Effect of Sources of Supplementary Protein on Intake, Digestion and Efficiency of Energy Utilization in Buffaloes Fed Wheat Straw Based Diets

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ABSTRACT : Sixteen adult male buffaloes (average body weight 443±14 kg) were equally distributed into four groups in an experiment to study the effect of supplementary protein sources on energy utilization efficiency in buffaloes fed a wheat straw-based diet. The animals in the control group were offered a basal diet composed of 700 g deoiled ground nut cake and *ad libitum* wheat straw. Animals of other groups were offered 1.8 kg of soyabean meal (SBM), linseed meal (LSM) or mustard cake (MC) along with the basal diet. Protein supplementation increased the digestibility of DM ($p<0.01$), OM ($p<0.01$) CP ($p<0.01$) and CF ($p<0.05$). Maximum CP digestibility was observed on SBM, followed by LSM and MC when compared to the control. Total DMI and DOMI was significantly ($p<0.01$) higher in protein supplemented groups with no differences between treatment groups. Digestible crude protein (DCP) intake and N balance were significantly ($p<0.01$) different between the groups; maximum response was obtained with SBM supplementation, followed by LSM and MC. Faecal energy was significantly ($p<0.01$) lower in SBM and LSM groups in comparison to other groups. Methane production (% DEI) was significantly ($p<0.05$) lower on the SBM treatment. Metabolizable energy (ME) intake increased significantly due to protein supplementation. Metabolizable energy intake (MEI) of animals in the MC group was less than LSM and SBM. Energy balance was increased significantly ($p<0.01$) due to protein supplementation and within supplement variation was also significant with maximum balance in SBM followed by LSM and MC groups. Protein supplementation significantly ($p<0.05$) increased the digestibility and metabolizability of energy from whole ration. Metabolizable energy (ME) content (Mcal/kg DM) of SBM, LSM and MC was 4.49, 3.56 and 2.56, respectively. It was concluded that protein supplementation of wheat straw increased intake, digestibility and metabolizability of energy and maximum response could be obtained when soybean meal was used as a supplement. ***(Asian-Aust. J. Anim. Sci. 2006. Vol 19, No. 5 : 638-644)***

Key Words : Buffalo, Soyabean Meal, Linseed Meal, Mustard Cake, Wheat Straw, Energy Utilization, Energy Balance, Methane Production

INTRODUCTION

Buffaloes occupy an important position (79 million, FAO, 1997) among domesticated ruminant livestock and contribute 28% of total bovine population. They contribute about 52% of India's milk production in addition to their well recognized draft capability and meat production potential (Chauhan, 1999). In India, cereal straws are the main component of buffalo diet. However, nutrient intake of animals consuming such straw diets is usually insufficient to support even maintenance. Supplementation of cereal straws with oilmeals has often resulted in large increase in intake and animal productivity (Abidin and Kempton, 1981; Kellaway and Leibholz, 1983; Chaudhury, 1999). The efficiency with which energy is utilized is known to be low on forage diets (ARC, 1980), however, the efficiency can be modified by manipulating the balance between absorbed nutrients (McRae and Lobely, 1986; Ortigues et al., 1990). One such manipulation is to increase the supply of absorbed amino acids from oilmeals containing rumen undegradable protein (Rafiq et al., 2002). However, contradiction already exists in the literature with respect to the effect of dietary protein content on efficiency of energy utilization (Ortigues et al., 1990).

Metabolizable energy (ME) system of energy evaluation is more accurate than total digestible nutrients (TDN) system because it takes into account the losses through urine and combustible gases. Another advantage of ME system is that efficiency of utilization of energy may be measured in this system. Inspite of these advantages Indian feeding standards (ICAR, 1985) use TDN to express energy content and requirements. This is largely because of paucity of information regarding ME values of common Indian feedstuffs. Reports regarding utilization of energy using calorimetric studies in buffaloes are limited (Khan et al., 1988; Tiwari et al., 2000) and effect of oilmeal supplementation on energy utilization in buffalo fed wheat straw as basal diet do not seem to be available in literature. Hence, this experiment was conducted to study the effect of supplementary protein sources on energy utilization in buffalo fed wheat straw based diet and to asses the ME content of some commonly used protein supplements.

MATERIALS AND METHODS

Animals, experimental design and feeding

Sixteen adult male buffaloes (average body weight

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443±14 kg) were procured from the Livestock Production Management Section of the Institute. The animals were already vaccinated against important bacterial and viral diseases according to the schedule followed at the Institute. Animals were dewormed using Panacur (Intervet India Pvt. Ltd., Pune, India) at 10 mg per kg body weight and were housed in a ventilated animal shed with the arrangements for individual feeding. Adequate clean drinking water was made available.

The animals were randomly distributed into four groups following randomized block design. The animals in control group received a basal ration consisting of 700 g de-oiled ground nut cake and wheat straw *ad libitum*. However, ground nut cake was supplemented with 2% mineral mixture and 1% common salt. Animals in other groups received 1.8 kg soybean meal (SBM), linseed meal (LSM) and mustard cake (MC) along with basal ration.

A metabolism trial along with chamber study was conducted in an Open Circuit Respiration Chamber after feeding the animals for 30 days. Intake and refusals of feed were recorded daily during the trial period. Samples of feed and refusal were pooled on a 6 d basis and were dried at 50°C for 48 h. The fecal samples were weighed daily and two sub samples were taken, one preserved in sulphuric acid (1.5 M) for N determination and the other one dried at 50°C to be analyzed for ash, CF, EE and GE. Urine was measured daily and two aliquots were kept, one for determination of N and another for GE. Animals were shifted to respiration chamber 2-3 days prior to recordings. Flow rate (250 L/min.) and composition of air flowing in and out the chamber was measured as described by Tiwari et al. (2000).

Analysis of samples

Air samples from the Respiration Chamber were collected and analyzed for oxygen by a Dual Channel Paramagnetic Oxygen Analyzer (Taylor Instrument Limited, Analytical Division, Grow borough, Susser, TN 6 3DU, England, Model OAT 184), carbon dioxide by a modified Sonden Apparatus with a 100 ml burette and methane by Infra-red Gas Analyzer (Analytical Development Company Ltd., Hoddesdon, England, Model, 300). Hostings Mass Flowmeter (Teledyne Hastings, Raydist, VA, USA) was used to record the flow rate and total volume of air coming out of respiration chamber. Atmospheric pressure was recorded electrically (Appleby and Ireland, Serial NO. 252730). The dry and wet bulbs' temperature was recorded by thermometers (Decibel Instruments, Chandigarh, India).

Organic matter (OM) content of the samples was determined by ashing the samples at 550°C. Proximate principles were determined according to the method of AOAC (1984). *In situ* digestibility parameters of the feed samples were determined (McDonald, 1981) using nylon bags. Samples were incubated for 3, 6, 9, 12, 18, 24 and 48 h in the rumen of fistulated buffaloes fed on wheat straw and concentrate mixture. The GE contents of feed, faeces and urine samples were determined with the help of Autobomb Adiabatic BombCalorimeter (Gallenkemp, CBA 301 Series). Before the analysis, urine samples were neutralized with NaOH to a pH of 7.5 to 8.5 followed by freeze-drying.

Calculation and statistics

Digestible energy intake (DEI) was equal to gross energy intake (GEI) minus faecal energy. Energy digestion (ED) was defined as DEI/GEI. Metabolizable energy intake (MEI) was calculated by subtracting energy in urine and methane from DEI. The metabolizability is MEI/GEI and denoted as q, however, qm is the metabolizability at maintenance level. Heat production was calculated as HP = $3.866O_2+1.2\ CO_2-0.518\ CH_4-1.431N$ (Brouwer, 1965). The energy balance (EB) was determined by subtracting heat production from MEI. The GEI, DEI and MEI of the supplement part of the ration were calculated as the difference between the total intake and intake of the basal feed. Efficiency of utilization of ME (Km) was calculated as Km = 0.35 qm+0.503 (ARC, 1980). Net energy intake was (NEI) = Km * MEI and Net energy maintenance was (NEm) = NEI-EB. Data obtained were subjected to analysis

Table 1. Chemical composition (% DM basis) of different feedstuffs

Particulars	WS	GNC	SBM	LSM	MC
Crude protein	3.62	45.56	52.44	31.25	42.81
Ether extract	0.97	0.70	1.06	2.81	0.83
Crude fibre	42.30	13.84	5.15	8.65	11.13
Organic matter	93.08	91.12	92.44	90.41	90.33
Total carbohydrate	88.49	44.86	38.94	56.35	46.69
Nitrogen free extract	46.19	31.02	33.79	47.70	35.56
Gross energy (kcal/g)	4.31	4.74	4.83	4.75	4.55
N degradation characteristics (%)					
a	3.78	44.18	31.00	32.11	39.15
b	46.24	44.24	29.00	30.11	38.25
c	1.59	7.78	6.99	6.43	7.68

a: Rapidly degradable fraction; b: Potentially degradable fraction; c: Rate of degradation.

WS: Wheat straw; GNC: Groundnut cake; SBM: Soybean meal; LSM: Linseed meal; MC: Mustard cake.

Table 2. Feed consumption and nutrient utilization in buffaloes fed wheat straw-based diet supplemented with different oil meals

Particulars	Groups[1]				
	Control	SBM	LSM	MC	SEM
Feed consumption (kg/day)					
Wheat straw	5.48	4.78	4.62	4.74	0.36
Groundnut cake	0.62	0.63	0.63	0.65	-
Supplement	-	1.63	1.64	1.65	-
Total intake**	6.10[a]	7.021[b]	6.89[b]	7.04[b]	0.36
DMI (g/kg $W^{0.75}$)**	60.60[a]	75.80[b]	74.41[b]	69.54[ab]	3.83
Digestibility of nutrients (%)					
DM**	50.2[a]	64.12[c]	63.14[c]	57.14[b]	1.57
OM**	54.26[a]	66.73[c]	64.27[bc]	61.14[b]	1.85
CP**	46.30[a]	82.26[c]	76.61[b]	73.39[b]	1.82
CF*	59.90[a]	67.77[b]	66.75[b]	62.89[ab]	1.78
EE**	37.42[a]	51.83[b]	66.83[c]	36.52[a]	2.25
NFE**	51.91[a]	59.15[b]	62.40[b]	55.07[ab]	1.50

Values bearing different superscript in a row differ significantly: * p<0.05; ** p<0.01.

[1] Basal ration consisted of 700 g deoiled groundnut cake and *ad libitum* wheat straw. Animals in other 3 groups received 1.8 kg of either soybean meal (SBM); linseed meal (LSM) or mustard cake (MC) as supplement in addition to the basal ration.

Table 3. Nitrogen balance in buffaloes fed wheat straw based diet supplemented with different oil meals

Parameters	Groups[1]				
	Control	SBM	LSM	MC	SEM
Nitrogen intake**	79.14	206.96[d]	153.05[b]	188.46[c]	2.20
Nitrogen voided (g/day)					
Faeces*	30.64[a]	36.82[a]	35.97[a]	50.40[b]	2.76
Urine**	41.26[a]	84.67[c]	66.98[b]	85.16[c]	5.24
Total**	71.90[a]	121.46[c]	102.95[b]	135.59[c]	5.64
N-absorbed**	48.50[a]	170.16[d]	117.08[b]	138.06[c]	1.36
Nitrogen balance					
g/day**	7.24[a]	85.50[c]	50.10[b]	52.87[b]	5.40
% of absorbed**	14.93[a]	50.14[b]	42.62[b]	38.27[b]	4.38
% of intake**	9.15[a]	41.34[c]	32.82[bc]	28.11[b]	3.12

Values bearing different superscripts in a row differ significantly: * p<0.05; ** p<0.01.

[1] For details see Table 2.

of variance (ANOVA) for a randomized block design and treatment means were separated using Student's Test as per Snedecor and Cochran (1967).

RESULTS

Chemical composition of feeds

Chemical composition of the basal diet and oil cake supplements is given in Table 1. The three oil cake supplements varied considerably in their crude protein (CP) content and degradability. Maximum CP content was observed in SBM, followed by LSM and MC. The CP content of SBM was higher than that of GNC, whereas CP content of LSM and MC was lower than GNC. All the three supplements were less degradable than GNC of basal diet. Among the supplements SBM and LSM were similar in degradability characteristics, whereas MC was more degradable than SBM and LSM.

Intake and digestibility

Feed consumption and apparent digestibility of nutrients are presented in Table 2. All the buffaloes consumed total amount of supplement offered. Wheat straw consumption was not significantly different among the groups. All protein supplements increased total dry matter intake (DMI) significantly (p<0.01), however, within supplements variation was non significant. On an average there was 15 to 25% increase in DMI.

Digestibility of all the nutrients was significantly (p<0.01) higher in protein supplemented groups than control group. Protein supplementation increased the digestibility of DM (p<0.01), OM (p<0.01), CP (p<0.01) and CF (p<0.05), however, maximum CP digestibility was observed in SBM followed by LSM, MC and control. Similar trend was also obtained for DM and OM digestibility. The increase in OM digestibility ranged between 13 to 22%. Combined effect of increased intake and digestibility resulted in significantly (p<0.01) higher digestible organic matter intake (DOMI) in protein supplemented groups. However, the differences among the supplemented groups (only) were not significant. Digestible crude protein (DCP) intake was significantly (p<0.01)

Table 4. Distribution and utilization of energy in buffaloes fed wheat straw-based diet supplemented with different oil meals

Attributes	Groups[1]				
	Control	SBM	LSM	MC	SEM
Distribution of energy (Mcal/d)					
Gross energy (GE)*	26.20[a]	31.40[b]	30.70[b]	30.10[b]	1.11
Faecal energy (FE)*	13.30[a]	10.80[ab]	10.90[ab]	12.78[ab]	0.65
Digestible energy (DE)*	12.94[a]	20.53[c]	19.80[bc]	17.38[b]	0.73
Urinary energy (UE)	0.62	0.91	0.77	0.71	0.15
Methane energy (CH_4-E)	1.44	1.41	1.82	1.52	0.11
Metabolizable energy (ME)*	10.84[a]	18.21[b]	16.73[b]	15.16[b]	0.96
Heat production (HP)	10.42[a]	9.56[a]	11.72[b]	11.99[b]	0.37
Urinary balance					
Utilization of energy (kcal/kg $W^{0.75}$/day)					
GE **	262.05[a]	339.58[c]	331.28[c]	296.73[b]	5.54
DE*	129.3[a]	222.30[c]	214.53[c]	171.83[b]	6.93
ME*	104.3[a]	197.15[c]	181.30[c]	149.83[b]	8.97
HP*	103.82[a]	103.64[a]	127.27[b]	118.80[b]	3.59
Net energy (NE) intake *	67.65[a]	139.40[c]	128.03[c]	101.90[b]	7.05
NE maintenance	67.45[a]	45.76[b]	73.96[a]	69.37[a]	2.93
Energy balance **	0.120[a]	93.64[d]	54.03[c]	32.53[b]	6.42
Efficiency of utilization (%)					
ED*	49.20[a]	65.56[c]	65.07[c]	58.05[b]	1.65
q*	41.60[a]	58.20[c]	56.60[bc]	50.52[b]	1.90
CH_4-E/%GE	5.20[ab]	4.45[a]	6.05[b]	5.16[ab]	0.32
CH_4-E/%DE	10.80[a]	7.39[b]	9.33[ab]	8.89[ab]	0.63
K_m*	64.86[a]	70.67[b]	70.55[b]	67.98[b]	0.62

Values bearing different superscript in a row differ significantly* $p<0.05$ ** $p<0.01$.
ED: Energy digestibility; q: Metabolizability; Km: Efficiency of ME utilization for maintenance.
[1] For details see Table 2.

different among the groups. There was an increase of 3.85, 2.66 and 2.87 fold in DCP intake over control in SBM, LSM and MC, respectively.

Nitrogen balance

Data pertaining to N intake, excretion in faeces and urine, and balance are presented in Table 3. Intake of N increased significantly ($p<0.01$) due to protein supplementation, the magnitude of increase was consistent with N content of the supplement. Maximum increase in N intake was observed in SBM, followed by LSM and MC. N excretion in faeces was significantly ($p<0.05$) higher in MC. N excretion through urine was significantly ($p<0.01$) higher in protein supplemented groups with maximum value observed in SBM followed by MC and LSM. N balance increased linearly ($p<0.01$) with increase N intake and maximum value was observed in SBM, followed by MC and LSM. Similar trend was also observed when N intake was expressed as % of intake. However, when the values were expressed as % of absorbed nitrogen within supplement variation was not significant.

Partitioning and efficiency of utilization of energy

The partition of GE intake as determined by calorimetry is presented in Table 4. Urinary energy represented 2.36 to 2.90% of the GE intake. Methane production by the buffaloes remained unchanged with protein supplementation. Faecal energy was significantly ($p<0.01$) lower in SBM and LSM in comparison to other two groups. Metabolizable energy (ME) intake was increased significantly with protein supplementation, however, the within supplements variation was not significant. Nevertheless, when MEI was expressed in terms of per unit metabolic body size, MEI of MC was less than SBM and LSM. The EB was significantly ($p<0.01$) increased with protein supplementation and within supplements variation was also significant with maximum balance observed in SBM, followed by LSM and MC. Protein supplementation significantly ($p<0.05$) increased the digestibility and metabolizability of the whole ration. The increase in ED was close to 33% in SBM and LSM, slightly less increase of 18% was observed in MC. Energy lost as methane (% DEI) was significantly ($p<0.05$) lower in SBM in comparison to other groups. Although there was a significant ($p<0.05$) increase in qm (21.44 to 39.90%) and Km (4.81 to 8.96%) of whole diet due to protein supplementation, the difference within supplement was non significant. Data pertaining to DE intake, ED, ME intake and qm of the whole ration and protein supplements are given in Table 5. DE content, ED, ME content and qm of MC was significantly ($p<0.05$) lower in comparison to SBM, whereas, corresponding values for LSM were intermediate.

Table 5. Energy partitioning in buffaloes fed wheat straw-based diets supplemented with different oil meals

Particulars	SBM	LM	MC	SEM
DE intake (Mcal/day)				
Whole ration	20.53	19.80	17.38	0.65
Basal diet	12.90	12.90	12.90	0.98
Test feed*	4.68[a]	4.21[a]	2.68[b]	0.46
DE (kcal/g)*	7.63[a]	6.90[a]	4.48[b]	0.73
ED (%)	94.11[a]	74.75[a]	49.60[b]	10.22
ME intake (Mcal/day)				
Whole ration	18.21	16.73	15.16	0.96
Basal diet	10.90	10.90	10.90	0.92
Test feed *	7.31[a]	5.83[ab]	3.72[b]	0.79
ME content (kcal/g)*	4.47[a]	3.56[ab]	2.26[b]	0.48
q (%)*	98.23[a]	88.58[ab]	59.67[b]	9.17

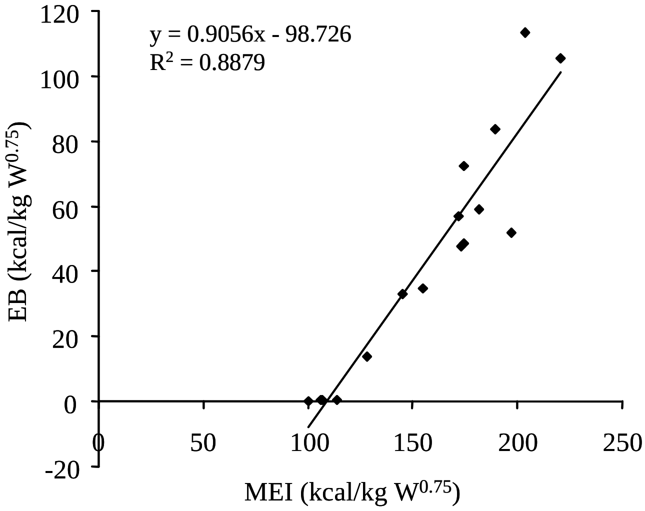

Figure 1. Relationship between MEI (kcal/kg$W^{0.75}$) and EB (kcal/kg $W^{0.75}$) in buffalo fed wheat straw based diet supplemented with oil meals.

DISCUSSION

Intake, digestion and N balance

Comparable consumption of wheat straw in all the groups indicated substitution effect of supplements was absent. Combined amount of supplement (GNC of basal diet plus supplement) did not exceed 1/3 of the ration in any of the groups. Substitution effect of supplements for basal diet occurred only at higher level of supplementation (Das and Singh, 1999). The increase in voluntary intake observed in the present study in response to provision of supplements are in accordance with numerous previous reports on the consequences of supplementation of low quality forages such as cereal straws with concentrates, including oil meals (Egan et al., 1987; Dixon and Egan, 2000; Rafiq et al., 2002).

Straw-based (control) diet supply low RDN and hence it can be expected to have lower rumen NH_3-N concentration than required for optimum microbial activity (Dixon et al., 2003). Addition of protein supplement to the basal diet enhanced digestibility of DM, OM and GE, mostly through an increased N and fibre digestibility. The elevated RDN supply to the rumen might have increased the rumen NH_3-N concentration (Ortigues et al., 1990; Tan et al., 2001), which could have elevated diet digestibility by enhanced rumen microbial activity. While provision of rumen degradable N in the supplement would increase rumen digestion of the straw. Any concurrent depression in rumen pH and increased passage rate would be expected to have an adverse effect on fibre digestion. The adverse effect of the pH depression (Vermorel and Bickel, 1980) and increased passage rate (Aitchison et al., 1985) were apparently of lower importance than the beneficial effects of RDN supply since the digestibility of diet increased in the present study and also in the similar experiments conducted on other species (Chaudhury, 1999; Dixon et al., 2003).

Nitrogen digestibility and balance were increased by protein supplementation. Similarly, Ortigues et al. (1990) also observed an elevated amino acid supply to the duodenum of steers supplemented with fish meal with straw-based diets. Studies using lambs, beef cattle and dairy cattle have demonstrated that highly degradable protein sources (soy bean meal, ground nut meal and rapeseed meal) are as good as fish meal (Plaisance et al., 1997; Dewhurst et al., 1999) in high fibre diets. Variation within supplements in respect to N balance observed in this experiment indicated the superiority of SBM over LSM and MC. The UDN supply was 66% higher in SBM than LSM, although the UDN content was similar. Thus, it seems that UDN supply into the intestine may also positively influence the N accretion.

Partition of energy intake and efficiency of ME utilization

Methane production is associated with production of acetate and butyrate in the rumen (Czerkawski, 1986). The proportion of acetate in the total volatile fatty acid production is negatively correlated with fibre content of ingested feed (Murphy et al., 1982). Thus, higher proportion of straw in the basal ration could partly explain higher methane production as a proportion of DEI in control group.

Urinary excretion of energy was related to excretion of N containing products, which is related to energy and N balance (Oosting, 1993). Protein supplemented buffaloes had higher energy and N balance and within supplement variation in N and energy balance was in the same order. Mustard cake had lower digestibility and metabolizability of energy in comparison to other supplements, which could partly be attributed to presence of glucosinolates in mustard cake, which may interfere with energy metabolism through impairment of thyroid function (Pattanaik et al., 2001). It is evident that protein supplementation increased intake, digestibility and metabolizability of energy. Overall, protein supplementation increased energy balance and the magnitude of response varied from source to source. Though, increased energy balance due to protein supplementation have been reported (Ortigues et al., 1990), contradictions over its effect on balance and efficiency of utilization were observed (Barry, 1981; Thomson et al., 1983). This finding indicates that supply of UDN may influence the energy balance.

Protein supplementation increased the qm. The increase in qm were within the same range when casein was infused into the abomasum of sheep (McRae et al., 1985). However, within supplement variation was not significant, Km value for both basal diet and protein supplemented diet were within a close range. Such similarity of efficiency of ME utilization for different types of diets are consistent with assumption made by SCA (1990) and AFRC (1993) that the efficiency with which ME is utilized for maintenance is similar irrespective of balance of nutrients providing this ME. Also in many other experiments where low quality forages have been supplemented with cereal grains or oil meals, efficiency with which ingested ME has been used appear not to have been affected by the type of supplement (Van Houlert and Leng, 1990; Dixon et al., 1999, 2003).

Estimation of ED, qm and M/D (Mcal/kg DM) of the three oil meal supplements determined by difference method suggested that out of the oilmeals soybean meal was superior than other 2 oilmeals. Significantly lower ED, qm and M/D value of mustard cake indicates that ME of mustard cake is much less efficiently utilized. The corresponding value for linseed meal was intermediate which could be due to higher fibre content of linseed meal in comparison to soybean meal.

NEm ranged between 46 to 74 kcal/kg $W^{0.75}$ among the rations. Reported NEm values for steers of approximately 400 kg weight are in the range of 56 to 88 kcal/kg $W^{0.75}$ (ARC, 1980; Blaxter, 1989). In this experiment NEm in SBM was lower than other groups. This could be due to higher energy balance in SBM (MacRae and Lobley, 1986). The large variation in NEm within species has previously been reported due to breed difference and feeding history (Oosting, 1993). The wide range of possible NEm within some species means that no average value could be adopted and this is even true for buffaloes, as only a limited number of studies have been conducted. By accepting a linear relationship between EB and MEI, a regression equation was therefore obtained.

$$\text{EB (kcal/kg } W^{0.75}) = -98.72+0.90 \text{ MEI (kcal/kg } W^{0.75})$$
$$(n = 16,\ R^2 = 0.88\ \text{RSD} = 12.59)$$
(Figure 1)

MEm and NEm extrapolated from this regression equation were 109 and 71 kcal/kg $W^{0.75}$. ME intake was 1.89, 1.77 and 1.44 times of basal diet in SBM, LSM and MC, respectively. Thus, the estimates of EB and MEI in this experiment were obtained at three planes of feeding (i.e. 1, 1.5 and 1.75 times maintenance). Thus, the estimates obtained from regression equation seems to be reasonable, Similar MEm and NEm values have been reported for steers of about 400 kg body weight fed on cereal straw based diet (Oosting, 1993).

CONCLUSION

The results revealed that supplementation of protein sources increased the intake, digestibility, metabolizability and balance of energy and protein. Soyabean meal showed good response of supplementation in respect to protein and energy balance, followed by linseed meal and mustard cake. Moreover, ME content (Mcal/kg DM) of soyabean meal, linseed meal and mustard cake was 4.49, 3.56 and 2.26, respectively, which also indicated the superiority of soyabean meal over linseed meal and mustard cake.

REFERENCES

Abidin, Z. and T. J. Kempton. 1981. Effect of treatment of barley straw with anhydrous ammonia and supplementation with protein meals on feed intake and live weight performance of growing lambs. Anim. Feed Sci. Technol. 6:145-155.

AFRC. 1993. In: (Ed. G. Alderman). Energy and Protein requirements of Ruminants. CAB international, Wallingford, UK.

Agricultural Research Council. 1980. The nutrient requirements of livestock. Commonwealth Agricultural Bureaux, Farnham Royal, UK.

Aitchison, E. M., M. Gill and D. F. Osbourn. 1985. The effect of supplementation with maize starch and level of intake of perennial ryegran (Lolium perenne CV endura) on the removal of digesta from the rumen of sheep. Br. J. Nutr. 56:463-476.

AOAC. 1984. Official methods of analysis association of official analytical chemists, Washington, DC.

Barry, T. N. 1981. Protein metabolism in growing lamb fed on fresh ryegrass (Lolium perme), Clover (Trifolium repens) pasture *ad lib.* 1. Protein and energy deposition in response to abomasums infusion of casein and methionine. Br. J. Nutr. 46:521-532.

Blaxter, K. L. 1989. Energy metabolism in animals and man. Cambridge University Press, UK.

Brouwer, E. 1965. Report to sub-committee on constants and factors. Energy Metabolism (Ed. *K. L. Blaxter*) Academic Press. pp. 641-643.

Chaudhury, S. A. 1999. Effect of graded level of mustard oil cake supplementation on intake, digestibility, microbial N yield of cannwoted native bulls fed rice straw. Asian-Aust. J. Anim. Sci. 12:715-722.

Chauhan, T. R. 1999. Current production and future prospects of buffalo meat production in India for domestic and export markets. Proc. IX Animal Nutrition Conference Hyderabad, (2-4th Dec., 1999), India. pp. 73-34.

Czerkawski, J. W. 1986. An introduction to rumen studies, Pergmon Press, Oxford, UK.

Das, A. and G. P. Singh. 1999. Effect of berseem (*Trifolium alexandrinum*) supplementation of wheat straw on some physical factors regulating intake and digestion. Anim. Feed Sci. Technol. 81:133-149.

Dewhurst, R. J., K. Aston, A. J. Fisher, R. T. Evans, M. S. Dhanoa and A. B. MacAllan. 1999. Comparison of energy and protein sources offered at low levels in grass silage based diets for dairy cows. Anim. Sci. 68:789-799.

Dixon, R. M. and A. R. Egan. 2000. Response of lambs fed low quality roughages to supplements based on urea, cereal grain or protein meal. Aust. J. Agric. Res. 51:811-821.

Dixon, R. M., W. Karda, B. J. Hosking and A. R. Egan. 2003. Effect of oilseed meals and grain urea supplements fed infrequently on digestion in sheep. 2. Cereal straw diets. Anim. Feed Sci. Technol. 110:95-110.

Dixon, R. M., R. Thomas and J. H. G. Holmes. 1999. Interaction between heat stress and nutrition and sheep fed roughage diet. J. Agric. Sci. (Camb) 132:351-359.

Egan, A. R., F. Perdok and R. M. Dixon. 1987. Improving efficiency of use of supplements by manipulation of management procedures. (Ed. R. M. Dixon), Ruminant feeding systems using fibrous Agriculture residues, IDP, Canberra, pp. 37-48.

FAO. 1997. In: FAO Year book. Food and Agricultural organization of United Nations 1997.

ICAR. 1985. Nutrient requirements for livestock and poultry. Indian Council for Agricultural Research, Krishi Bhavan, New Delhi, India.

Kellaway, R. C. and J. Leibholz. 1983. Effect of nitrogen supplementation on intake and nutrient utilization of low quality roughages. World Anim. Rev. 48:33-37.

Khan, M. Y., Jaikishan, Murari lal and D. C. Joshi. 1988. Energy requirements of Murrah buffalo for maintenance. Proc. II World Buffalo Cong., New Delhi, India (Dec. 12-16). pp. 238-243.

MacRae, J. C. and G. E. Lobley. 1986. Interaction between energy and protein. In: control of digestion and metabolism in ruminants (Ed. L. Milligan, W. L. Grouvam and A. Dobson). Englewood Cliff. Prentice Hall: pp. 367-385.

MacRae, J. C., J. S. Smith, P. J. S. Dewey, A. C. Brewer, D. S. Brown and A. Walker. 1985. The efficiency of utilization of metabolizable energy and apparent absorption of amino acids in sheep given spring and autumn harvested dry gram. Br. J. Nutr. 54:197-209.

McDonald, J. 1981. A revised model for estimation of protein degradation in the rumen. J. Agric. Sci. (Camb) 96:251-252.

Murphy, M. R., R. L. Baldwin and L. J. Koong. 1982. Estimation of stoichiometric parameters for rumen fermentation of roughage and concentrate diets. J. Anim. Sci. 55:411-421.

Oosting, S. J. 1993. Wheat straw as ruminant feed: Effect of supplementation and ammonia treatment on voluntary intake and nutrient availability. Doctoral thesis, Agricultural University, Wageningen, The Netherlands, pp. 99-117.

Ortigues, I., T. Smith, M. Gill, S. B. Commell and N. W. Yarrow. 1990. The effect of fish meal supplementation of a straw based diet on growth and calorimetric efficiency of growth in heifers. Br. J. Nutr. 64:639-651.

Pattanaik, A. K., S. A. Khan, V. B. Varshney and S. P. S. Bedi. 2001. Effect of iodine level in mustard (*Brassica Juncea*) cake based concentrate supplement on nutrient utilization and serum thyroid hormones of goats. Small Rumin. Res. 14:51-59.

Plaisance, R., H. V. Petit, J. R. Seone and R. Rioux. 1997. The nutritive value of canola, heat treated canola and fish meal as protein supplements for lambs fed grass silage. Anim. Feed Sci. Technol. 68:139-152.

Rafiq, M., R. M. Dixon, B. J. Hosking and A. R. Egan. 2002. Leaf content of straw diets influences supplementation responses by sheep. Anim. Feed Sci. Technol. 100:93-106.

SCA, 1990. Feeding standards for Australian livestock, Ruminants, CSIRO, East Melbourne, Australia.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical Methods. Iowa State University, Annes, USA.

Tan, Z. L., D. X. Lu, W. Y. Niu, C. Y. Han, X. P. Ran, R. No and S. L. Lin. 2001. Effect of dietary nitrogen sources on fibre digestion and ruminal fluid characteristics in sheep fed wheat straw Asian-Aust. J. Anim. Sci. 14:1374-1382.

Thomson, D. J., M. J. Halnes, A. R. Austin, S. B. Cammell, D. E. Beever, M. S. Dhanoa and R. L. Barnes. 1983. The voluntary intake, gain, retention and efficiency of energy and protein utilization by Freisan steers of perennial ryegrass and white clover. Anim. Prod. 36:501-547.

Tiwari, C. M., Chandramoni, S. B. Jadhao and M. Y. Khan. 2000. Fasting heat production in growing buffalo calves. Asian-Aust. J. Anim. Sci. 13:307-312.

Van Houlert, F. and R. A. Leng. 1993. The effect of supplementation with protein, lipid and propionate on nutrient partitioning in roughage-fed lambs. Anim. Prod. 56:341-349.

Vermorel, M. and H. Bickel. 1980. Utilization of feed energy by growing ruminant animals. Annals de Zootechnie 28:127-143.