Influence of Grain Processing and Dietary Protein Degradability on Nitrogen Metabolism, Energy Balance and Methane Production in Young Calves

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ABSTRACT : Crossbred (*Bos taurus*×*Bos indicus*) calves were used from birth till 14 weeks of age to evaluate three sources of protein that differed in ruminal degradability viz. groundnut cake alone (HD) or in combination with cottonseed meal (MD) and meat and bone meal (LD), when fed along with two sources of non-structural carbohydrates viz. raw (R) and thermally processed (P) maize. Twenty four new born calves were arranged in six groups in a 3×2 factorial design and fed on whole milk up to 56 d of age. All the different calves received calf startes along with green oats (*Avena sativa*) from 14 d of age onwards free-choice. A metabolism trial of 6 d starters duration, conducted after 90 d of experimental feeding, revealed greater ($p<0.05$) digestibility of DM, OM, total carbohydrates, NDF and ADF in calves fed on the P diets than on the R diets promoting greater ($p<0.05$) metabolizable energy intake. The digestibility of NDF was higher ($p<0.01$) on LD diets where as calves on MD diets exhibited significantly lower digestibility of ADF ($p<0.01$). The retention of nitrogen per unit metabolic body size was significantly ($p<0.05$) higher on the LD-P diet than on the diet HD-P which, in turn, was higher ($p<0.05$) than that of HD-R. Nitrogen retention as percentage of intake was significantly greater ($p<0.05$) on LD-P than on LD-R diets (52.2 vs. 36.4%). Also, P fed calves utilized nitrogen more efficiently than the R fed as shown by retention of significantly greater proportions of intake (47.4 vs. 40.9%) and absorbed (65.8 vs. 59.5%) nitrogen. Calorimetric evaluation of the diets through open-circuit respiration chamber revealed that the dietary treatments had no impact on methane production by calves. The intake of DE and ME was improved ($p<0.01$) because of maize processing resulting in greater ($p<0.01$) retention of energy. The protein degradability exerted no influence on the partitioning or retention of energy. A significant interaction between cereal and protein types was evident with respect to retention of both nitrogen ($p<0.01$) and energy ($p<0.05$). In conclusion, no discernible trend in the influence of cereal processing was apparent on the dietary protein degradability, but the positive effect of cereal processing on energy retention diminished with the increase in dietary undegradability. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 10 : 1443-1450)***

Key Words : Cereal Processing, Protein, Nitrogen Retention, Energy Balance, Calves

INTRODUCTION

Constant and persistent efforts are being made by animal scientists to bridge the gap between availability and requirement of good quality feedstuffs for the enormous livestock population in a developing country like India. Of the two approaches generally being undertaken, viz. looking for newer unconventional feed resources and nutritional manipulation to improve the efficiency of utilization of the existing feedstuffs, the latter appears to be more promising as the presence of toxic factors would impede the effective utilization of unconventional feeds (Punj, 1995).

In many instances enhancement of undegradable dietary protein (UDP) concentration in diets of ruminant livestock failed to increase productivity which, besides other factors, depends on the type of animal and the nature of the diet. Herrera-Saldana and Huber (1989) have suggested that the response to varying protein degradability can be altered by the rate of starch breakdown in the rumen. Hence there is a need to consider the degradability characteristics of both the protein and carbohydrates simultaneously so as to achieve a synchronous supply.

Thermal processing of cereals such as pressure cooking increases the ruminal starch degradability (Gaylean et al., 1981; Theurer, 1986) through gelatinization by increasing its susceptibility to microbial attack in the rumen; this is especially so with maize which is most resistant to microbial attack (Campling, 1991). Young calves have shown better performance when their diets contained thermally processed cereal sources (Grubic, 1988; Abdelgadir et al., 1996). Some of the studies involving weanling calves have demonstrated a mixed response to the process of synchronization (Olivares-Reyna et al., 1992; Maiga et al., 1994). In a subsequent study it was proposed that synchronized availability of carbohydrate and protein in calf starters would improve the efficiency of nutrient utilization (Abdelgadir et al., 1996). Morever, the impact of such dietary manipulation on energy metabolism of young calves is largely unexplored.

The present study, therefore, was aimed at assessing the influence of incorporating differently processed maize on apparent nutrient digestibility and balances of nitrogen and energy by young calves fed starters varying in ruminal protein degradability.

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MATERIALS AND METHODS

Animals, feeds and feeding

Twenty-four newborn crossbred (*Bos taurus*×*Bos*

Table 1. Ingredient and chemical composition of experimental calf starters[a]

	HD		MD		LD	
	R	P	R	P	R	P
Ingredient composition (percent air dry basis)						
Maize, raw	50	-	50	-	50	-
Maize, processed	-	50	-	50	-	50
Wheat bran	12	12	-	-	19	19
Groundnut meal	35	35	25	25	19	19
Cottonseed meal	-	-	22	22	-	-
Meat and bone meal	-	-	-	-	10	10
Mineral mixture[b]	2	2	2	2	1	1
Common salt	1	1	1	1	1	1
Chemical composition (g kg^{-1} DM)						
OM	910	923	912	932	918	930
CP	224	216	229	224	235	232
EE	30	24	42	32	48	38
TCHO[c]	656	684	641	677	634	660
Ash	90	77	88	68	82	70
NDF	229	307	218	324	238	338
ADF	130	163	141	173	110	115
ADL	27	34	34	41	21	22

HD, MD and LD: high, medium and low protein degradability. R and P: raw and processed maize.
[a]Added vitamin mix @ 20 g per 100 kg, containing 50,000 IU of vitamin A and 5,000 IU of vitamin D_3 per g.
[b] Moisture (maximum): 70 g kg^{-1}; calcium (minimum): 280 g kg^{-1}; phosphorus (minimum): 120 g kg^{-1}; iron: 5 g kg^{-1}; iodine: 0.26 g kg^{-1}; copper: 0.77 g kg^{-1}; cobalt: 0.13 g kg^{-1} (all minimum levels) and fluorine (maximum): 0.40 g kg^{-1}.
[c] TCHO=OM-(CP+EE).

indicus) calves, weighing approximately 27 kg, were procured from the institute herd after 24 h of colostrum feeding. They were randomly assigned to six experimental calf starters in a 3×2 factorial design involving three levels of protein degradability and two cereal processing methods.

Accordingly, six equinitrogenous and equicaloric calf starters were formulated (Table 1) containing either groundnut meal alone or along with cottonseed meal, and meat and bone meal-each replacing 50 percent of the groundnut meal nitrogen- to supply protein of high (HD), medium (MD) and low (LD) degradability in combination with either ground raw (R) or processed maize (P).

Thermal processing of maize was done by pressure cooking the coarsely ground cereal with water (1:2.5, w/w) at a pressure of 15 psi for 10 min. The ruminal protein degradability of the feedstuffs was determined by *in situ* nylon bag technique (Ørskov and McDonald, 1979). The bags (16×7 cm; 50 µm pore size) were incubated in the rumen for 0, 3, 6, 9, 12 and 24 h. At each incubation time, one bag for each feed ingredient was incubated in three calves. All the bags, attached to a polypropylene thread of 90 cm, were wetted in water to prevent any lag time for microbial attachment, before placing them deep in the liquid phase of the ventral sac of the rumen. On removal from rumen, each bag was held under running tap until the washings became clear. Subsequently, the bags were dried to constant weight for 48 h in a forced draft oven at 60°C. The constants a, b and c were calculated and used for estimation of rumen degradable protein (RDP) content. Accordingly, the RDP content of the HD, MD and LD diets were estimated to be 73, 68 and 63 percent, respectively.

The respective calf starters along with green oats (*Avena sativa*) were made available to the calves free choice from second week of age onwards. The details regarding the feeds, feeding and animal management has been described elsewhere (Pattanaik et al., 2000).

Metabolism trial

A metabolism trial of six days duration was conducted on the calves towards the end of the 13 weeks of experimental feeding by housing them in metabolic cages with facilities for total collection of faeces and urine. After a suitable adjustment period, faeces and urine voided and feed residues for each 24 h period were weighed, thoroughly mixed and sampled, together with the feeds offered. The samples of feeds, residues, faeces and urine were pooled over the six collection days, and preserved suitably for further laboratory analysis.

Respiration calorimetry

Following the metabolism trial, a three day energy balance trial was conducted on the calves in an open-circuit respiration calorimeter for small animals constructed by Khan and Joshi (1983). The details regarding the chamber has been published elsewhere (Sahoo et al., 2000).

Each animal was weighed in the morning before feeding and watering and then shifted to the respiration chamber maintained at 25°C with a relative humidity of 65% for

Table 2. Apparent digestibility and daily nutrient intake by calves during the metabolism trial

	HD		MD		LD		SEM	Significance[1]		
	R	P	R	P	R	P		D	C	D×C
Apparent digestibility of nutrients (%)										
DM	68.0[bd]	72.9[ac]	72.9[ac]	71.3[bc]	71.7[acd]	75.1[a]	1.3	NS[2]	**	*
OM	69.5[cf]	75.3[ad]	74.3[ad]	73.2[bdf]	73.7[bd]	77.5[a]	1.3	NS	*	*
CP	66.6	69.8	71.3	72.2	68.2	73.2	2.1	NS	NS	NS
EE	73.9[b]	68.6[b]	87.7[a]	86.8[a]	82.9[a]	82.0[a]	1.4	NS	**	*
TCHO	70.2[b]	77.1[a]	74.4[a]	72.8[b]	74.8[ab]	77.5[a]	1.4	NS	*	*
NDF	45.1[de]	57.4[b]	43.0[de]	46.7[ce]	51.3[c]	63.0[a]	1.7	**	**	*
ADF	39.0[b]	54.3[a]	34.6[b]	34.6[b]	40.7[bc]	47.9[ac]	2.7	**	**	*
GE	68.4	73.4	74.5	73.7	71.9	76.6	1.7	NS	NS	NS
Daily intake of nutrients (unit/kg $W^{0.75}$)										
DM, g	75.3	85.9	72.2	75.1	80.3	79.7	3.2	NS	NS	NS
CP, g	15.2	17.3	15.3	15.3	15.8	17.5	2.1	NS	*	NS
DCP, g	10.1	12.1	10.9	11.4	11.9	13.1	1.9	*	*	NS
ME, kcal	214.3	262.0	221.8	236.3	237.8	268.6	9.6	NS	**	NS

HD, MD and LD: high, medium and low protein degradability. R and P: raw and processed maize.
[1] D: effect of protein degradability; C : effect of starch sources; DXC: interaction. [2] NS: Non-significant.
[a, b, c, d, e] Values in the same row bearing different superscripts differ significantly. * $p<0.05$; ** $p<0.01$.

adaptation. A three-day balance trial was conducted (after an adjustment period of 2-3 d) involving total collection and sampling of faeces and urine. During the last two days, gaseous exchange of individual animals was measured on 24 h basis. The flow rate and total volume of out coming air of the chamber was recorded by Hastings mass flow meter (Teledyne Hastings-Raydist, VA, USA). Dry and wet bulb temperatures (Decible Instruments, Chandigarh, India; Sr. No. 23/83) and atmospheric pressure (Appleby, Ireland; Sr. No. 252730) were recorded electronically. Oxygen consumption, carbon dioxide and methane production were determined by measuring the total outflow through the system and the difference in concentration of respective gases between ingoing and outcoming air. Sub samples of chamber outflow air was collected in Douglas bags. The air samples were analyzed for oxygen by a dual type Paramagnetic Oxygen Analyzer (Servomex Taylor, Model OAT 184), carbon dioxide by a modified Sonden apparatus with a 100 ml burette, and methane by infra red gas analyzer (Analytical Development, Hoddesdon, UK; Model 300).

Chemical analyses

Representative pooled and ground samples of feeds, residues and faeces were analyzed for proximate principles as per AOAC (1990). Nitrogen content of feed, faeces and urine was estimated by steam distillation using Kjeltec Auto analyzer (Tecator, Sweden) following kjeldahl digestion. The NDF, ADF and acid detergent lignin were estimated according to Goering and Van Soest (1970). Gross energy (GE) content of the samples was measured by complete ignition under oxygen pressure in a Gallenkemp ballistic bomb calorimeter.

Calculations and statistical analyses

Digestible energy (DE) was calculated by subtracting faecal energy from GE intake and metabolism energy (ME) by subtracting energy loss through methane and urine from DE intake. Energy content of mathane was taken as 9.45 kcal per litre (Brouwer, 1965). Energy balance was determined by subtracting heat loss from ME intake. Heat production, in turn, was calculated as per the following equation (Brouwer, 1965):

$$H=16.175\ O_2+5.021\ CO_2-2.167\ CH_4-5.987\ N$$

Where, H is the heat production (kJ d^{-1}); O_2 is the volume of oxygen consumed (L d^{-1}); CO_2 is the volume of carbon dioxide produced (L d^{-1}); CH_4 is the volume of methane produced (L d^{-1}), and N is the amount of nitrogen excreted in urine (g d^{-1}).

Data were analyzed in a factorial design to find out the effects of protein degradability, cereal processing and their interaction (Snedecor and Cochran, 1967). Where significant, the difference between means were compared by Duncan's Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

Intake and digestibility of nutrients

The chemical composition of the experimental starters is presented in Table 1. The daily intakes (Table 2) of DM, and CP were similar ($p>0.05$) among the dietary treatments. Similarly to the present observations, Matras et al. (1991) and McAllister et al. (1992) also noticed no effect of combinations of degradable protein and starch sources on dry matter intake of lambs. The calves fed on processed maize diets consumed more ($p<0.05$) DM through calf

Table 3. Intake, excretion and retention of nitrogen by calves

	HD		MD		LD		SEM	Significance[1]		
	R	P	R	P	R	P		D	C	D×C
Intake										
g d^{-1}	48[bc]	64[a]	49[bc]	54[ac]	65[a]	63[a]	4.4	*	NS[2]	NS
g $W^{-0.75}$ d^{-1}	2.4	2.8	2.5	2.5	2.8	2.9	0.1	**	NS	NS
Excretion (g d^{-1})										
Faecal	15.9	19.3	14.1	14.9	20.6	17.0	1.6	*	NS	NS
Urinary	13.4[b]	17.3[ab]	11.6[b]	14.0[b]	21.0[a]	13.2[b]	2.1	NS	NS	*
Retention										
g d^{-1}	18.7[bde]	27.9[ac]	23.5[bce]	25.0[ade]	23.7[bcd]	32.9[a]	2.2	NS	**	NS
g $W^{-0.75}$ d^{-1}	1.0[c]	1.2[b]	1.2[bc]	1.2[bc]	1.0[bc]	1.5[a]	0.1	NS	**	*
% N intake	39.0[de]	44.0[bce]	47.3[ac]	46.2[bc]	36.4[de]	52.2[a]	1.9	*	**	*
% N abs.	58.7[bc]	62.3[bc]	66.5[ac]	63.9[ac]	53.6[b]	71.3[a]	3.0	NS	*	*

HD, MD and LD: high, medium and low protein degradability. R and P: raw and processed maize
[1] D: effect of protein degradability; C: effect of cereal sources; DXC: interaction. [2] NS: Non-significant.
[a, b, c, d, e] Values in the same row bearing different superscripts differ significantly. * $p<0.05$; ** $p<0.01$.

starters (1.60 vs. 1.37 kg d^{-1}) as thermal processing resulting in gelatinization of starch enhanced the palatability as was observed by Zinn (1993). The degradability characteristics of protein failed to exert any influence (p>0.05) on the voluntary DM intake, which agrees with earlier reports of Cummins et al. (1982) and Fiems et al. (1986). The daily intakes of CP and ME were comparable for the calves fed on the various diets. However, the lower (p<0.05) intake of ME on MD diets was further confirmation of reduced ME intake through cottonseed meal containing diet in buffaloes as reported by Sahoo (1992). The calves on processed maize diets ate more (p<0.01) ME, in accordance with the higher DM intake induced by thermal processing. Likewise, Lee et al. (1990) also observed a higher ME intake on diets containing processed maize.

Though dietary protein degradability did not exert any effect on DM digestibility, incorporation of thermally processed maize significantly (p<0.01) influenced the digestibility of DM (Table 2), which is similar to the findings of Grubic (1988) with young calves. Further, this improvement was much more (p<0.05) pronounced with HD diets than MD or LD diets owing to a significant interaction between protein and processing effects. Optimal synchronization of protein and starch degradability might be the probable reason for improved (p<0.05) DM digestibility on pressure cooked maize containing HD-P diet as compared to the HD-R diet. Incorporation of thermally processed maize improved the digestibility of OM, which is similar to the observations of Guglya and Safonov (1985) and Zinn (1993). It could be attributed to the enhanced NDF digestibility as OM digestibility was reported to be positively correlated with NDF digestion (Hussein et al., 1991).

Neither the source of protein or starch had any significant effect on the apparent CP digestibility by the calves. The digestibility of EE varied significantly (p<0.01) among the diets. However, it was similar between raw and processed maize diets in contrary to the earlier reports that moist heat treatment of grains depress EE digestibility (Prasad et al., 1975; Epifanov et al., 1988). Morever, it varied significantly (p<0.01) between the protein sources being highest in MD diets followed by LD and HD diets. The digestibility of total carbohydrates (TCHO) varied (p<0.05) among the dietary treatments indicating a significant interaction between protein and starch sources. The improved TCHO digestibility on thermally processed maize could be attributed to a probable enhancement in the digestibility of its NFE component as shown by various workers (Prasad et al., 1975; Guglya and Safonov, 1985; Grubic, 1988).

A significant (p<0.05) interaction between protein and starch sources was noticed with respect to the digestibility of NDF and ADF (Table 2). Inclusion of pressure cooked maize in the diets induced a significantly higher digestibility of NDF and ADF (p<0.01). The provision of non-structural carbohydrate of greater ruminal fermentability, due to thermal processing, could have stimulated higher production of iso-acids viz. iso-butyrate and iso-valerate which, in turn, could have encouraged proliferation of cellulolytic bacteria and enhanced fibre digestion (Stokes et al., 1991). There exist various reports to support the present observations of enhanced digestibility of NDF and ADF (Morgan et al., 1991; Zinn, 1993) upon feeding of variously processed cereals.

The source of degradable protein exerted significant variation on the digestibility of fibre fractions. The calves on LD diets had higher (p<0.01) digestibility of NDF than those on rapidly degradable HD diets. Ruminal fibre digestion has been inversely correlated to ruminal protein degradability (McAllan and Griffith, 1987). The present observations are further confirmation of the findings of Hussein et al. (1991) that replacement of highly degradable protein with less degradable sources might improve ruminal fibre digestion. Similar improvements in fibre digestion had

Table 4. Intake and metabolism of energy by experimental calves

	HD		MD		LD		SEM	Significance[1]		
	R	P	R	P	R	P		D	C	D×C
Gross energy										
Mcal d^{-1}	6.60	8.88	6.49	7.34	8.28	8.32	0.52	*	*	NS
kcal $W^{0.75}$ d^{-1}	335	382	321	343	356	377	13.80	NS	*	NS
Faecal energy										
Mcal d^{-1}	2.07	2.37	1.63	1.93	2.31	1.96	0.17	*	NS	NS
kcal $W^{-0.75}$ d^{-1}	106	102	81	90	100	89	7.55	NS	NS	NS
Digestible energy										
Mcal d^{-1}	4.53	6.51	4.85	5.41	5.97	6.37	0.42	NS	**	NS
kcal $W^{-0.75}$ d^{-1}	229	280	240	253	255	289	10.84	NS	**	NS
Methane energy										
Mcal d^{-1}	0.213	0.306	0.291	0.277	0.320	0.296	0.04	NS	NS	NS
kcal $W^{-0.75}$ d^{-1}	10.80	13.08	14.07	12.97	13.65	13.40	1.31	NS	NS	NS
Urinary energy										
Mcal d^{-1}	0.078	0.104	0.067	0.082	0.084	0.087	0.007	NS	*	NS
kcal $W^{-0.75}$ d^{-1}	3.92	4.48	3.32	3.84	3.62	3.94	0.29	NS	NS	NS
Metabolizable energy										
Mcal d^{-1}	4.24	6.10	4.49	5.06	5.57	5.98	0.38	NS	**	NS
kcal $W^{-0.75}$ d^{-1}	214	262	222	236	238	271	9.59	NS	**	NS
Heat production										
Mcal d^{-1}	2.64	3.47	2.66	3.02	3.28	3.60	0.21	*	**	NS
kcal $W^{-0.75}$ d^{-1}	133	151	132	141	140	164	4.93	**	**	NS
Energy retention										
Mcal d^{-1}	1.60[b]	2.63[a]	1.83[bc]	2.04[bc]	2.29[ac]	2.38[ac]	0.20	NS	*	*
kcal $W^{-0.75}$ d^{-1}	81.3	110.9	90.0	95.6	97.7	107.8	6.90	NS	**	NS

HD, MD and LD: high, medium and low protein degradability. R and P: raw and processed maize.
[1] D: effect of protein degradability; C: effect of starch sources; DXC: interaction. [2] NS: Non-significant.
[a, b, c] Values in the same row bearing different superscripts differ significantly. * $p<0.05$; ** $p<0.01$.

also been recorded when fish meal replaced rapeseed meal (Lindberg, 1981) or soybean meal (McCarthy et al., 1989). The slowly degradable proteins result in a more gradual release of ammonia-N, peptides and branched chain volatile fatty acids, making these essential growth factors available to the cellulolytic bacteria for a much longer period after feeding as has been suggested by Veen (1986). However, the above hypothesis failed to explain the significantly ($p<0.05$) lower digestibility of NDF and ADF observed with MD diets in the present study.

Nitrogen retention

The intake of nitrogen varied significantly ($p<0.05$) across the dietary treatments and was lower ($p<0.05$) with MD diets than with LD diets (Table 3). The faecal loss of nitrogen, although similar ($p>0.05$), appeared to be influenced by the level of intake. The urinary nitrogen excretion varied significantly among the calves under different groups, being higher ($p<0.05$) on LD-R diet in comparison to all other diets, except the HD-P diet. No effect of source of degradable protein or starch was evident on urinary nitrogen loss.

The nitrogen retention either as g d^{-1} or per unit metabolic body size or as percentage of intake and absorbed nitrogen, varied significantly ($p<0.05$), the highest and lowest being in calves fed LD-P and HD-R diets, respectively. The significant ($p<0.05$) increase in nitrogen retention (g d^{-1} kg $W^{-0.75}$) when processed maize replaced raw maize in HD based diet suggested better nitrogen utilization because of synchronization of ruminal nitrogen and energy supply, both being rapidly degradable. Matras et al. (1991) have also observed more efficient nitrogen utilization in lambs when rapidly degradable starch and nitrogen sources were consumed together. Theoretically, the calves on the LD-R diet, synchronized for slow ruminal degradability, were expected to perform better than those on the LD-P diet which was asynchronized. But this did not happen, as the retention was significantly higher ($p<0.05$) in calves fed on the latter diet. The explanation could be that, both the LD diets contained 19% groundnut meal in addition to 10% meat and bone meal (Table 1). Therefore, with the provision of readily fermentable thermally processed maize in the LD-P diet, the ammonia released from the rapid degradation of groundnut meal was efficiently utilized by ruminal microbes even in comparison to HD-P diet (because of lower level of groundnut meal in the former) leading to greater synthesis of microbial protein. This was reflected in a lower ($p<0.05$) urinary nitrogen loss on diet LD-P than LD-R or HD-P. The increased quantum of microbial protein together with the undegraded intake

Table 5. Methane production by experimental calves

	HD		MD		LD		SEM	Significance[1]		
	R	P	R	P	R	P		D	C	D×C
Methane production										
liters d^{-1}	22.5	32.3	30.7	29.3	33.8	31.3	3.74	NS[2]	NS	NS
g d^{-1}	16.1	23.1	22.0	21.0	24.2	22.4	2.68	NS	NS	NS
g/ kg DOM d^{-1}	17.4	16.8	21.2	19.4	19.2	17.5	1.39	NS	NS	NS
g/ kg LW gain	59.47	53.83	71.93	68.76	67.86	63.64	7.62	NS	NS	NS
MCR[3]	3.23	3.43	4.55	3.86	3.85	3.56	0.23	*	NS	NS

HD, MD and LD: high, medium and low protein degradability. R and P: raw and processed maize.
[1] D: effect of protein degradability; C: effect of starch sources; DXC: interaction. [2] NS: Non-significant. [3] MCR: Methane conversion ratio. * $p<0.05$.

protein in the form of meat and bone meal probably presented a better assortment of amino acids at the intestinal level to be absorbed and utilized by the host's enzymatic system, resulting, therefore, in greater nitrogen retention on MD-P diet. Donelly (1983) and Coomer and Amos (1991) demonstrated similar increased nitrogen efficiency of milk fed calves when two protein sources varying in degradability were given in combination. The positive effects emanating from such a combination could be attributable to the complementary profile of amino acids as has been suggested by Klopfenstein (1988).

When starch sources were compared, the calves on processed maize diets had a higher ($p<0.01$) nitrogen retention than those on raw maize diets. They also exhibited more efficient nitrogen utilization as indicated by retention of 47.4 vs. 40.9% of the intake nitrogen. This could have been due to better utilization of ruminal ammonia for microbial protein synthesis because of the provision of readily fermentable energy through pressure cooked maize.

Energy balance

The GE intake was significantly ($p<0.05$) higher in calves fed processed maize diets compared to that fed raw maize (Table 4), reflecting DM intake. Similarly, among protein sources, calves on MD diets consumed lower ($p<0.05$) GE in comparison to LD diets which was again in accordance to DM consumption. The type of protein, however, had no influence on the intake of DE owing to comparatively lower ($p<0.05$) excretion of faecal energy on MD diets. No effect of protein degradability was also evident on energy loss through urine and methane leading to similar ($p>0.05$) intake of ME. On the other hand, calves fed processed maize exhibited significantly greater ($p<0.05$) intake of DE and ME than calves fed raw maize, attributable to greater intake of GE coupled with its higher digestibility. Similar to the present findings, Lee et al. (1990) have also observed greater ME intake by cattle on processed maize diets.

Heat production by calves on processed maize diets was significantly ($p<0.01$) higher compared to those on raw maize diets (Table 4). This could be due to the possible increase in heat increment because of rapid fermentation as would be expected of the highly degradable starch of the processed maize. However, in spite of higher heat production, the processed maize diets induced significantly greater ($p<0.05$) energy retention, owing chiefly to their positive influence in promoting greater DM and, therefore, GE intake.

Among the protein types calves on MD diets containing cottonseed meal showed lower ($p<0.05$) heat production compared to calves fed LD diets. Earlier Sahoo (1992) have also recorded a lower heat production by buffaloes fed cottonseed meal based diets. However, type of protein as such had no impact on energy retained by calves of different groups. Similar to the present findings, Pattanaik et al. (1998) also observed no influence of protein degradability on the energy retention of yearling bull calves. Nevertheless, the impact of incorporation of processed maize on energy balance was more pronounced with HD diets which showed a diminishing trend as degradability of the diets reduces, implying, in effect, a significance interaction ($p<0.05$) between protein type and maize processing methods.

Methane production

The dietary treatments had no influence on methane production by calves (Table 5). Similar to the present findings, Tiwari et al. (2000) observed no impact of dietary protein degradability on the methane production (g/d) by buffalo calves. Moreover, processing of cereal also failed to influence methane production as was reported by Lee et al. (1990). It has recently been suggested that methane production per unit animal production i.e., g/kg live weight gain (LWG) is a more suitable index for comparing greenhouse gas emission of livestock under different feeding systems (Kurihara et al., 1999). In the present study, however, no effect of protein degradability or cereal processing was evident when methane production was expressed as g/kg LWG, based on the average daily gain of the calves (Pattanaik et al., 2000). The methane conversion ratio (MCR) of different diets revealed that the values are without significant differences. However, calves on MD diets exhibited significantly ($p<0.05$) higher MCR in comparison to those on LD or HD diets and this may be correlated to the relatively higher fibre (ADF) and lignin content of the said diet. Because, higher MCR is presumably related to higher levels of fibre and lignin besides, lower levels of non-fibre carbohydrates (Van Soest, 1994). The MCR values for cattle typically accounts for 5.5-6.5% (Johnson and Ward, 1996); the lower values (3.2-4.5%) obtained in the present experiment may be attributed to the younger age (~ 3 months) of the calves.

The results revealed no specific trend with regards to the effect of cereal processing on the diets with varying protein degradability in terms of nutrient utilization and nitrogen retention. But the positive effect of cereal processing on energy retention diminished with the increase in dietary protein undegradability and moreover, thermal processing of maize appeared to enhance the utilization of nitrogen and energy in early life of the crossbred calves.

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