as % Gross Energy Intake								
57.90	56.74	55.82	58.09	55.56	0.80	NS	NS	NS
Metabolizable Energy as % Digestible Energy Intake								
89.47^{c}	87.35^{b}	84.37^{a}	88.65^{p}	85.47^{q}	0.48	**	*	NS
Heat Increment as % Gross Energy Intake								
33.18^{b}	36.07^{ab}	38.65^{a}	40.54^{p}	31.39^{q}	1.51	*	**	NS
Net Energy as % Gross Energy Intake								
24.72^{b}	20.67^{ab}	17.17^{a}	17.54^{q}	24.16^{p}	1.43	*	*	NS
ME:GE Ratio								
0.58	0.57	0.56	0.58	0.56	0.008	NS	NS	NS
ME:DE Ratio								
0.89^{c}	0.87^{b}	0.84^{a}	0.88^{p}	0.86^{q}	0.004	**	**	NS

Mean bearing different superscripts in a column and row differ significantly, *P<0.05; **P<0.01
SEM, standard error of the mean (n=36); T = Dietary treatment; S = Species (Crossbred cattle and buffalo); T×S = Interaction between species and dietary treatments; DE = Digestible energy; ME = Metabolizable energy. C=Concentrate; W =Wheat straw; G=Green maize.

GE intake (Mcal/d) and Intake/kgW$^{0.75}$ (kcal/d) differ significantly (P<0.01) among all the treatments. It varied significantly (P<0.01) with T_1 and T_3 and non-significant with T_2. Among the various treatments it was highest for T_1 because of high level of concentrate in it, this is supported by the GE intake is the function of level of energy and energy density of ration.

Faecal energy (FE) loss (Mcal/d) and faecal energy outgo (faeces/kgW$^{0.75}$) of crossbred cattle and buffaloes was non-significant (P>0.05) each other. Among the treatments FE loss (Mcal/d) and faeces/kgW$^{0.75}$ were significant (P<0.05) with each other. Similar observation was found by Blaxter and Wainman (1964) which match with the results obtained in the current experiment increased faecal energy loss with increasing proportion of faked maize in the diet beyond 60 to 80%. Contrary to this Kurihara *et al*. (1999) observed faecal energy loss was highest (P<0.01) for cattle fed on Angleton grass and lowest (P<0.01) for cattle fed on the high-grain diet. FE loss as percentage of GE intake was non-significant (P>0.05) among the various treatments and in crossbred cattle and buffaloes. Castillo *et al*. (2001) observed faecal nitrogen output was not affected by different sources of energy, but there was a significant increase in urinary nitrogen output.

Urinary energy (UE) loss (Mcal/d) and UE loss/kgW$^{0.75}$ (kcal/d) in crossbred cattle and buffaloes group was significantly (P<0.01) higher in buffalo than crossbred cattle. Among the treatments UE loss (Mcal/d) and UE loss/kgW$^{0.75}$ (kcal/d) were significant with each other whereas, T_3 high roughage diet was significantly (P<0.01) higher than low roughage diet T_1 with decrease in concentrates the energy losses increases. The dietary gross energy deficiency in the low concentrate diet shifted the excreted N fraction towards the urine rather than the faeces. Contrary, Kurihara *et al*. (1999) reported there was non-significant difference in urinary energy loss between the three different diets. UE loss as percentage of GE intake was significant (P<0.01) among the various treatments and significantly (P<0.01) higher in buffaloes than crossbred cattle. The urinary energy loss ranged from 1.87 to 2.36% of GE (Murari lal *et al.* 1987).

DE intake (Mcal/d), DE intake kcal/kgW$^{0.75}$ and DE as percentage of GE intake were non-significant (P>0.05) in crossbred cattle and buffaloes, respectively. Similar observation observed by Castillo *et al*. (2001).

Among the various treatments DE intake (Mcal/d) and DE intake/kgW$^{0.75}$ (kcal/d) was significant (P<0.01) between T_1 and T_3 and both varied non-significant (P>0.05) with T_2 and DE as percentage of GE intake was non-significant (P>0.05) among various treatment groups. Digestibility was higher in high concentrate diet than the high roughage diet. Kawashima *et al*. (2006) found that the ratio of DE to GE was the lowest in treatment with lower CP (%) and followed by that of treatment in which CP percentage is 10.34 and it was highest in treatment with (13.47%) which matches with the result of current research.

Methane energy (Mcal/d) was significantly (P<0.01) lower in crossbred cattle than buffaloes, respectively and its corresponding values were Methane energy loss/kgW$^{0.75}$ (kcal/d) was significantly (P<0.05) lower in crossbred cattle than buffaloes, respectively. Methane energy loss as the percentage of GE intake was also found to be significantly higher (P<0.01) in buffaloes than crossbred cattle. Gopal Krishna *et al*. (1969) reported when wheat straw formed in predominant component of the ration loss of energy as methane ranged from 5.92 to 8.34% of GE. Methane production do fall from a level of 6-7% of energy intake when forages are fed at maintenance to as low as 2-3% when high grain concentrates are fed at near *ad libitum* intake levels (Johnson and Johnson, 1995). Contrary to this, Kawashima *et al*. (2006) reported that energy loss into methane production on the basis of GE intake tended to be lower in buffalo (3.7%) than in cattle (4.4%) when fed with grass hay (*Brachiaria ruziziensis)*. Among the various treatments Methane energy loss (Mcal/d) and Methane energy loss/kgW$^{0.75}$ (kcal/d) was significantly higher for high roughage diet group T_3 and lowest for low roughage diet group T_2. Among the various treatments methane energy loss as the percentage of GE intake was significantly higher (P<0.01) for T_3 than T_2 and T_1. Methane production since methane production related directly to the methane energy loss. The main component affecting methane production is the type of carbohydrate and relative rate of fermentation.

ME intake (Mcal/d) was non-significant (P>0.05) in crossbred cattle and buffaloes, respectively and its corresponding values ME intake/kgW$^{0.75}$ (kcal/d) was significantly (P<0.05) higher in crossbred cattle than buffaloes. ME intake (Mcal/d) among treatment groups were significantly (P<0.05) highest for T_1 than T_3 and T_2 lied non-significantly between them. ME intake/kgW$^{0.75}$

(kcal/d) among the treatments groups T_1, T_2 and T_3, respectively were highly significant (P<0.01) with T_1 and T_3, where T_2 is non-significant between T_3. ME intake as percentage of GE intake varied non-significant (P<0.05) among treatments group and within both species but when it expressed on DE intake it was highly significant (P<0.01) in crossbred cattle than buffaloes and among the treatments they showed significantly (P<0.01) highest in $T_{1,}$ T_2 than T_3 groups. Percent metabolizable energy expressed on DE intake was significantly (P<0.01) highest in group fed high concentrate ratio than in group which were fed high roughage ratio. Hart *et al*. (2009) found that the DM digestibility of grass had a direct effect on the CP digestibility, which could be attributed to the high concentration of metabolizable energy (ME) of the highly digestible diet compared to the poorly digestible one. These results were in agreement with the reports of Mcleod and Baldwin (2000) and Haddad (2005) who reported higher ME in the high-concentrate diets than low-concentrate diets.

Heat increment (Mcal/d), HI/kg$W^{0.75}$ (kcal/d) and HI as percentage of GE intake were significantly (P<0.01) higher in crossbred cattle than buffaloes and among various treatment groups HI (Mcal/d) and HI/kg$W^{0.75}$ were non-significant (P>0.05). HI as percentage of GE intake was significantly highest in high roughage diet T_3 and lowest in low roughage diet T_1. Kurihara *et al*. (1999) reported that heat production was not significantly affected by dietary treatment. Heat production across diets was affected by intake of energy as animals in a lower plane of nutrition showed higher heat productions. This is indicative of the more energy loss as heat production on high roughage diet which may be due to wastage of more energy on work of digestion on all roughage rations as compared to concentrate diet (Armstrong and Blaxter, 1957).

Net energy (Mcal/d), NE/kg$W^{0.75}$ (kcal/d) and NE as percentage GE intake were significantly (P<0.05) lower in crossbred cattle than buffaloes, respectively. However, Ichinohe *et al*. (2004) observed utilization of feed energy, buffaloes were found to have higher Gross Energy (GE) digestibility than cattle and in a comparison of swamp buffaloes and Malaysian local cattle, it was found that the maintenance energy requirement of the buffalo was lower and efficiency of NE utilization was significantly higher in buffaloes as compared to crossbred cattle. Contrary, Kawashima *et al*. (2006) reported no significant difference in energy intake, energy loss and energy retention between Brahman cattle and swamp buffalo during feeding grass hay (*Brachiaria ruziziensis)*. Among the various treatment groups NE (Mcal/d), NE/kg$W^{0.75}$ (kcal/d) and NE as percentage of GE intake were significantly (P<0.01) higher for high concentrate diet group T_1 and lower for low concentrate diet group T_3 and group T_2 non-significant (P>0.05) lied between both groups.

CONCLUSION

It was concluded that the crossbred cattle showed lower CH_4 emission than buffaloes. The efficiency of energy utilization was significantly higher in buffaloes as compared to crossbred cattle. Higher concentrate to roughage ratio in the diet significantly reduces enteric CH_4 emissions.

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