Indian Journal of Animal Sciences **88** (1): 99–104, January 2018/Article

Effect of feed restriction on nutrient utilization, growth and metabolic profile in crossbred calves

B K OJHA[1], NARAYAN DUTTA[2] and A PATTANAIK[3]

ICAR-Indian Veterinary Research Institute, Izatnagar, Bareilly, Uttar Pradesh 243 122 India

Received: 25 May 2017; Accepted: 21 July 2017

ABSTRACT

Present study elucidated the effect of feed restriction on growth, nutrient utilization and metabolic profile in crossbred calves. Eighteen crossbred male calves (*Bos taurus* × *Bos indicus*) of about 4–6 months age and 85.7±5.6 kg body weight were randomly divided into 3 groups (Control, T–15 and T-30) of 6 each in completely randomised design. The calves in control group were fed *ad libitum* as per predicted requirement; while in group T-15 and T-30, calves were fed 15% and 30% restricted diets of predicted requirements. Daily intake of DM and OM was significantly higher in control group relative to T-30; however, T-15 had an intermediate position. Digestibility coefficient of DM and OM was significantly higher in T-30 group as compared to control and T-15 groups. Efficiency of N-utilization was better in T-30 and T-15 groups than control. BW gain (kg) and average daily gain (ADG; g) were significantly higher in control and T-15 groups as compared to T-30. Feed conversion ratio (FCR) of calves was better in T-15 as compared to T-30. Haematological parameters and serum enzymes did not differ significantly among treatment groups. However, serum glucose, total protein, albumin and serum urea were significantly lower in T-30. Present study concluded that dietary restriction at 15% level was efficient and at par with the control group having no feed restriction.

Key words: Calves, Feed restriction**,** Growth, Metabolic profile, Nutrient utilization

Feeding and managing dairy calves is expensive, requires extensive labour and contributes significantly to farm expenses. Restricted feeding to growing cattle has been shown to have positive effects on cattle performance. Restricted-feeding may reduce feed cost and nutrient excretion which are of great concern in the dairy industry (Kumar *et al.* 2015). Mild restrictions in dry matter intake can lead to improvements in feed efficiency for calves (Anderson *et al.* 2015, Kumar *et al.* 2017). The blood biochemical parameters are important indicator to decide the optimum restriction level of feed in diet. The mild restriction in concentrate feeding moderately reduced the growth intensity without affecting the normal plasma indices and gene expression indicating that restricting concentrate feeding scheme could be applied in dairy calves (Lohakare *et al*. 2013). Thus, in the present study, restricted feeding was carried out in crossbred calves (*Bos taurus* × *Bos indicus*) to ascertain the effects on nutrient utilization, growth performance, metabolic profile and immune status.

Present address: [1]Assistant Professor (drbrijesh.ojha @gmail.com), College of Veterinary Science & Animal Husbandary, Rewa. [2,3]Principal Scientist (dutta65@gmail.com, akpattanaik1@gmail.com), Centre of Advanced Faculty Training in Animal Nutrition.

MATERIALS AND METHODS

Experimental design and feeding: The experiment was undertaken at the Animal Nutrition Research Shed of ICAR-Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh, India. Eighteen crossbred male calves (*Bos taurus* × *Bos indicus*) of about 4–6 months age and 85.7±5.6 kg body weight were selected from the well maintained herd for experimental study. The calves were randomly divided into 3 groups of 6 each in a completely randomized design and randomly allocated to control, T-15 and T-30 groups. Calves of control group were fed a ration consisting of concentrate: roughage ratio of approximately 50:50 *ad libitum* as per predicted requirement (NRC 2001); while in group T-15 and T-30, calves were fed 15% and 30% restricted diets, respectively of predicted requirements. The concentrate mixture composed of maize: 25; wheat bran: 42; deoiled soybean: 30; mineral mixture: 2 and common salt 1 kg per 100 kg. A small amount of green maize was also provided to calves. Fresh water was offered *ad libitum* twice daily to all the calves. The weight of concentrate and roughage offered and residue left after 24 h was measured to find out intake of feed/DM.

The calves were housed in a clean ventilated shed having provision for individual feeding and watering. They were treated for endo and ecto-parasites before the onset of the experiment. All the calves were adapted to their respective experimental diets for a period of 15 days, during which their voluntary feed intake was recorded. All the calves were maintained under strict hygiene and uniform management conditions during the 120 days of the experimental feeding. The BW of individual calves was recorded at fortnightly intervals in the morning before feeding, in order to assess changes in BW and ADG. The ration schedule was adjusted fortnightly after recording the BW of each calf.

A metabolism trial for 6 d collection period was conducted after 3 months of experimental feeding to assess the intake, nutrient digestibility, plane of nutrition and nitrogen (N) balance. The collection of faecal and urine samples was made after 3 days adaptation of the calves in metabolic cages. The records of daily faeces and urine voided (24 h) were maintained during 6 days collection. Blood samples were collected through jugular vein puncture at 0, 60 and 120 days of experimentation, serum was separated and preserved at –20°C in chemically clean sterile vials for further analysis. Another 2 ml blood sample was collected in tubes containing ethylene diamine tetra acetate (1 mg/ml blood), for haemoglobin (Hb) and packed cell volume (PCV) estimation.

Chemical analysis: Representative samples of feed offered, residue left, faeces voided and urine excreted were processed and analyzed for OM, CP, ether extract, NDF and ADF (AOAC 2005). Hb and PCV were estimated in whole blood immediately after blood collection by cyanomethaemoglobin method (Dacie and Lewis 1969) and Wintrobe's tube, respectively. Serum glucose concentration was determined colorimetrically (Barham and Trinder 1972). The serum protein and albumin content were measured as per Vatzidis (1977) and Doumas *et al*. (1971), respectively. Serum urea was estimated by the method of Hallett and Cook (1971).

Statistical analysis: Results obtained from the study were subjected to analysis of variance (ANOVA) using Statistical Package for social sciences, version 17 (SPSS 17) software and treatment means were ranked using Duncan's multiple range tests. The periodic alterations in biochemical parameters and immunity were analyzed using repeated measures design (General linear model, Multivariate). Significance of treatments with respect to different characters was declared at P<0.05 unless otherwise stated. All the statistical procedure was done as per Snedecor and Cochran (2004).

RESULTS AND DISCUSSION

Chemical composition of feeds: The OM, CP, total ash, NDF and ADF contents in concentrate mixture, wheat straw and green maize were 91.5, 91.6 and 90.8; 22.1, 3.29 and 10.3; 8.5, 8.5 and 9.2; 27.3, 76.1 and 61.7; 12.6, 48.9 and 34.8%, respectively. The chemical composition of concentrate mixture, wheat straw and green maize offered to experimental calves was within the normal range and comparable to the values reported by earlier worker (Ranjhan 1998, Singh *et al*. 2008, Patil *et al*. 2017).

Intake and digestibility of nutrients: The daily intake of concentrate, wheat straw, DM and OM by calves was significantly (P<0.05) higher in control group as compared to T-30; however, T-15 had an intermediate position between control and T-30 groups (Table 1). It is understandable because the calves were offered 15 and 30% less feed of the normal feed intake in T-15 and T-30 groups. The results of present study were in conformity the findings of Singh *et al*. (2008), who reported significantly (P<0.05) higher intake of DM and OM in calves fed 95% restricted diet of the *ad-libitum* followed by calves fed 80, 60 and 40% restricted diets, respectively. Similarly, Helal *et al*. (2011) observed reduced DMI in calves fed 70 and 85% restricted diets of the concentrate mixture as compared to calves fed *ad libitum*. Murphy and Loerch (1994) also found higher DMI in growing steers fed all concentrate diet at *ad libitum* followed by 90 and 80% restricted diets of *ad libitum*, respectively.

Digestibility coefficient of DM and OM was significantly (P<0.01) higher in T-30 group as compared to control and T-15 groups; however, digestibility of CP did not differ significantly (P>0.05) among three groups (Table 1). Digestibility (%) of NDF, ADF and EE was significantly (P<0.01) higher in T-30 followed by T-15 and control group. Present results were in conformity with the findings of Parsons and Stanton (2000), who reported that restricted feeding of corn silage to cattle revealed higher (P<0.05) DM and OM digestibility compared to *ad libitum* feeding. The negative relationship between intake and digestibility of a diet has been widely described. Different processes of

Table 1. Effect of feed restriction on nutrients intake and digestibility in different group of calves

Attribute	Treatment			SEM	P values
	Control	T-15	T-30		
Metabolic body size (kg$W^{0.75}$)	36.12	34.09	32.08	1.54	0.59
Nutrient intake (gkg$^{-1}W^{0.75}$)					
DM	99.55^c	86.40^b	71.89^a	3.04	<0.01
OM	92.56^b	80.33^b	56.28^a	5.22	0.01
Concentrate	48.18^c	40.22^b	32.52^a	1.67	<0.01
Wheat Straw	45.07^b	39.49^b	32.51^a	1.62	<0.01
Green	6.29	6.69	6.85	0.35	0.84
DCP	10.95^b	9.59^{ab}	8.14^a	0.33	<0.01
DOM	58.36^c	53.04^b	45.80^a	2.17	0.03
TDN	61.28^c	55.69^b	47.64^a	2.27	0.04
Nutrient digestibility (%)					
DM	58.77^a	60.58^a	64.86^b	0.79	<0.01
OM	61.28^a	63.12^a	66.97^b	0.69	<0.01
CP	77.81	79.93	81.89	1.03	0.29
EE	71.74^a	74.80^b	77.60^c	0.70	<0.01
NDF	45.61^a	48.30^b	54.50^c	1.02	<0.01
ADF	34.72^a	39.80^b	45.20^c	1.15	<0.01
Nutrient density (%)					
DCP	10.83	10.94	11.29	0.38	0.88
TDN	59.69	62.87	65.40	1.52	0.32

^{ab}Means with different superscripts within a row differ significantly.

rumen digestion showed that the main cause of the variation in digestibility is the retention time of particles in the rumen (Doreau *et al*. 2003). Loerch (1990) speculated that the improvement in digestibility occurred because limiting feed intake reduces the passage rate, which increases residence time in the digestive tract and thereby allows more time for digestion.

Nutritive value and plane of nutrition: Nutrients intake ($gkg^{-1}W^{0.75}$) of the composite diets in terms of DOM and TDN was significantly (P<0.01) higher in control group as compared to T-30; however, T-15 group had intermediate position between control and T-30 groups (Table 1). However, the DCP intake ($gkg^{-1}W^{0.75}$) was significantly higher (P<0.05) in control group followed by T-15 and T-30 groups. Nutrients density (%) of the composite diets in terms of DCP and TDN was comparable (P>0.05) among the treatment groups. Our results were in agreement with the findings of George *et al*. (2005), who reported decreased intakes of DCP (9.6, 7.9 and 5.7) and TDN (59.3, 45.8 and 34.5 $gkg^{-1}W^{0.75}$) in crossbred calves fed at 100, 80 and 60% of normal DMI. Similarly, Singh *et al*. (2008) observed significantly (P<0.05) lower intake of DOM, DCP and TDN in calves fed 80, 60 and 40% restricted diets as compared to 95% restricted diet of the *ad libitum*. Kumar *et al*. (2015) also reported that mild restriction at 12.5% level was found to be more efficient because nutrient metabolism, plane of nutrition, blood biochemical profile and body weight changes in goats were at par with the control group.

Nitrogen balance: N-intake and retention (gd^{-1}) were significantly (P<0.01) higher in control as compared to T-30, while T-15 had an intermediate position. The excretion of N through faeces, urine and total (gd^{-1}) was significantly higher (P<0.01) in control followed by T-15 and T-30 groups, respectively. Net retention of N as % of intake and as % of absorbed N (an indication of apparent biological value) was significantly (P<0.01) higher in T-30 followed by T-15 and control, respectively (Table 2). Our results were in consistency with the observations of Santra and Pathak (2009), who reported higher retention of N (as % of intake and as % of absorbed N) in low concentrate (30%) fed calves as compared to high concentrate (60%) fed group. Similarly, Grimaud and Doreau (1995) and Kumar *et al*. (2015) found improved N retention at low level of N intake due to lower urinary and faecal N losses. Singh *et al*. (2008) reported significantly (P<0.01) higher faecal N excretion in calves fed 95% restricted diet of the *ad libitum* as compared to calves fed 80, 60 and 40% restricted diets, respectively.

In the present study, restricted feed/N intake resulted in a better utilization of N as revealed by analogous N retention among different groups. The percent reduction in N excretion was 27.86 and 31.14% lower in T-15 and T30, respectively, relative to control group. This might be partially attributed to lower MFN which is positively related to DM intake (Hutchinson and Morris 1936, Maynard 1985) and more closely due to improved CP digestion in restricted groups (Kumar *et al*. 2015).

Growth performance and feed conversion efficiency: The initial and the final BW (kg) of calves were comparable (P>0.05) irrespective of the dietary treatments. However, total BW gain (kg) and ADG (g) for the period of 120 days were significantly (P<0.01) higher in control and T-15 groups as compared to T-30. The overall DMI (kg or gd^{-1}) was significantly (P<0.05) higher in control as compared to T-30, while T-15 had an intermediate position between control and T-30. The FCR by calves (kg DMI/kg gain) was significantly better (P<0.01) in T-15 as compared to T-30; however, FCR was comparable between control and T-15 group (Table 3). The results of present study were in conformity with the findings of Helal *et al*. (2011), who reported higher gain in buffalo calves fed *ad libitum* than the restricted (85 and 70% of *ad libitum*) groups in all experimental periods. However, buffalo calves fed the 85% restricted concentrate were significantly (P<0.05) more efficient in converting their feed to gain than the control

Table 2. Effect of feed restriction on nitrogen balance in different group of calves

Attribute	Treatment			SEM	P value
	Control	T-15	T-30		
Nitrogen balance (gd^{-1})					
N intake	82.12^{b}	66.15^{ab}	51.12^{a}	4.80	0.02
Faecal- N	17.94^{c}	13.13^{b}	8.92^{a}	1.16	<0.01
Urinary-N	23.73^{c}	16.93^{b}	11.15^{a}	1.72	<0.01
Total-N excretion	41.67^{c}	30.06^{b}	20.07^{a}	2.73	<0.01
N retained (gd^{-1})	40.44^{b}	36.08^{ab}	31.04^{a}	1.38	0.01
N retained % of intake	49.14^{a}	54.40^{b}	60.41^{c}	1.22	<0.01
N retained % of absorbed	63.2^{a}	68.07^{b}	73.92^{c}	1.17	<0.01
% reduction in N excretion	0.00^{a}	27.86^{b}	31.14^{b}	3.67	<0.01

[abc]Means with different superscripts within a row differ significantly.

Table 3. Effect of feed restriction on overall performance of different group of calves

Attribute	Treatment			SEM	P value
	Control	T-15	T-30		
Initial BW (kg)	85.51	85.73	85.90	5.59	1.00
Final BW (kg)	136.5	129.5	115.6	7.19	0.51
Total BW gain (kg)	50.99^{b}	43.79^{b}	29.77^{a}	2.84	<0.01
Voluntary feed intake					
Total (kg)	413.97^{b}	334.82^{ab}	279.49^{a}	22.60	0.03
g/d	3449.80^{b}	2790.18^{ab}	2329.10^{a}	188.39	0.03
ADG, g	424.94^{b}	364.9^{b}	248.1^{a}	23.70	<0.01
FCR	8.14^{a}	7.53^{a}	9.87^{b}	0.32	<0.01

ADG, average daily gain; FCR, feed conversion ratio (kg DMI, kg/gain). [ab]Mean values with different superscripts within a row differ significantly (P<0.05).

group at almost all the experimental periods. Similarly, Ikhar *et al*. (2011) reported significantly (P<0.05) lower ADG (g) in heifers fed restricted diet (70% of DCP and TDN requirements), whereas the reduction was not significant in group fed 80% restricted diet in comparison of *ad libitum* fed group. Kumar and Gupta (2000) reported that intake of DM, DCP and TDN for per kg growth was less (P<0.05) in restricted buffalo heifers than *ad libitum* fed heifer, showing better feed conversion efficiency in restricted heifers. Hicks *et al*. (1990) reported improvements in FCR by 8.4 and

Table 4. Effect of feed restriction on metabolic profile in different group of calves

Attribute	Period			Treatment	P Value		
	0 day	60 day	120 day	Mean ±SE	G	P	G*P
			Haemoglobin (gdl^{-1})				
Control	12.82±0.79	12.84±0.44	11.66±0.34	12.44±0.33	0.75	<0.01	0.25
T15	12.96±0.69	13.97±0.93	10.74±0.22	12.56±0.49			
T30	13.12±0.33	12.16±0.64	11.32±0.51	12.20±0.33			
Mean±SE	12.96±0.34^{B}	12.99±0.42^{B}	11.24±0.22^{A}				
			PCV (%)				
Control	32.05±1.99	32.12±1.11	29.16±0.86	31.11±0.83	0.75	<0.01	0.26
T15	32.41±1.74	32.94±2.34	26.87±0.56	31.40±1.24			
T30	32.80±0.84	30.41±1.60	28.30±1.27	30.50±0.82			
Mean±SE	32.42±0.87^{B}	32.49±1.05^{B}	28.11±0.56^{A}				
			Glucose (mgdl^{-1})				
Control	51.67±1.42	53.75±2.09^{b}	53.17±1.57^{b}	52.86±0.95^{b}	<0.01	0.06	0.01
T15	51.15±1.61	50.83±1.17^{b}	50.32±1.57^{b}	50.77±0.79^{b}			
T30	51.08±1.41	46.65±0.64^{a}	42.16±0.65^{a}	46.63±1.02^{a}			
Mean±SE	51.29±0.80	50.41±1.05	48.55±1.24				
			Total protein (gdl^{-1})				
Control	7.29±0.20	7.43±0.21^{b}	7.48±0.09^{b}	7.40±0.10^{b}	<0.01	0.01	<0.01
T15	7.48±0.16	7.32±0.10^{b}	7.25±0.04^{b}	7.35±0.07^{b}			
T30	7.72±0.51^{B}	6.48±0.07^{aA}	6.29±0.12^{aA}	6.83±0.22^{a}			
Mean±SE	7.50±0.18^{B}	7.07±0.13^{A}	7.01±0.13^{A}				
			Albumin (gdl^{-1})				
Control	3.44±0.09	3.57±0.09^{b}	3.69±0.10^{b}	3.57±0.05^{b}	0.03	0.94	0.24
T15	3.51±0.11	3.53±0.06^{b}	3.48±0.09^{b}	3.51±0.04^{b}			
T30	3.50±0.11	3.25±0.25^{a}	3.20±0.07^{a}	3.32±0.09^{a}			
Mean±SE	3.48±0.05	3.45±0.09	3.46±0.06				
			Globulin (gdl^{-1})				
Control	3.85±0.22	3.85±0.20	3.78±0.14	3.83±0.10	0.14	0.03	0.10
T15	3.96±0.12^{B}	3.78±0.12^{A}	3.76±0.07^{A}	3.83±0.09			
T30	4.22±0.43^{B}	3.22±0.29^{A}	3.08±0.15^{A}	3.51±0.21			
Mean±SE	4.01±0.16^{B}	3.62±0.13^{A}	3.54±0.11^{A}				
			A/G ratio				
Control	0.91±0.06	0.94±0.06	0.98±0.05	0.94±0.03	0.46	0.20	0.72
T15	0.89±0.04	0.94±0.04	0.93±0.04	0.92±0.02			
T30	0.86±0.07	1.08±0.18	1.05±0.06	1.00±0.06			
Mean±SE	0.88±0.03	0.99±0.06	0.99±0.03				
			Urea (mgdl^{-1})				
Control	36.50±1.09^{A}	40.01±1.28^{B}	40.63±0.99^{B}	39.05±0.75^{b}	0.07	<0.01	0.28
T15	35.13±0.98^{A}	38.57±1.00^{B}	39.11±1.17^{B}	37.60±0.71^{ab}			
T30	36.94±0.73^{A}	36.59±0.71^{A}	38.24±0.79^{B}	37.25±0.44^{a}			
Mean±SE	36.19±0.55^{A}	38.39±0.65^{B}	39.32±0.59^{B}				
			AST (IU/l)				
Control	83.68±1.63	85.43±2.14	83.60±1.81	84.24±1.03	0.70	0.59	0.74
T15	84.54±1.96	86.04±2.53	84.73±1.51	85.11±1.12			
T30	83.68±2.74	85.26±2.57	88.22±2.19	85.72±1.43			
Mean±SE	83.97±1.17	85.57±1.31	85.52±1.12				
			ALT (IU/l)				
Control	22.74±1.41	21.63±1.62	19.17±1.36	21.18±0.87	0.77	0.74	0.38
T15	21.33±1.76	21.27±1.20	19.91±0.87	20.84±0.74			
T30	20.39±1.24	22.14±1.16	22.30±1.11	21.61±0.67			
Mean±SE	21.49±0.84	21.68±0.73	20.46±0.69				

[ab]Means with different superscripts within a column differ significantly (P<0.05).

10.9% in yearling steers receiving 85 and 89% of *ad libitum*. In the present study, calves fed 15% restricted diet (T-15) of *ad libitum* showed better feed conversion efficiency as compared to fed *ad libitum* due to improved nutrient utilization.

Metabolic profile: The Hb and PCV levels of calves under different treatments were within the normal range (Kaneko 2008). Similar to present results, Lohakare *et al*. (2012) reported that the Hb and haematocrit were within the normal range in both control and restricted group calves. Sahoo *et al*. (2002) also reported comparable Hb levels in calves fed restricted protein diet (75%) and/or *ad libitum*. Mean serum glucose levels and levels at 60 and 120 d were significantly (P<0.01) lower in T-30 as compared to T-15 and control groups (Table 4). Present results were in consistency with the findings of Lohakare *et al*. (2012), who reported that serum glucose level was higher (P<0.05) in control group than restricted group (50% of concentrate) at 70 d. Santra and Pathak (2000) also reported higher (P<0.05) glucose level in calves fed high concentrate diet (60%) as compared to low concentrate (30%) diet.

Mean serum protein and albumin levels (gdl^{-1}) were significantly (P<0.05) lower in T-30 than T-15 and control groups. The mean value of globulin (gdl^{-1}) and A:G ratio did not differ significantly (P>0.05) among various treatments. The lower level of albumin in T-30 group was in agreement with the findings of previous worker (Jeejeebhoy *et al*. 1975, Pain *et al.* 1978), who observed decreased synthesis of albumin in response to a low dietary N intake. Similarly, Jones *et al*. (1990) also observed significant (P<0.05) decrease in serum albumin level in cattle fed restricted diet as compared to *ad libitum* group at 55 d. Van Saun (2000) reported that serum protein and albumin is a potent indicator of protein status of animals, however, the comparable levels of serum proteins in T-15 and control group are suggestive of adequacy of the protein even on the 15% restricted diet. Serum urea level of calves in T-30 group was lower (P<0.07) than control, however, T-15 had intermediate position between control and T-30 groups. The serum urea level was significantly (P<0.01) higher at 60 and 120 d as compared to 0 d. Similarly, Sun and Christopherson (2005) and Promkot and Wanapat (2005) had observed a positive relationship between blood urea-nitrogen and dietary CP in ruminants. The decreased serum urea level in T-30 group was despite the body regulatory mechanism of a reduced urinary-N excretion with major proportion of urea being recycled into the rumen through saliva (Satter and Roffler 1977). Activity of serum ALT and AST did not differ significantly among dietary treatments and were within normal range (Kaneko 2008).

The present results suggested that restricted feeding of calves induced no adverse effect on target haematological parameters (Hb & PCV), globulin and activity of serum enzymes (ALT & AST) in calves throughout the experiment; however, serum glucose, total protein, albumin and urea levels were lower in T-30 group relative to T-15 and control group. The results clearly indicate that restricted feeding of calves up to 30% level has no harmful effect on liver, heart, other soft organs and skeletal muscles of the body.

On the basis of above results, it may be concluded that dietary restriction at 15% level was more efficient because total body gain, average daily gain, feed conversion efficiency and metabolic profile were at par with the control group. The feed restriction significantly improved nutrients digestibility and N-utilization efficiency by crossbred calves, however, dietary restriction at 30% level was found to adversely affect some of the related parameters.

ACKNOWLEDGEMENT

This study was financially supported by funds provided by the Indian Council of Agricultural Research (AICRP), New Delhi, India.

REFERENCES

Anderson J L, Kalscheur K F, Garcia A D and Schingoethe D J. 2015. Feeding fat from distillers dried grains with solubles to dairy heifers: I. Effects on growth performance and total-tract digestibility of nutrients. *Journal of Dairy Science* **98**: 5699–08.

AOAC. 2005. Official Methods of Analysis. 18th ed. Association of Official Analytical Chemists, Arlington, VA, USA.

Barham D and Trinder P. 1972. An improved color reagent for the determination of blood glucose by the oxidase system. *Analyst* **97**: 142–45.

Dacie Z and Lewis S. 1969. Practical Heamatology (4th edn). J. and A., Churchill, London.

Doreau M B, Michalet-Doreau P, Atti Grimaud N and Noziere P. 2003. Consequences of underfeeding on digestion and absorption in sheep. *Small Ruminant Research* **49**: 289–301.

Doumas B T, Watson W A and Biggs H G. 1971. Albumin standards and the measurements of serum albumin with bromocresol green. *Clinica Chimica Acta* **31**: 87–96.

George S K, Dipu M T, Mehra U R, Singh P and Verma A K. 2005. Growth of crossbred bulls affected by level of feed intake. *Indian Journal of Animal Nutrition* **22**: 81–84.

Grimaud P and Doreau M. 1995. Effect of extended underfeeding on digestion and nitrogen balance in non-lactating cows. *Journal of Animal Science* **73**: 211–19.

Hallett C J and Cook J G H. 1971. Produced nicotinamide adenine dinucleotide coupled reaction for emergency blood urea estimation. *Clinica Chimica Acta* **35**: 33–37.

Helal F I S, Abdel Rahman K M, Ahmed B M and Omar S S. 2011. Effect of feeding different levels of concentrates on buffalo calves performance, digestibility and carcass traits. *American-Eurasian Journal of Agricultural and Environmental Science* **10**(2): 186–92.

Hicks R B, Owens F N, Gill D R, Martin J J and Strasia C A. 1990. Effects of controlled feed intake on performance and carcass characteristics of feedlot steers and heifers. *Journal of Animal Science* **68**: 233–44.

Hutchinson J C D and Morris S. 1936. The digestibility of dietary protein in the ruminant. I. Endogenous nitrogen in starvation. *Biochemical Journal* **30**: 1682.

Ikhar U V, Singh S K and Mudgal V. 2011. Effect of different feeding regimen on growth and reproductive performance of Sahiwal heifers. *Indian Journal of Animal Nutrition* **28**(2): 181–84.

JeeJeebhoy K N, Ho J, Greenburg G R, Phillips M J, Robertson A B and Sodtke U. 1975. Albumin, fibrinogen, and transfarin synthesis in isolated rat hepatocyte suspensions. *Biochemical Journal* **146**: 141–55.

Jones S J, Starkey D, Calkins C R and Crouse J D. 1990. Myofibrillar protein turnover in feed-restricted and realimented beef cattle. *Journal of Animal Science* **68**: 2707–15.

Kaneko J J, Harvey J W and Bruss M L. 2008. Clinical Biochemistry of Domestic Animals. 6th ed. Academic Press, San Diego, USA.

Kumar R and Gupta L R. 2000. Effect of restricted feeding of berseem on growth performance of Murrah buffalo heifers. *Indian Journal of Dairy Science* **53**(1): 33–37.

Kumar S, Dutta N, Baliyan S, Pattanaik A K and Singh S K. 2015. Effect of feed restriction on nutrient metabolism, metabolic profile and excretion of nutrients in goats. *Animal Nutrition and Feed Technology* **15**: 361–74.

Kumar S, Narayan Dutta, Pattanaik A K, Ojha B K and Chaturvedi V B. 2017. Effect of feed restriction on energy metabolism and methane emission in goats. *Journal of Animal Research* **7**(2): 1–8.

Loerch S C. 1990. Effects of feeding growing cattle high concentrate diets at a restricted intake on feedlot performance. *Journal of Animal Science* **68**: 3086–95.

Lohakare J D, Singh N K, Nejad J G, Sung K I and Ingale S L. 2013. Effects on growth performance, plasma variables and gene expression of hepatic gluconeogenic enzymes in holstein calves fed limited amount of concentrate. *Animal Nutrition and Feed Technology* **13**: 1–13.

Lohakare J D, van de Sand H, Gerlach K, Hosseini A, Mielenz M, Sauerwein H, Pries M and Südekum K H. 2012. Effects of limited concentrate feeding on growth and blood and serum variables, and on nutrient digestibility and gene expression of hepatic gluconeogenic enzymes in dairy calves. *Journal of Animal Physiology and Animal Nutrition* **96**(1): 25–36.

Maynard L A, Looseli J K, Hintz H F and Warner R G. 1985. Animal Nutrition. Tata McGraw-Hill Publishing Company Limited, New Delhi.

Murphy T A and Loerch S C. 1994. Effect of restricted feeding of growing steers on performance, carcass characteristics and composition. *Journal of Animal Science* **72**: 2479–07.

NRC. 2001. Nutrient Requirements of Dairy Cattle. 7th ed. National Academy Press, Washington, DC, USA.

Pain V M, Clemens M J and Garlick P J. 1978. The effect of dietary protein deficiency on albumin synthesis and on concentration of active albumin messenger ribonucleic acid in rat liver. *Biochemical Journal* **172**: 129–35.

Parsons C H and Stanton T L. 2000. Effects of roughage type and restricted feed intake on digestibility and finishing cattle performance. *Professional Animal Scientist* **16**: 182–87.

Patil S S, Sharma K, Narayan Dutta and Pattanaik A K. 2017. Intake, nutrient utilization and growth performance of lambs fed detoxified *Jatropha curcas* meal. *Indian Journal of Animal Sciences* **87**(3): 88–91.

Promkot C and Wanapat M. 2005. Effect of level of crude protein and use of cottonseed meal in diets containing cassava chips and rice straw for lactating dairy cows. *Asian Australasion Journal of Animal Science* **18**: 502–11.

Ranjhan S K. 1998. Nutrient Requirement of Livestock and Poultry. 2nd ed. Indian Council of Agricultural Research (ICAR) Publication, New Delhi, India.

Sahoo A, Mishra S C and Pathak N N. 2002. Dietary protein restriction on growth and immuno-biochemical response of crossbred calves during post-ruminant phase of life. *Asian Australasian Journal of Animal Science* **15**(8): 1121–27.

Santra A and Pathak N N. 2000. Effect of dietary concentrate level on body immune response in calves fed a wheat straw-based diet. *Journal of the South African Veterinary Association* **71**(4): 244–45.

Santra A and Pathak N N. 2009. Effect of restricted concentrate feeding on nutrient utilization and growth performance of crossbred calves maintained on wheat straw based diet. *Indian Journal of Animal Science* **79**(9): 906–11.

Satter L D and Roffler R E. 1977. Influence of nitrogen and carbohydrate inputs on rumen fermentation. Recent Advances in Animal Nutrition. 1st Edn, pp. 25–49 (Eds). Haresign W and Lewis D. Butterworth Publication, London, UK.

Singh P, Verma A K, Sahu D S and Mehra U R. 2008. Utilization of nutrients as influenced by different restriction levels of feed intake under sub-tropical conditions in crossbred calves. *Livestock Science* **117**: 308–14.

Snedecor G W and Cochran W G. 2004. Statistical Methods (9th edn). Iowa State University Press, Ames, IA, USA.

Sun S and Christopherson R J. 2005. Urea kinetics in wethers exposed to different ambient temperatures at three dietary levels of crude protein. *Asian Australasian Journal of Animal Science* **18**: 795–01.

Van Saun J R. 2000. Blood profiles as indicators of nutritional status. 18th Annual Western Canadian Dairy Seminar, 1–20 March, 2000, Red Deer, Alberta, Canada.

Vatzidis H. 1977. An improved biuret reagent. *Clinical Chemistry* **23**: 908.