Comparative Calorimetric Evaluation of Ammoniated Straw-Based Rations Supplemented with Low Levels of Untreated and Formaldehyde Treated Groundnut Cake and Fish Meal with Respect to Growing Buffalo Calves

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ABSTRACT : Eighteen growing male Murrah buffalo (*Bubalus bubalis*) calves were divided into three groups consisting of six animals each and fed three urea ammoniated wheat straw (UAS) -based rations supplemented with concentrate mixtures (roughage: concentrate ratio 58:42) containing deoiled ground nut cake, GNC (8%), formaldehyde treated GNC (8%) or fish meal (8%) to undertake comparative evaluation of these rations in terms of their CH_4 production and growth (285 d duration) potential. A digestibility trial (10 d duration) was followed by a comparative calorimetric study in respiration chamber. Dry matter (DM) intake (84.3 to 89.3 g/kg $W^{0.75}d^{-1}$) did not differ between treatments. The digestibility coefficient of DM, organic matter (OM), crude protein (CP), neutral and acid detergent fiber did not differ significantly in different diets. Urinary energy loss as a percent of gross energy (GE) was not affected by diets. Average values of CH_4 production were 84.3, 77.6 and 99.1 g/d and CH_4 energy losses as percent of gross energy were 5.7, 5.2 and 6.1 percent on GNC, formaldehyde treated GNC and fishmeal, respectively, and did not differ significantly. When expressed per unit of digestible OM intake, CH_4 production (g) was lower ($p<0.05$) on formaldehyde treated GNC (30.6) than on untreated GNC (30.6) and fish meal (31.9). Total ME intake and heat production were similar and hence the energy balances on different diets were similar. Nutritive value of rations in terms of digestible CP and ME were similar. Average daily gain calculated on the basis of regression of fortnights on cumulative liveweight gain in calves fed on concentrate containing unprotected GNC, protected GNC and fish meal were 437.1, 483.9 and 481.6 g, respectively. This indicated that the intake of energy was sufficient to meet the requirement of calves growing at 400 g per d. However, CP intake was around 150% of the stipulated standard (Kearl, 1982). Feed conversion ratios on unprotected GNC, protected GNC and fish meal were 11.60, 11.10 and 10.4 respectively. It was concluded that because significantly ($p<0.05$) low CH_4 is produced on protected GNC (8%), it is very good and sustainable protein source in comparison to poor quality fish meal and untreated GNC to be used in concentrate mixture for supplementing UAS-based diets. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 6 : 761-773*)

Key Words : Buffalo Calves, Growth, Calorimetry, CH_4 Production, Ammoniated Wheat Straw, Protein Supplements

INTRODUCTION

Buffalo calves have well recognized meat production potential. The buffalo beef industry (since neglected) has tremendous scope for expansion in India because ban on cow slaughter is not applicable to buffaloes but needs proper organization. Feeding of calves is important from the standpoint of getting good returns. Rearing of these animals on straws which is available in large quantities (321.4 MMT) in India (Ramchandran, 1989) can offer economic benefit to livestock raisers. However, straws have poor nutritive quality practically in terms of digestible protein and energy.

Nutritive value of straw can be improved by various treatments and supplementation of animal or plant protein sources or combination of these. Urea ammoniation is cheaper, easier, practicable and accepted and adopted form of straw treatment for improving its nutritive value. Ammoniated straw can form maintenance ration (Birkelo et al., 1986; Tiwari et al. unpublished) but to sustain growth rate in growing calves, it has to be supplemented with undegradable protein sources such as fish meal or protected oil cakes which can meet protein demand for growth. The two fold local problem with the use of fish meal besides its high price is that it is very much needed in well organised and rapidly expanding poultry industry. Secondly quality fishmeal is not easily available. So alternative left is supplementation of oil cakes, in the production of which, India ranks first in the world.

It is also noteworthy to mention that India ranks first not only in ground nut production (6.6 MMT) but also in its total area (7.7 million hectare) under cultivation of which majority area (6.6 million hectares) is un-irrigated in which cultivation is done in *Kharif* season (June-September). It is estimated that

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with the use of latest technology, its production can be increased by 3.5 MMT. Groundnut is also grown in many tropical areas where there is low rainfall. In some reports it has been shown that supplementation of small amount of fish meal to untreated straw or ammoniated straw increased the growth rate in calves (Ortigues et al., 1990; Singh 1991). However some did not find a significant effect of fishmeal supplementation to straw-based rations in improving live weight gain in calves (Kumar et al., 1988; Sil, 1992). Sustainable animal production systems now a days want that the CH_4 produced should be less per unit output of the animal product, so it has to be kept in mind that the formulated ration on feeding emits less CH_4. CH_4 energy loss is less in ammonia treated rather than untreated straw (Moss et al., 1994) and in one study (Tiwari et al., unpublished), we noted similar CH_4 production on urea ammoniated wheat straw (UAS) and UAS+200 g fishmeal i.e. 4.2% of total ration. Hence, for investigation reported in this paper, it was thought worthwhile to compare response of growing calves fed UAS but supplemented with concentrate mixture containing fish meal and groundnut cake (GNC), protected or as such, which is produced locally in abundant quantities. Although, supplementation of low levels of fishmeal or protected protein to improve economic efficiency of buffalo production is practically and economically possible is India and the third world countries, the potential utility of these from sustainability points of view needs to be evaluated. As such scanty literature (Sundstol, 1982; Wainman and Dewey, 1989) with conflicting information is available on CH_4 production in animals fed ammoniated straw supplemented with low level of fish meal or protected protein supplement. This may be the reason for Moss (1994) to state in a recent review about the variable results reported for fishmeal supplementation of straws and the limited data on CH_4 production which indicated the need for more extensive research in this area. World wide published reports indicate calorimetric evaluation of ammoniated straw supplemented with fish meal or mostly soybean but not groundnut cake.

Approach in energetic evaluation of feedstuff is important to interpret the results obtained in experimentation. Estimates of energy intake and its utilization using the respiration calorimetry technique appears to be more accurate and may help in the evaluation of beneficial effects of ammonia treatment of crop residues or protected protein supplementation. Islam and Begum (1997) discussed global methane emissions and facilities to reduce it in developing countries. However, no experimental evidences have been cited for methane production in buffaloes. In the literature, few studies are available which were carried out using the respiration calorimetry technique (Birkelo et al., 1986; Ortigues et al., 1990; Oosting et al., 1993). Comparative calorimetric evaluation of UAS supplemented with fish meal and GNC (untreated or formaldehyde treated) in concentrate mixture seems to be not available in literature, although many reports dealing with conventional evaluation of these or nutritionally similar diets is available. (Kumar et al., 1988). Therefore, in the present experiment fish meal was compared with deoiled GNC, either untreated or formaldehyde treated, which were offered to growing buffalo calves as an ingredient (8% each) of an isonitrogenous, isocaloric conentrate mixture along with ammoniated wheat straw.

MATERIALS AND METHODS

Animals, diets and experimental design

Eighteen healthy, intact male Murrah Buffalo (*Bubalus bubalis*) calves of 6 to 10 months age and weighing about 136 kg were procured from the Livestock Production Research Division of the institute. The animals were either already vaccinated or later vaccinated against important bacterial and viral diseases following the schedule followed at the institute. Animals were dewormed using Panacur at 10 mg per kg body weight and housed in an animal shed with *pucca* (concrete) floor with adequate ventilation and arrangements for individual feeding. Adequate clean drinking water was given.

All buffalo calves were fed on a balanced concentrate mixture and ad-libitum urea ammoniated wheat straw (UAS) for three weeks period, before the start of growth trial. Then the animals were randomly distributed into three groups of six animals each with similar body weights following completely randomized design. Fish meal was compared with deoiled GNC either untreated or formaldehyde treated which were offered to animals forming 8% of isonitrogenous, isocaloric concentrate mixture containing adequate amount of mineral mixture. An additional source of sulphur which is known to be one of the important critical nutrient for optimum rumen fermentation especially in high NPN diets was given in the form of ammonium sulphate (Ortigues et al., 1990; Moss, 1994). One % chalk was added in concentrate mixture (1 and 2) without fishmeal to balance calcium content in the three concentrate mixtures. Three concentrate mixtures were allotted to three groups to meet nutrient requirement as per the recommendations of Kearl (1982) for a daily gain of 400 g/head/d. All the animals were offered ad libitum UAS and either of the concentrate mixtures depending on the group. The composition of the concentrate mixtures is given in table 1. An attempt was made to offer animals in the different groups, a similar quantity of the three concentrates mixtures, whose quantities were adjusted

Table 1. Composition of concentrate mixtures and ammoniated wheat straw (UAS) fed to experimental buffalo calves

	Group I	Group II	Group III	UAS
Ingredient composition (%)				
Crushed barley	25.0	25.0	25.0	
Wheat bran	63.0	63.0	64.6	
Deolied groundnut cake	8.0	-	-	
Formaldehyde treated Groundnut cake	-	8.0	-	
Fish meal	-	-	8.0	
Mineral mixture	1.0	1.0	0.8	
Salt	1.0	1.0	0.6	
Ammonium sulphate	1.0	1.0	1.0	
Calcium carbonate (chalk)	1.0	1.0	-	
Chemical composition (% DM basis)				
Organic matter	92.0	92.5	92.7	92.5
Crude protein	19.5	18.4	19.0	12.6
Ether extract	1.9	2.2	2.3	0.9
Total ash	9.0	7.5	9.3	7.5
Neutral detergent fiber	35.6	38.8	35.6	71.1
Acid detergent fiber	11.2	11.7	9.6	53.2
Hemicellulose	24.4	27.6	27.0	20.6
Cellulose	6.6	8.1	6.6	44.0
Acid detergent lignin	4.6	3.6	3.1	9.1
Gross energy (MJ/Kg)	18.2	19.0	17.3	18.4

as per the live weight of individual animal and period of growth.

Urea ammoniated wheat straw (UAS)

Wheat straw was ammoniated with fertilizer grade urea @ 4 kg urea dissolved in 65 litres of water per 100 kg wheat straw following ensiling principles to meet the requirement of the experiment.

Two *pucca* (concrete) rectangular silo pits of size $20^{1} \times 10^{1} \times 12^{1}$ to accommodate 2.6 tons of straw with approximately 50% moisture, were used for ensiling of treated straw. Wheat straw was spread over tarpaulin sheet and then urea solution was sprayed over it uniformly with a garden sprayer. Simultaneously mixing was done manually to ensure even distribution of dissolved urea in treated straw and then transferred into the silo pit and trampled vigorously from all sides and corners to ensure proper filling with least air pockets.

Wheat straw in batches of 0.2 tons was treated using similar amount of water and urea as per details given above. Following this procedure whole wheat straw enough to fill a pit was treated and lastly about 0.2 tons of plain wheat straw was laid over treated straw. Pit was covered with a larger size tarpaulin sheet well inserting the free end to maintain anaerobic condition inside the pit. To keep sheet in its position, tin sheets were placed and finally pressed with heavy wooden logs and stones. The incubation period of 28 days duration was followed for urea-ammoniation. On 29th day silo pit was opened and exposed to atmosphere for aeration, for a period of 48-72 hrs to facilitate the escape of ammonia and also heat generated during fermentation and then the straw was utilized for feeding of experimental animals.

Formaldehyde treatment of groundnut cake (GNC)

GNC was treated with formalin (40% formaldehyde solution) at 1 g formaldehyde per 100 g crude protein. One hundred kg of deoiled GNC was treated in batches of 25 kg. A weighed amount of GNC was spread over a tarpaulin and a calculated quantity of formalin was sprayed over it. Simultaneously, thorough mixing was done to ensure even distribution of formalin in the material and flakes formed were broken down. Treated GNC was then transferred into a steel container with heavy lid. The treated deoiled GNC was kept in the container for one week. On 8th day, the lid was opened and formaldehyde treated cake was transferred into gunny bags and utilized for the preparation of concentrate mixture-2.

Feeding and weighing of animals

A weighed amount of concentrate mixture was offered to the animals at 9.30 a.m. daily, which followed UAS. Residues were collected individually throughout the growth period. Clean drinking water was provided once or twice a day depending on ambient temperature. Fortnightly, the live weight of each animal (16 hr shrink weight) was recorded between 9:00 and 10:00 a.m. before feeding and watering.

One set of metabolism trials of 10 days with a three-day adaptation period and seven days collection period was conducted after about 150 days of experimental feeding period on each individual animal in the experiment. The weight of the animal was recorded after each metabolism trial. Feed was offered at 9:30 a.m. and water was provided twice in a day at 11.30 a.m. and 4.30 p.m. The collection of faeces, urine and feed residues was done at 9:30 a.m. Aliquots of faeces (1/300) were dried at 100℃ for DM determination and at 60℃ for gross energy estimation and chemical analysis. For nitrogen estimation, fresh faeces aliquots (1/300) were kept in weighed bottles after mixing with about 5 ml of dilute (1:4) sulphuric acid. Aliquots of urine (1/200) were kept in duplicate for nitrogen and GE estimation. The aliquots of urine for nitrogen estimation were transferred into a 500 ml Kjeldahl flask containing 50 ml of concentrate sulphuric acid and aliquots for GE determination were stored in refrigerator.

Respiration calorimetry

Respiration calorimetry trials were conducted on each animal following the metabolism trial. The details of the open circuit respiration chamber are described elsewhere (Tiwari et al., 2000). Actual recordings were done after ensuring adjustment of the animal in the respiration chamber as indicated by level of feed consumption. Measurement of gaseous exchange was done on each animal for two consecutive days in an open circuit respiration chamber. The animals received their respective diets (UAS+concentrate mixture) as during metabolism trial with a slight adjustment in relation to their body weight during this part of study. Heat production was calculated according to the equation of Brouwer (1965). Energy balance was determined as ME - heat production.

Analytical techniques

Feed residues and faecal samples were analysed for proximate constituents as per the methods of AOAC (1980) and for various fiber fractions according to method of Goering and Van soest (1970) with slight modifications. Gross energy of biological samples was determined using Gallenkamp Auto bomb Calorimeter (CBA 301 series). Nitrogen content was determined by the Micro-Kjeldahl's method. Data from the experiment were analysed using analysis of variance test for completely randomised design (Snedecor and Cochran, 1967)

RESULTS AND DISCUSSION

Chemical composition of the concentrate mixtures used in the experiment was almost similar (table 1). Commercially available fish meal was used and contained 39.8% crude protein and 63.8% organic matter.

Nutrients intake and digestibility

Nutrient intake and digestibility data are given in table 2. The dry matter intake, DMI, (4.43 to 4.65 kg/d) by buffalo calves on the three diets did not differ significantly. DMI in the present study (2.2 to 2.3 kg/100 kg body weight) is close to the values of 2.23 to 2.37 percent reported in buffalo calves gaining at a rate of 375 to 453 g/d fed on NPN supplemented or UAS -based diets (Singh, 1991). The DMI/kg $W^{0.75}$/d (84.3 to 89.3 g) is in agreement with the values of Arora et al. (1978) who reported 87.2 g DMI/kg $W^{0.75}$/d in Murrah buffalo calves fed ad libitum on concentrate mixture, wheat straw and green fodder. The DM requirement for growing buffaloes has been calculated using 97.4 g DM kg $W^{0.75}$/d assuming metabolisable energy density of 10.46 MJ/kg DM (Kearl, 1982) which is slightly higher than the observed value of 84.3 g/kg $W^{0.75}$/d at similar energy density 10.48 MJ/kg DM (table 1). The higher values reported by Kearl (1982) are based on the ten highest DMI values reported in literature obtained with high plane of nutrition. The DM intake (89.97 to 95.52 g/kg $W^{0.75}$/d) in buffalo calves observed by Singh (1991) was marginally higher than the present study.

The digestibility coefficient of DM, organic matter (OM), CP, ether extract (EE) did not differ significantly due to variation in dietary protein supplements. Kumar et al. (1988) also noted non-significant differences in DMI and digestibility in buffalo calves fed unprotected and formaldehyde protected GNC. Faichney and Weston (1971) observed lower CP and OM digestibility in sheep on feeding formaldehyde-protected casein. Formaldehyde protected faba beans in comparison to unprotected faba beans resulted in similar digestibility coefficients of DM, CP and EE in lactating goats (Tewatia et al., 1995) and our observation conforms with their report. The change in digestibility is the effect of type of roughages. Since, Ortigues et al. (1990) used alkali treated wheat straw, may be perhaps due to which they could not notice improvement in digestibility in fish meal supplemented diet. It is also in agreement with Smith et al. (1980), Kumar et al. (1988), Singh and Mehra (1990) and Tiwari and Yadav (1993).

The digestibility coefficients of cellulose were not significantly different on the different diets. However, hemicellulose digestibility in group I was significantly ($p<0.05$) lower than in group II and III. The observed

Table 2. Nutrient intake, digestibility and nitrogen (N) balance in growing buffalo calves fed on ammoniated straw-based rations supplemented with different protein sources[1]

Attributes	Group I	Group II	Group III	SEM
Dry matter				
Intake, concentrate, g/d	2260.0	2245.0	2252.0	36.24
Intake, ammoniated straw, g/d	2168.3	2408.3	2402.0	170.85
Intake, total, g/d	4428.3	4653.3	4654.0	205.54
Intake, g/kg $W^{0.75}$/d	84.3	89.0	89.3	0.91
Digestibility (%)	64.3	64.3	63.6	0.31
Organic matter				
Intake, g/kg $W^{0.75}$/d	77.9	82.3	81.8	0.82
Digestibility (%)	67.3	67.2	66.9	0.28
Ether extract				
Intake**, g/kg $W^{0.75}$/d	1.2^b	1.4^a	1.4^a	0.02
Digestibility (%)	71.9	71.8	76.0	0.91
Nitrogen				
Intake, total g/d	114.8	112.8	117.0	4.23
Intake, g/kg $W^{0.75}$/d	2.21	2.24	2.25	0.02
Digestibility (%)	61.1	63.0	62.5	0.55
Urinary N	22.4	21.9	21.1	1.59
N balance (g/d)	48.8	43.4	54.8	2.19
N retained as % of intake	42.7	38.7	46.5	1.07
N retained as % of absorbed	68.8	61.2	71.1	1.57
Fiber fractions				
Neutral detergent fiber				
Intake, g/kg $W^{0.75}$/d	44.2	49.0	47.8	0.81
Digestibility (%)	62.1	63.7	65.6	0.48
Acid detergent fiber				
Intake, g/kg $W^{0.75}$/d	26.1	29.7	28.2	0.74
Digestibility (%)	65.2	66.9	66.3	0.74
Hemicellulose				
Intake*, g/kg $W^{0.75}$/d	18.0^b	20.0^a	19.5^a	0.19
Digestibility (%)	58.3^b	62.2^a	64.1^a	0.70
Cellulose				
Intake, g/kg $W^{0.75}$/d	20.4	23.3	22.8	0.66
Digestibility (%)	78.3	79.0	77.0	0.85

[1] Refer table 1.

Mean bearing different superscripts in a row differ significantly (*$p<0.05$, **$p<0.01$).

digestibility coefficient in fish meal group are in agreement with the values reported by Reddy (1989) and Singh and Mehra (1990). Virk et al. (1993) reported that the digestibility coefficients of cellulose was significantly higher in buffalo calves fed UAS as a sole feed in comparison to control group fed on untreated wheat straw supplemented with 2 kg concentrate mixture. Further their values of ADF (60.4), NDF (68.7) and cellulose digestibility coefficients are in agreement with present values. Similar coefficients were observed in other studies (Jaiswal et al., 1988; Reddy, 1989). High values of digestibility coefficients of fiber fractions may be due to increased cellulolytic activity of rumen microbes or due to delignification of straw by ammoniation which might have increased the availability of nutrients (Laurent et al., 1983) as evidenced by faster degradation rate of NDF and ADF for ammoniated wheat straw in comparison to untreated wheat straw (Tiwari et al., unpublished).

Digestibility coefficients of cellulose was similar in crossbred calves fed on fish meal or deoiled GNC or mustard cake supplemented diets (Sil, 1992) and our finding is in agreement with his observation. However, Hussein et al. (1991) reported higher digestibility coefficients of fiber fractions in fish meal supplemented groups in comparison to soybean meal or urea supplemented group. No significant effect on

Table 3. Energy metabolism (per d) of growing buffalo calves fed ammoniated straw-based rations supplemented with different protein sources[1]

Particulars	Group I	Group II	Group III	SEM
Metabolic weight (kg $W^{0.75}$)	51.9	52.6	52.3	2.17
Energy intake				
Gross energy, GE (MJ)	81.1	85.8	83.1	4.37
GE (KJ/kg $W^{0.75}$)	1543	1643	1593	16.02
Digestible energy, DE (MJ)	52.3	56.8	53.3	2.98
DE (KJ/kg $W^{0.75}$)	1002^b	1087^a	1020^b	8.50
Metabolisable energy, ME (MJ)	46.3	50.8	46.7	2.56
ME** (KJ/kg $W^{0.75}$)	888^b	974^a	896^b	7.60
DE/GE	65.1	66.2	64.0	0.38
ME/GE	57.7	59.3	56.2	0.41
ME/DE	88.6	89.6	88.7	0.29
Energy losses				
Faecal energy (MJ/100MJ GE)	34.9	33.8	36.0	0.38
Urinary energy (MJ/100MJ GE)	1.7	1.7	1.7	0.12
Methane energy (MJ/100MJ GE)	5.7	5.2	6.1	0.15
Methane energy (MJ/100MJ DE)	8.8	7.8	9.6	0.25
RQ (fed)	0.89	0.91	0.90	0.01
Heat produced				
KJ/kg $W^{0.75}$	594	581	654	2.61
MJ/100MJ GE	38.5	35.4	41.0	0.58
MJ/100MJ ME	66.9^b	59.7^a	72.7^b	1.13
Energy balance				
MJ	16.4	17.7	16.7	0.65
MJ/kg LWG	36.6	36.6	34.7	1.37
Nutritive value				
Digestible crude protein (%)	10.0	9.8	9.8	0.12
ME (MJ/kg)	10.5	10.9	10.0	0.07

[1] Refer to table 1.

Mean bearing different superscripts in a row differ significantly (*$p<0.05$, **$p<0.01$).

LWG-live weight gain.

digestibility coefficients of NDF and ADF between formaldehyde protected and untreated GNC in present study is in conformity with the observation of Faichney and Davis (1972)

Nitrogen balance

N retention (+ on all diets) were not significantly influenced by the type of protein supplements in the diet which may be due to similar N-intake and outgo in faeces and urine (table 2). Formaldehyde protected GNC fed animals had similar N retention as those fed untreated GNC and this is in agreement with findings of Kumar et al. (1988). Though formaldehyde protection is known to reduce urinary-N excretion (Barry, 1972), no such effect was found. It may be due to the fact that the basal roughage used was UAS, which supplied a large proportion of N in the form of NPN. In the present study, high N balances are not commensurate with the live weight gains in animals. High N balances have also been reported on high NPN diet in ruminants (Rai et al., 1988; Virk et al., 1993).

Substitution of formaldehyde treated GNC with fish meal did not affect N-retention significantly (Ravi et al., 1988). Although, Smith et al. (1985) and Ortigues et al. (1990) reported improved N-retention in animals fed fish meal supplemented diets, no such effect of fish meal supplementation was observed. It may be due to high N intake on account of feeding UAS and similar degradability of isonitrogenous concentrate mixtures (Tiwari, 1995, unpublished). Non-significant differences in N retention found could also be due to provision of sulphur in all the diets, as supplementation of elemental sulphur is known to improve rumen fermentation pattern (Moss, 1994).

Energy intake and losses

Energy metabolism data are presented in table 3. Gross energy (GE) intake was not affected significantly by protein supplementation of different types to UAS-based diets. This can be attributed to non significant differences in body weight of calves and almost equal energy density of diets in different groups. Similar GE intakes by buffalo calves fed on wheat straw-based rations has been observed by Sivaiah (1979), and Prakash (1990). As the ratio of roughage to concentrate in all the rations was almost 58:42, the observed faecal losses (33.8 to 36.0%) were intermediate to the values 40 to 50% and 20 to 30% in case of roughages and concentrates, respectively, as reported by Maynard et al. (1979). Similar faecal losses have been reported by Sivaiah (1979) and Baruah (1982). The comparable digestibility coefficients (table 2) of all the nutrients resulted in statistically similar (DE) intake (51.8 to 56.5 MJ/d) among the dietary treatments. Growth rates were similar but the DE intake in growing buffalo calves fed UAS -based diets (63.3 MJ/d) was slightly higher in the the study of Singh (1991) than this study.

The DE as percentage of GE (64 to 65.1) was higher than the value of 60.2 percent in steers fed on UAS based diets as reported by Birkelo et al. (1986). This variation may be due to species difference since buffalo is considered to digest low quality roughages better than cattle (Langer et al., 1968).

The urinary energy (UE) losses were similar and constituted 1.7 percent of GE intake on all diets. Khan et al. (1988) also reported UE loss of 1.3 to 1.8 percent of GE intake from adult Murrah buffaloes fed on wheat straw based rations. Following ammoniation UE loss was reduced in comparison to untreated straw (Birkelo et al., 1986). Further the observed UE values are within the range of 1.5 to 2.1% observed in growing buffaloes by Sivaiah (1979) and Baruah (1982). However, Singh (1991) reported urinary energy loss of only 0.77% of GE intake in growing buffaloes fed on UAS- based diets which was much lower than 1.7% loss observed in this study.

Methane conversion ratio (MCR) termed by IPCC (1996) as CH_4 energy loss expressed as percentage of GE intake is of major impotance for inventories of CH_4 emissisories of ruminants because it is used in alogarithms for estimating emission of ruminants population (US EPA, 1994; IPCC, 1996, Johnson and Ward, 1996). MCR on all the three diets did not differ significantly (table 3) which could be due to similar intake and digestibilities of the diets. MCR values (5.2 to 6.1) were not varying much even from those recommended for use in greenhouse gas inventories of cattle fed on temperate forage diets (US EPA, 1994; IPCC, 1996; Johnson and Ward, 1996) but were less than the average value of 7% in cattle (Maynard et al., 1979), 6.7 (high grain) and 10.4 to 11.4 (for grasses) reported for cattle in the tropics (Kurihara et al., 1999). Although, MCR depends on the level of fiber and lignin in the diet, ultimately it depends on its digestibility. It is to mention that buffaloes can digest fiber better than cattle. MCR in buffaloes on ammoniated straw supplemented with different proteins in this and our other study (Tiwari et al., unpublished) are more interesting as the figures found (5.2 to 6.1) are closer to MCR of 4% (IPCC, 1996) recommended for feedlot diets in USA typically having forage component of 10%. It is also important to mention that loss of CH_4 energy (Mcal/day) calculated by the equation ($y=0.26+0.09x$ digestible energy intake, Mcal/day) of Prakash (1990) resulted in values closer to the observed CH_4 energy loss. It shows that equation developed to calculate CH_4 energy loss in cattle (Swift et al., 1948) do not give precise value of CH_4 energy loss in buffalo.

CH_4 produced (g/d) in calves fed on different diets did not differ significantly (table 4). Recently, Moss (1994) recommended that the traditional unit for expression of CH_4 energy loss (CH_4 energy as proportion of GE) should be extended to CH_4 production per unit OM digested or per kg of the animal product. Expressed on such basis, CH_4 produced on formaldehyde treated GNC was lower ($p<0.05$) than on untreated GNC and fish meal supplemented diets (table 4). Preston and Leng (1987) reported 0.36 kg CH_4 per kg meat in growing cattle given urea, minerals and bypass protein as against 2.4 kg on unsupplemented straws. However, CH_4 production in this study on UAS supplemented with untreated GNC and fish meal was 48.6% and 57.3% less on protected GNC than value reported by them. MCR and CH_4 g/kg digestible OM intake as reported (or calculated in some cases) are presented in table 5. When compared to all reported values on fish meal containing, CH_4 production in buffaloes fed on UAS supplemented with fish meal in this study was low. There is paucity of published literature in which effect of protected protein supplementation (to UAS) on CH_4 production is reported.

Table 4. Methane production in growing buffalo calves fed ammoniated straw-based rations supplemented with different protein sources[1]

	Group I	Group II	Group III	SEM
Methane production				
g/d	84.3	77.6	91.1	4.12
g/kg $W^{0.75}$/d*	1.55^{ab}	1.41^{a}	1.70^{b}	0.03
g/kg DOMI*	30.6^{b}	26.8^{a}	31.9^{b}	0.78
g/kg LWG*	210.7^{b}	179.2^{a}	201.1^{b}	5.52

[1] Refer to table 1.

DOMI-digestible organic matter intake.

Live weight gain (using total over 285d).

Mean bearing different superscripts in a row differ significantly (*$p<0.05$).

LWG-live weight gain.

Various reasons can be attributed to differences in CH_4 production on different diets. CH_4 loss is significantly influenced by energy intake (Prakash, 1990) and as ME intake was significantly ($p<0.01$) higher on protected GNC-based diet, lower CH_4 loss was expected. The difference between CH_4 production on ammonia treated straw supplemented with protected protein or unprotected protein can mainly be explained in terms of changes in synchronization of rumen fermentation events for positive effects and full utilisation of rumen microbial efficiency and effective post-ruminal availability of proteins with reduced methane. Fahmy et al. (1984) reported that supplementation of ammonia treated straw with soybean meal did not improve DM degradation in rumen. This indicates that rumen environment created by ammonia treated straw can not be improved by addition of protein. On all the three diets ammonia-N concentration of 12.08 to 12.78 mg/100 ml rumen liquor has been found (Tiwari et al., 1999a). Though, the range of 5-28 mg/100 ml is suggested depending on microbial growth and fermentable activities (Hespell, 1984), 5 mg/100 ml is optimum for efficient microbial growth (Salter and Slyter, 1974). For improving ruminant productivity beyond that achievable with maximum rumen microbial potential through optimum rumen fermentation (indicative of reduced CH_4) on straw based diets, supplementation of protected protein is inevitable. Heat production as a percent of ME on formaldehyde treated GNC (59.7) was lower ($p<0.05$) than untreated GNC (66.9) and fishmeal (72.7). This may be due to high intake of concentrate mixture (table 7) containing protected GNC than unprotected GNC and fish meal. Lower CH_4 loss may be due to less rumen fermentation of protected GNC. Similar findings have been reported by Sahoo (1992) in buffaloes fed cottonseed cake.

The metabolizability (GE/ME, i.e. q) of the composite rations in the present study was higher (56.2 to 59.3%) than value of 50% reported by Birkelo et al. (1986) for ammoniated straw which may be due to supplementation of concentrate mixture. The lower q and DE/ME reported by Rane (1990) may be due to the feeding of untreated wheat straw- based ration supplemented with low level of concentrate and the differences in the species of the animal.

The similar heat loss among the dietary treatments may be due to similar levels of DM intake. Heat production is directly proportional to the level of DM intake (Blaxter and Graham, 1956). Reports on higher heat loss as percentage of GE intake are available (Prakash, 1990; Singh, 1991; Oosting et al., 1993). The high digestibility and metabolizability than some reports may be due to combined effect of ideal N, S and P ratio of the diet, effective ammoniation and optimum concentrate to roughage ratio, which in turn led to lower heat loss as percentage of GE.

Respiration calorimetry

The oxygen consumption, carbon dioxide production and respiratory quotient (RQ) on the diets did not differ significantly. Fish meal supplementation causes lipolysis and the released endogenous energy is utilized efficiently for live weight gain, especially with low energy diets (Ørskov, 1991). Since the rations supplied adequate amount of energy and were balanced in respect of minerals (especially Ca, P and S), no such effect of fish meal was observed, although, oxygen consumption ($l/kgW^{0.75}$) was numerically higher (32) for fish meal group than unprotected GNC (29.1) and protected GNC (28.4) supplemented group.

The observed RQ values of 0.89 to 0.91 is close to the reported values of 0.9 which indicates that a mixture of 67.5 percent carbohydrate and 32.5% of fat was being oxidized (McDonald et al., 1984). Relatively higher RQ of 0.91 on treated GNC diet (group II) indicates that comparatively higher proportion of carbohydrate was being utilized for lipogenesis as evident from the higher fat percentage of round (Tiwari et al., 1999b). However, RQ can at best give an approximate idea of the kind of nutrient which is being oxidized in the body and can not be a true index of nature of intermediate metabolism particularly when the magnitude of RQ is between 0.7 to 1.0 (Maynard et al., 1979).

The similar ME intake resulted in non-significant heat production (HP) among the treatments as HP is highly correlated with ME intake (Lofgreen and Garret, 1968). This ultimately resulted in non significant differences in energy balance (16.4 to 17.74 MJ/d) which were similar to those (14.4 MJ/day) recorded by Prakash (1990) in buffalo calves fed on diets providing energy as per the recommendation of Sen et al. (1978).

The ME requirement for live weight gain (LWG) is calculated from energy balance, since the energy expenditure on maintenance is lost as heat. It was reported to be 37.0 MJ per kg for buffalo calves fed on straw based rations (Prakash, 1990). This figure is in close to the energy balance per kg LWG (34.72 to 36.7 MJ) of the buffalo calves in this study. Further, the ME intake (46.3 to 50.8, MJ/d) in the buffalo calves is close to the values (48.7 MJ/d) reported for 200 kg body weight buffaloes growing at the rate of 500 g per day (Kearl, 1982). Incorporation of fish meal or formaldehyde treated GNC in the concentrate mixture had no significant effect on ME utilised per kg LWG in the buffalo calves (table 3).

Plane of nutrition and gross efficiency of nutrient utilisation

Nutrient intakes in terms of DM, CP and energy (TDN, DE and ME) expressed as percentage of Kearl's (1982) standard for daily gains of 400 g revealed higher intakes (table 4) of DM, CP and ME. The higher DM and ME intakes were reflected in higher ADG (437, 484 and 482 g/d). The TDN and DE intakes were very close to recommended standard.

However, CP intake was approximately 150% of the Kearl's standard and this could be attributed to *ad libitum* intake of UAS. It is further felt that CP requirement on NPN based diets may be high than those arrived using conventional/natural protein sources.

The comparable nutritive value (table 3), DM intake, plane of nutrition and growth rate among the dietary treatments resulted in similar efficiency of nutrient utilization (table 4) in terms of CP, DCP, TDN, DE and ME among the dietary treatments. This is in agreement with Reddy (1992).

Growth rate and feed conversion efficiency

Growth rate was determined by regressing fortnights (X axis) on cumulative live weight gains (LWG). The equations were as follows:

UAS+conc. mix with untreated GNC (group I):
$Y = 0.0468+6.1193X$
UAS+conc. mix with HCHO treated GNC (group II):
$Y = -2.2610+6.7750X$ and
UAS+conc. mix with fish meal (group III):
$Y = 4.3679+6.7458X$

On the basis of these equations, the average daily gains (ADGs) were found to be 437.1, 483.9 and 481.6 g in buffaloes fed UAS supplemented with concentrate containing untreated GNC, formaldehyde treated GNC and fish meal, respectively, which did not differ significantly. The comparable fortnightly DM consumption (data not shown) accompanied by similar availability of nutrients and almost equal roughage to concentrate ratio as evinced by similar intake of DM; protein and energy (table 5) resulted in non-significant ADGs among the treatments.

The fortnightly feed conversion efficiency (FCE) (data not shown) did not differ significantly in buffaloes fed on UAS- based diets, supplemented with different protein supplements. Similar total DM intake and LWG during the experiment (1 to 19 fortnights) resulted in non-significant difference in FCE among the dietary treatments (table 5). Kumar et al. (1988) found equal FCE in growing cross-bred calves fed UAS supplemented with untreated and treated GNC. The superior FCE as observed during early period of growth (1 to 9 fortnights) is obvious, as the efficiency of feed utilization decreases with the age of the animal due to higher energy content of tissue deposited which contains higher fat and lower water content during later stage of growth.

Table 5. Methane production on straw based diets in ruminants

Author	Species	MCR	CH_4 g/kg DOMI	Diets fed
Sundstol (1982)	Sheep	7.9		Ammoniated straw + fishmeal (7% of DM)
Wanapat et al. (1985)		18.4	97.5	Ammoniated barley straw + fishmeal (0.1% DM)
Birkelo et al. (1986)	Cattle	6.47		Ammoniated straw + soybean meal (9% DM)
Lal et al. (1987)	Buffalo	6.44	45	Untreated wheat straw + ground nut cake (GNC)
Khan et al. (1988)	Buffalo	6.6-4.6		60% to 100% of maintenance requirement, wheat straw-based ration
Vermorel and Jouany (1989)	Sheep	5.8		89% AWS+6.2% fish meal+supplements
		6.1		18% pelleted maize+71% AWS+6.2% fishmeal+ supplements
Wainmann and Dewey (1989)	Sheep	8.8		Ammoniated straw + fishmeal (8 to 24% of DM)
Prakash et al. (1990)	Buffalo	6.1-7.3		Straw based, different energy and protein levels
Oosting et al. (1993)	Wethers	5.6	37.9	Ad lib AWS
	steers	6.8	42.8	Ad lib AWS
Moss et al. (1994)	Sheep	5.3		Ammoniated straw
Santra et al. (1994)	Buffalo	7.28	44.2	Wheat straw : concentrate mixture (conc. mix) 1:1
Pattaniak et al. (1996)	Buffalo	9.0	53.6	Wheat straw+conc. mix. with poultry droppings (3:1)
		6.6	44.6	Straw + conc. mix. with poultry droppings (3:1)
		6.9	53.8	-do- + 0.5kg molasses
Tiwari (1995)	Buffalo	5.6	35	AWS
(unpublished)		6.9	46	AWS + 0.2kg fishmeal
		4.9	32	Urea supplemented straw
Present study	Buffalo	5.7	31.0	AWS + conc. mix. with 8% GNC
		5.2	26.7	AWS + conc. mix. with 8% HCHO-treated GNC
		6.1	31.8	AWS + conc. mix. with 8% fishmeal

MCR-methane conversion rate i.e. methane energy as a percent of GE.
DOMI digestible organic matter intake.
AWS-ammoniated wheat straw.

Table 6. Nutrient intake as % of stipulated standard (Kearl, 1982) and gross efficiency of nutrient utilisation (per kg gain in weight) in growing buffalo calves fed on ammoniated wheat straw-based rations supplemented with different protein sources[1]

Nutrient	Group I	Group II	Group III	SEM
Dry matter (kg)				
% intake	107.2	115.4	106.2	-
Gross efficiency	11.65	11.13	10.44	0.28
Crude protein (kg)				
% intake	148.4	149.5	151.0	-
Gross efficiency	1.87	1.73	1.63	0.04
Digestible crude protein (kg)				
Gross efficiency	1.16	1.09	1.02	0.03
Total digestible nutrients (kg)				
% intake	97.9	102.7	101.3	-
Gross efficiency	7.39	7.14	6.56	0.18
Digestible energy (MJ)				
% intake	99.4	101.6	99.6	-
Gross efficiency	138.9	130.46	119.20	3.26
Metabolizable energy (MJ)				
% intake	107.2	115.3	106.3	-
Gross efficiency	122.8	121.60	104.35	2.93

[1] Refer to table 1.

Mean bearing different superscripts in a row differ significantly (*p<0.05, **p<0.01).

Table 7. Efficiency of feed utilization over the period of live weight gain in growing buffalo calves fed on ammoniated wheat straw (UAS)-based rations supplemented with different protein sources[1]

Attributes	Group I	Group II	Group III	SEM
Initial body weight (kg)	137.0	138.83	133.2	10.20
Final body weight (kg)	250.8	262.2	260.6	12.61
Gain in weight (kg)	113.8	123.3	127.4	3.20
Feed consumed				
Total concentrate mix. (kg, DM)	571.2	578.8	564.2	9.60
Total UAS (kg, DM)	748.8	780.50	774.8	37.05
Total DM (kg, DM)	1320.0	359.3	1339.0	44.76
UDP intake				
Through concentrate mix.*	94.3^{b}	107.0^{a}	94.0^{b}	1.61
Through UAS	140.8	155.0	155.0	9.18
Total	235.2	262.0	249.0	12.36
Total RDP intake	480.2	464.3	481.2	14.98
Feed conversion ratio (kg feed/kg gain)	11.60	11.10	10.40	0.28
Roughage : Concentrate ration	57.43	57.43	58.42	-

[1] Refer to table 1.

Mean bearing different superscripts in a row differ significantly (*p<0.05, **p<0.01).

RDP-rumen degradable protein, UDP-rumen undegradable protein.

RDP and UDP content of feeds/rations from Tiwari et al. unpublished data.

The ADG is reported to be significantly influenced by level of energy (Sivaiah, 1979 and Baruah, 1982). As the contents and intakes of ME were similar on all diets, there were non-significant differences in ADGs. Besides energy, the availability of protein in terms of RDP (480, 464 and 481 g/d) and UDP (235, 262 and 249 g/d) were similar among the dietary treatments (table 7) resulting in similar ADGs. Sahoo et al. (1991) also observed comparable growth rates in calves fed on fishmeal and formaldehyde protected mustard cake incorporated rations. Similar growth rates on unprotected and formaldehyde protected GNC supplemented UAS-based diets were observed by Kumar et al. (1988) in crossbred calves and our finding agree with their report. However, significantly higher growth rate with formaldehyde treated protein supplement has been reported by Upadhyay and Gupta (1991). Further, the beneficial effect of fish meal supplementation at low level in this and some other studies (Smith et al., 1980; Singh and Mehra, 1990; Beever and Gill, 1990) on the LWG could not be observed. The importance of high proportion of UDP for animals with moderate growth rate of 400-500 g/d as observed in the studies of this type has less relevance.

The FCE values of 10.40 to 11.60 (table 5) in the study are in agreement with those reported (11.59 to 12.03) for buffaloes by Reddy (1992). However, lower values have also been reported for buffalo calves by Baruah (1982) 7.2 to 9.5; Prakash (1990) 9.8 to 10.2 and Sivaiah (1979) 8.0 to 10.9. On contrary, inferior FCE (14.09 to 16.51) has been reported by Singh (1991) in buffaloes fed urea supplemented/urea ammoniated wheat straw based diets. Variation in FCE in aforesaid reports in comparison to this study could be due to variation in age, sex, and rate of gain, DM intake method of body weight (shrink weight or otherwise) recoding and type of diets. Although nonsignificant, FCR in fish meal supplemented group was relatively superior (10.44) which may be due to relative superiority of gross efficiency of protein and energy utilisation (table 4) though it was comparable to untreated (11.60) and treated GNC supplemented (11.10) groups.

CONCLUSION

Although earlier reports based on conventional evaluation approach from India (eg. Kumar et al., 1988; Tiwari and Yadav, 1993; Upadhyay and Gupta, 1991) inferred that the efficiency of feed conversion for growth in calves is similar on UAS supplemented with untreated or formaldehyde treated groundnut cake (or other oil cake) but the consequences of CH_4 emission on such diets could not be perceived. It can be now well inferred that supplementation of protected (1 g formaldehyde/ 100 g CP) ground nut cake (GNC) as compared with unprotected GNC or low quality fish meal (8% each) in balanced concentrate mixture to urea ammoniated straw- based diets of growing buffalo calves is sustainable since CH_4 production is low, besides supporting growth rate of 464 g/d, which is similar to that obtained on other mixtures.

IMPLICATIONS

The study has some important practical implications. Firstly, it demonstrates mitigation strategies to enhance sustainable ruminant productivity and improve economic efficiency of ruminant (especially buffalo) production in many parts of Asian-Australasian and African region where there are/may be situations of gap between qualitative and quantitative demand of feeds/fodders and its fluctuating supply (e.g. Deficiency of 100 MMT of green and 20 MMT of dry fodder in India by 2001 AD, Ramchandran, 1989). Secondly, it provides figures of CH_4 production on practical diets which can be used for calculation of contribution of buffaloes for global methane pool, experimental data of which are not easily available in literature (Johnson et al., 1999) and extent to which it can be reduced by dietary management.

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