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Effect of feeding complete ration vis-à-vis conventional ration on nutrient utilization and rumen metabolism in crossbred cattle

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ABSTRACT

Rumen fistulated male crossbred cattle (3), 2 to 2.5 years old (average body weight of 325 kg) were fed concentrate mixture, wheat straw and green berseem separately (conventional ration, treatment 1), uniformly blended concentrate mixture and wheat straw (complete ration, treatment 2) and uniformly blended concentrate mixture, wheat straw and green berseem (complete ration, treatment 3) in a 3×3 latin square switch-over design. The rations were formulated so as to support for maintenance and 500 g gain. There was no significant difference in the daily dry matter, total digestible nutrients (TDN) and digestible crude protein (DCP) intake per kg metabolic body size among the 3 treatment groups. The digestibility coefficient values for dry matter, organic matter and crude fibre in treatment 3 were significantly higher than that in treatment 2. The total nitrogen, TCA- precipitable protein nitrogen and non-protein nitrogen concentration in strained rumen liquor (SRL) of animals increased after feeding and the peak was observed at 2 to 4 h post-feeding in all the treatments, but the mean values did not differ significantly among different treatment groups. The mean values of ammonia nitrogen and total volatile fatty acids (TVFA) concentration in SRL of animals in treatment 1 and 3 in which green berseem was supplemented were comparable and were significantly higher than that in treatment 2 in which complete feed was prepared without green berseem. The activity of ruminal enzymes, viz. α-amylase, carboxymethyl cellulase, xylanase, α-glucosidase, ß-glucosidase and ß-xylosidase was highest in particulate material followed by extra cellular and cellular fraction of SRL. The maximum activity of most of the enzymes was at 2 h post-feeding. The mean activity of α-amylase, carboxymethyl cellulase and ß-glucosidase was significantly higher in treatment 3 than that in treatments 1 and 2. Whereas, the mean activity of xylanase, α-glucosidase, ß-glucosidase and ß xylosidase in SRL was significantly higher in treatments 2 and 3 than that in treatment 1.

The results revealed that the activities of different ruminal enzymes responsible for fibre degradation were higher in animals fed complete ration as compared to animals fed conventional ration and also due to supplementation of green fodder. The change in biochemical parameters and more nutrients digestibility indicated improved utilization with complete feeding system over conventional feeding system.

Key words: Animal nutrition, Biochemical parameters, Complete ration, Ruminal enzymes, Nutrients utilization, Total mixed ration

In complete feed system also synonymously used as total mixed ration, animals get balanced diet for better rumen microbial growth and digestion. There is increase in feed intake and utilization of nutrients needed for synthesis of body tissues and milk, reduction in wastage of feed and being practiced in developed countries (Owen 1979). Miron *et al.* (2000) showed improved feed efficiency with partial replacement of corn by citrus pulp in total mixed ration of high producing dairy cows. Lailer *et al.* (2005) reviewed the use of complete feed system and opined that complete feed system is becoming popular as it allows extensive use of agricultural by-products, crop residues and non-conventional feeds in livestock ration for maximizing production and minimizing cost. Advantages of complete feed system in terms of improved digestibility of dry matter, acid detergent fibre and neutral detergent fibre and increase in number of ruminal bacteria and protozoa coupled with higher fibre degrading enzyme activities, have been reported (Li *et al.* 2003). In the present study an effort was made to study the effect of feeding complete ration vis-à-vis conventional ration without and with green fodder on nutrient utilization and rumen metabolism in crossbred cattle.

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MATERIALS AND METHODS

Rumen fistulated male crossbred (HFxSahiwalxJ) cattle (3), 2 to 2.5–year-old, weighing on average 325 kg, fitted

Table 1. Chemical composition of experimental feeds and fodders (per cent dry matter basis)

Attributes	DM	OM	CP	EE	CF	NFE	Ash
Wheat straw	88.00	86.80	3.22	0.84	35.86	46.88	13.20
Green berseem	14.30	87.16	19.08	2.85	25.69	39.54	12.84
Concentrate mixture	89.80	88.99	23.21	7.64	7.99	50.15	11.01
Complete feed (without green fodder)	90.00	87.91	13.34	4.30	21.80	48.47	12.09
Complete feed (with green fodder)	35.94	87.22	14.89	3.93	22.75	46.15	12.28

with rumen canula made of inert hard plastic material having a diameter of 100 mm × 75 mm, were fed 3 dietary treatments in a 3×3 latin square switch-over design. In treatment 1 (conventional feeding system) 2.5 kg concentrate mixture, 2.5 kg wheat straw and 12.0 kg green berseem were fed to animals separately. In treatment 2 (complete feed without green fodder) the animals were offered 4.0 kg wheat straw and 4.0 kg concentrate mixture after mixing into uniform blend whereas, animals in treatment 3 (complete feed with green fodder) were offered 2.5 kg concentrate mixture, 2.5 kg wheat straw and 12.0 kg green berseem after mixing into a uniform blend. The concentrate mixture contained maize 40 parts, mustard-cake 25 parts, linseed-cake 22 parts, rice polish 5 parts, wheat bran 5 parts, mineral mixture 2 parts and common salt 1 part per 100 kg whereas, concentrate mixture in treatment 2 was fortified with 20 g vitamin supplements per 100 kg to supply vitamins A and D. The treatments were allotted randomly in the first instance and thereafter these were switched-over in such a way that each animal received all the 3 treatments at one time or the other of the experimental period. The rations were formulated so as to support for maintenance and 500 g daily gain. The daily feeding was done only once at 9.00 AM. However, in treatment 1, under conventional feeding system, the weighed quantity of concentrate mixture allowance was offered at 9.00 AM and immediately after the consumption of concentrate mixture, a weighed quantity of wheat straw and green berseem mixed together was offered that served as roughage. Fresh clean drinking water was provided to each animal daily at 10.00 AM and 5.00 PM however, water was restricted on the days of rumen liquor collection till the last collection. Digestion trials for 5 days after 13 days feeding trial were conducted on these animals in 3 different periods during which records of feed intake and faeces voided were kept daily. The samples of feed, fodder and faeces were analysed for proximate principles (AOAC 1995). The feeding trial in

Table 2. Daily dry matter and nutrients intake and digestibility coefficients of organic nutrients in fistulated crossbred male cattle fed complete ration vis-à-vis conventional ration

Attributes	Treatments		
	1 (conventional ration with green fodder)	2 (complete ration without green fodder)	3 (complete ration with green fodder)
Nutrients intake			
Dry matter intake/day (kg)	6.13±0.11	6.85±0.38	6.14±0.10
Dry matter intake (kg/100 kg body weight)	1.87±0.02	2.09±0.10	1.88±0.06
Dry matter intake (g/kg $W^{0.75}$)	79.71±0.81	89.02±4.44	79.90±2.29
DCP intake/day (kg)	0.621±0.029	0.616±0.052	0.632±0.029
DCP intake (g/kg $W^{0.75}$)	8.07±0.31	8.00±0.63	8.23±0.47
TDN intake/day (kg)	3.555±0.208	3.888±0.313	3.582±0.217
TDN intake (g/kg $W^{0.75}$)	46.19±2.28	50.52±3.78	46.66±3.32
Digestibility coefficients			
Dry matter*	61.05^{ab}±2.96	57.83^{b}±2.10	61.37^{a}±3.16
Organic matter*	61.65^{ab}±2.90	59.03^{b}±1.93	61.96^{a}±3.11
Crude protein	68.47±2.14	66.92±2.49	69.68±2.22
Ether extract	84.58±1.24	84.67±0.37	86.11±1.77
Crude fibre*	61.99^{ab}±2.93	58.65^{b}±1.70	63.05^{a}±3.07
Nitrogen-free extract	57.34±3.32	56.01±0.70	56.91±3.56

^{ab}Values bearing with different superscripts in a row differ significantly from each other, *P<0.05.

each period lasted for 20 days. During last 2 days of the experimental feeding period, the rumen contents were collected from each animal at 0,2,4,6 and 8 h post-prandial for the estimation of biochemical parameters in strained rumen liquor. Rumen contents were fractionated into particulate material, cellular and extra cellular fractions by lysozyme treatment and analysed for different ruminal enzyme activities (Sastry *et al.* 1999). The data were analysed as per Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

The chemical composition of experimental feeds and fodder is presented in Table 1. The complete ration without green fodder (treatment 2) contained 13.34% crude protein, 4.30% ether extract, 21.80% crude fibre, 48.47% nitrogen-free extract and 12.09% ash whereas, the corresponding values for complete ration with green fodder (treatment 3) were 14.89, 3.93, 22.75, 46.15 and 12.28%, respectively. The data on nutrients intake and digestibility coefficient of nutrients are presented in Table 2. There were nonsignificant differences among the treatments for daily total dry matter intake and dry matter intake per 100 kg body weight and per kg metabolic body size. The digestible crude protein (DCP) intake was 8.07±0.63, 8.00±0.47 and 8.23±0.47 g/kg $W^{0.75}$/ day in treatments 1, 2 and 3, respectively, whereas corresponding values for daily total digestible nutrients (TDN) intake per kg metabolic body size were 46.19±2.28, 50.52±3.78 and 46.66±3.32 g, respectively. The DCP and TDN intakes did not differ significantly among the different treatment groups. Similar observations on DM, DCP and TDN intakes with complete ration and conventional feeding

Table 3. Concentrations of nitrogenous fractions and TVFA in the rumen liquor of crossbred cattle fed complete feed versus conventional feed

Post-feeding time interval (h)	Treatments 1 (conventional ration with green fodder)	2 (complete ration without green fodder)	3 (complete ration with green fodder)	Mean**
Total nitrogen (mg/100 ml)				
0	85.00±2.53	86.86±3.29	88.13±4.44	86.66^{e}±0.90
2	123.73±3.28	124.73±2.20	130.46±4.83	126.31^{b}±2.09
4	130.00±0.77	128.86±1.14	132.13±5.35	130.35^{a}±0.95
6	122.26±1.87	115.73±0.93	115.73±4.41	117.91^{c}±2.17
8	94.60±2.12	95.69±1.08	93.53±2.23	94.61^{d}±0.62
Overall mean	111.13±8.94	110.38±8.20	112.00±9.14	111.17±0.47
TCA-precipitable protein nitrogen (mg/100 ml)				
0	42.93±3.37	44.40±4.16	42.93±5.20	43.42^{c}±0.49
2	73.73±4.07	69.66±3.32	68.93±2.37	70.77^{ab}±1.19
4	71.26±0.77	70.20±3.60	74.26±0.81	71.91^{a}±1.21
6	68.80±0.83	62.40±2.34	62.80±1.87	64.68^{b}±2.06
8	51.20±2.47	48.20±0.35	48.00±0.83	49.13^{c}±1.03
Overall mean	61.58±6.12	58.97±5.39	59.40±6.02	59.98±0.80
Ammonia nitrogen (mg/100 ml)				
0	30.60±0.20	20.06±2.44	30.80±2.52	27.15^{c}±3.15
2	40.13±0.84	29.56±2.41	44.20±1.93	37.96^{a}±4.36
4	35.90±1.87	24.40±1.35	37.60±2.54	32.63^{b}±4.14
6	31.50±1.07	19.43±1.34	30.43±0.64	27.12^{c}±3.85
8	28.80±0.34	18.76±1.33	23.40±1.46	23.65^{c}±2.89
Overall mean**	33.38^{a}±2.05	22.44^{b}±2.03	33.28^{a}±3.53	29.70±3.63
Total volatile fatty acids (m mol/litre)				
0	61.80±2.83	50.66±1.28	67.03±0.81	59.83^{d}±4.82
2	89.03±2.07	86.23±0.61	91.10±0.26	89.05^{b}±1.45
4	105.83±1.18	101.70±0.84	106.13±0.83	104.55^{a}±1.43
6	90.00±2.55	87.50±1.66	89.56±2.59	89.02^{b}±0.77
8	77.73±0.93	76.96±3.19	78.53±1.02	77.74^{c}±0.45
Overall mean**	85.04^{a}±7.33	80.61^{b}±8.47	86.47^{a}±6.55	84.04±1.7

[abcd] Mean values bearing with different superscripts in a row or column differ significantly from each other, **P<0.01.

Table 4. Average ruminal enzyme activities (units/100g whole rumen contents) in the particulate material, extracellular and cellular fraction of rumen contents in crossbred cattle fed complete feed versus conventional feed

Ruminal fractions	Treatments		
	1 (conventional ration with green fodder)	2 (complete ration without green fodder)	3 (complete ration with green fodder)
α-amylase			
PM**	183.81^{c}±26.20	200.28^{b}±28.40	207.87^{a}±29.50
EC**	21.69^{b}±3.40	22.87^{ab}±3.75	24.03^{a}±3.79
C*	10.19^{b}±1.72	11.07^{ab}±1.89	11.91^{a}±1.94
Carboxymethyl cellulase			
PM**	43.85^{c}±5.58	46.48^{a}±6.08	49.14^{a}±6.43
EC*	3.12^{ab}±0.67	3.01^{b}±0.67	3.17^{a}±0.62
C**	2.61^{b}±0.45	2.69^{ab}±0.54	2.80^{a}±0.53
Xylanase			
PM**	78.38^{b}±10.80	89.85^{a}±9.63	89.10^{a}9.17
EC**	6.40^{b}±0.78	6.50^{a}±0.79	6.40^{b}±0.70
C*	5.75^{b}±1.19	5.72^{b}±1.10	5.82^{a}±1.10
α-glucosidase			
PM**	2.73^{b}±0.30	3.11^{a}±0.33	3.20^{a}±0.38
EC**	1.22^{b}±0.37	1.22^{b}±0.40	2.09^{b}±0.50
C	0.99^{a}±0.38	1.03±0.38	1.38^{b}±0.34
β-glucosidase			
PM**	15.80 c±3.06	18.56^{b}±3.80	19.43^{a}±3.82
EC**	2.17^{a}±0.48	2.11^{b}±0.52	1.30^{a}±0.37
C	1.47^{a}±0.38	1.34±0.32	1.01±0.35
β-xylosidase			
PM**	13.90^{b}±2.38	15.70^{a}±2.45	15.94^{a}±2.60
EC**	1.58^{b}±0.26	1.70^{a}±0.29	1.55^{b}±0.26
C**	0.65^{b}±0.17	0.69^{a}±0.16	0.71^{a}±0.16

PM, Particulate material; EC, extracellular fraction; C, cellular fraction.

^{ab}Values bearing with different superscripts in a row differ significantly from each other, *P<0.05, **P<0.01.

system have been reported (Reddy 1992).

The digestibilities for dry matter, organic matter and crude fibre in crossbred cattle were higher in treatments 1and 3 as compared to treatment 2 which might be because of supplementation of green fodder in treatments 1 and 3. However, the digestibilities for all the nutrients were higher in treatment 3 in which animals were fed complete ration with green fodder, which might be due to the uniform supply of nutrients and maintaining steady rumen environment and also the higher rumen enzyme activities as evident from the results on ruminal enzyme activities in the present study (Table 4). Similar to the present findings Li *et al.* (2003) also reported higher digestibility of DM, CP, NDF and ADF in Holstein steers receiving total mixed ration than steers receiving ration under separate feeding system. However, the effects of complete feed system on the digestibility of nutrients as compared to separate feeding system as reported by various workers are contradictory. Holter *et al.* (1997) did not find any significant effect on the digestibility of nutrients due to complete feed system as compared to separate feeding. Contrary to this report Yang and Varga (1989) and McCullough (1991) indicated improvement in nutrient digestibility with total mixed ration compared with separate feeding.

The average values of biochemical parameters concentration in strained rumen liquor (SRL) obtained from fistulated crossbred cattle at different post-prandial time intervals are presented in Table 3. There were significant (P<0.01) differences in total nitrogen, TCA-precipitable protein nitrogen, non-protein nitrogen, ammonia nitrogen and total VFA concentration in SRL at different time intervals of rumen liquor collection. The peak concentration of all the biochemical parameters was observed at 2 to 4 h post-feeding and thereafter declined. This might be due to more rumen microbial activity during this period. The peak concentrations of total nitrogen, protein nitrogen, ammonia nitrogen and TVFA in SRL have also been reported during this period (Tiwari 1995, Venkanna *et al.* 1997, Tomar and Sengar 1999, Reddy and Reddy 1985). No significant difference in total nitrogen and TCA-precipitable protein nitrogen was observed among different treatments. The ammonia nitrogen and TVFA concentration also did not differ significantly between

treatments 1 and 3 in which the rations were similar but the mean values in treatments 1 and 3 were significantly (P<0.01) higher than mean values in treatment 2. The higher ammonia nitrogen and TVFA concentration in treatments 1 and 3 might be due to green berseem supplementation and more soluble nitrogenous compounds and deamination of amino acid and when feeds are more digestible (Erdman *et al.* 1986). Higher ammonia nitrogen and protein digestibility in treatments 1 and 3 than that in treatment 2 might be due to green berseem supplementation and not due to feeding system. However, Li *et al.* (2003) reported significantly lower ammonia nitrogen concentration in steers fed under separate feeding system (5.83 mg/100 ml) than in steers fed total mixed ration (8.48 mg/100 ml) but this difference may not be due to feeding systems as the composition of ration under 2 feeding systems was different. The TVFA concentration was significantly (P<0.01) higher in treatments 1 and 3 (85.04±7.33 and 86.47±6.55 m mol/litre) than in treatment 2 (80.61 m mol/litre) which might be due to supplementation of green berseem in treatments 1 and 3 resulting into higher fibre digestibility in the rumen (Table 2) coupled with higher fibre degrading enzyme activities (Table 4) in the present study. However, there was no effect of feeding systems on TVFA concentration in SRL. Li *et al.* (2003) also reported no significant effect in TVFA concentration in rumen liquor of steers between complete feed and separate feeding system, however, increase in propionic acid concentration was noted in complete feed system. It has been documented that composition and production of VFA depends largely on the proportion of hay in the ration and an amount of intake (Sasaki *et al.* 2001). The acetate to propionate ratio also increases with higher intake of dried hay. Li *et al.* (2003) suggested that coarse roughage proportion in total mixed ration might have resulted in lower acetate and higher propionate in the rumen liquor. The mean pH value of rumen liquor was 6.88±0.18, 6.83±0.17 and 6.91±0.15, respectively in treatments 1, 2 and 3. The mean pH values were significantly higher in treatments supplemented with green berseem than in treatment 2 (without green berseem) which might be due to higher ammonia nitrogen concentrations in treatments 1 and 3 supplemented with green berseem. However, there was no effect of complete feed system on pH of rumen liquor as compared to separate feeding system, provided composition of dietary regimen is similar. Son *et al.* (1994) in lactating cows and Li *et al.* (2003) in Holstein steers also did not observe any difference in the rumen pH level due to feeding systems.

The mean values of ruminal enzymes activities, viz. α-amylase, carboxymethyl cellulase, xylanase, α-glucosidase and ß-xylosidase (Table 4) in particulate material, extra cellular and cellular fraction of rumen contents and also among different treatments differed significantly (P<0.01). The maximum activities of ruminal enzymes were observed at 2 to 4 h post-feeding. The maximum activities of these enzymes were in particulate material followed by extra cellular and cellular fraction of rumen contents. The activity of α-amylase was significantly (P<0.01) higher in cattle fed complete ration coupled with green fodder supplementation. The mean ruminal activities of α-amylase, carboxymethyl cellulase and ß-glucosidase were significantly (P<0.01) higher in animals fed complete ration with green fodder (treatment 3) than in animals fed either conventional ration with green fodder (treatment 1) or complete ration without green fodder (treatment 2). The activities of carboxymethyl cellulase, xylanase, α-glucosidase, ß-glucosidase and ß-xylosidase were significantly (P<0.01) higher in treatments 2 and 3 as compared to treatment 1 indicating that blending of all the feed ingredients into uniform mix might have stimulated the colonization process and increased the level of cellulose degrading microbes as the digestibility of crude fibre was also maximum in treatment 3 (Table 2). The present findings corroborated with the results of Williams *et al.* (1989) and Agarwal *et al.* (1993). Li *et al.* (2003) also observed a tendency of higher carboxymethyl cellulase and xylanase activity in the rumen of steers fed total mixed ration compared to those fed separately.

The results of the study revealed that complete feeding system has advantages over conventional feeding system in terms of nutrients digestibility and utilization. The activities of different ruminal enzymes such as α-amylase, carboxymethyl cellulase, xylanase, α-glucosidase, ß-glucosidase and ß-xylosidase were higher in animals fed complete ration as compared to animals fed conventional ration. Supplementation of green fodder in the complete ration enhanced the nutrient digestibility, concentration of ammonia nitrogen and TVFA and the fibrolytic enzyme activity in the rumen. Further, the results of biochemical parameters and ruminal enzymes indicated that rumen contents could be sampled at 2 to 4 h post-feeding being maximum for future studies.

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REFERENCES

Agarwal N, Kewalaramani N, Sawal R K, Kamra D N and Pathak N N. 1993. Effect of feeding oat and berseem on rumen enzymes of black buck (*Antilope cervipara*). *Indian Journal of Animal Nutrition* **10**(1): 53–55.

AOAC. 1995. *Official Methods of Analysis*. 6th edn. Association of Official Analytical Chemists, Arling on Va, USA.

Erdman R A, Proctor G H and Vandersall J H. 1986. Effect of rumen ammonia concentration on *in situ* rate and extent of digestion of

feedstuffs. *Journal of Dairy Science* **69**: 2312–20.

Holter J B, Urban W E, Hayes H H (Jr.) and Davis H A. 1977. Utilization of diet components fed blended or separately to lactating cows. *Journal of Dairy Science* **60**: 1288–93.

Lailer P C, Dahiya S S, Lal D and Chauhan T R. 2005. Complete feed for livestock. Concept, present status and future trend: A review. *Indian Journal of Animal Sciences* **75**(1): 84–91.

Li D Y, Lee Sang S, Choi N J, Lee S Y, Sung H G, Ko J Y, Yun S G and Ha J K. 2003. Effects of feeding system on rumen fermentation parameters and nutrient digestibility in Holstein steers. *Asian -Australasian Journal of Animal Sciences* **16**(10): 1482–86.

McCullough M E. 1991. *Total Mixed Rations and Super Cow*. Hoard's Dairyman. W.D. Hoard & Sons Co. WI. USA.

Miron J, Yoset E, Ben-Ghedalia D, Chase L E, Bauman D E and Solomon R. 2002. Digestibility by dairy cows of monosaccharide constituents in total mixed rations containing citrus pulp. *Journal of Dairy Science* **85**: 89–94.

Owen J B. 1979. Complete feed. *World Animal Review* **20**: 26.

Reddy K C V. 1992. 'Performance of buffalo (*Bubalus bubalis*) calves fed alkali treated and urea ammoniated neem (*Azadirachta indica*) kernel cake incorporated ration.' M.V. Sc. Thesis submitted to Deemed University, Indian Veterinary research Institute, Izatnagar, India.

Reddy K J and Reddy M R. 1985. Effect of feeding complete feeds on various nitrogen fractions and total VFA concentration in the rumen fluid of sheep. *Indian Journal of Animal Science* **55**(9): 819–23.

Sasaki H, Horiguchi K and Takahashi T. 2001. Effects of concentrate and roughage ratios on ruminal balance of long chain fatty acids in sheep. *Asian-Australasian Journal of Animal Sciences* **14**: 899–1050.

Sastry V R B, Kamra D N and Pathak N N. 1999. *Laboratory Manual of Animal Nutrition*. IVRI, Izatnagar pp. 187–94.

Snedecor G W and Cochran W G. 1967. *Statistical Methods*. 6th edn. IBH Publishing Co. Calcutta Iowa State University Press, Ames, Iowa, USA.

Son Y S, Yu B W, Han H C, Lee S H and Kim K S. 1994. A field study on the ruminal pH of lactating cows according to feeding system in Korea. *Korean Journal of Dairy Science* **16**: 326–34.

Tiwari C M. 1995. 'Evaluation of fishmeal supplementation of ammoniated straw based rations in buffalo calf using respiratory calorimetric technique.' Ph.D. thesis submitted to Deemed University, Indian Veterinary Research Institute, Izatnagar, India.

Tomar S K and Sengar S S. 1999. Rumen fermentation pattern on complete diets with different sources of nitrogen in buffaloes. *Indian Journal of Dairy Science* **52**(5): 330–32.

Venkanna P, Reddy M R and Reddy G V N. 1997. Rumen fermentation pattern on complete diets based on dry mixed grass or cottonseed hulls in crossbred bulls. *Indian Journal of Animal Nutrition* **14**(4): 245–49.

Williams A G, Withers S E and Strachan N H. 1989. Post prandial variation in the activity of polysaccharide degrading enzymes in microbial populations from the digesta solids and liquor fractions of rumen contents. *Journal of Applied Bacteriology* 66: 15–26.

Yang C J and Varga G A. 1989. Effect of three concentrate feeding frequencies on rumen protozoa, digesta kinetics and milk yield in dairy cows. *Journal of Dairy Science* **72**: 950–57.