Indian Journal of Animal Sciences **81** (3): 282–88, March 2011

Quantification of nutritional sustenance and microbial protein production of sheep during different physiological stages in semi-arid regions

BANDLA SRINIVAS[1], N SWAIN[2] and N P SINGH[3]

Central Sheep and Wool Research Institute Avikanagar, Rajasthan 304 501 India

Received:23 November 2009; Accepted: 12 December 2010

ABSTRACT

Female lambs, yearlings, pregnant and lactating ewes, 24 each, were randomly divided into 2 equal groups of 12 each. All groups were fed guar straw as basal roughage without (control, CG) and with (experimental, EG) concentrate supplement (CS) consisted 18% total CP and 18 MJ/kg of gross energy. CS offered @25 g/kg $W^{0.75}$. DM intake was recorded daily and compared with the recommendations of ARC (1998). Metabolism trial was conducted during each physiological stage. CS intake was 20 to 25 g/kg $W^{0.75}$ with an increase of 1 to 2 g/kg $W^{0.75}$ with age. DM, N and energy were deficient without CS during all physiological stages. Although CS provided deficit nutrients, efficiency of their utilization was far below the standards (ARC 1998). Purine derivatives excreted in the urine of adult sheep was lesser than lambs or yearlings and ascertained their inverse relationship with body size. Inefficiency in microbial protein production (MBP) without CS, ranged between 25 and 50% compared to optimum production of 30 g/kg apparently digested organic matter in rumen. Performance output index (POI) calculated as function of efficiency indicated 60 to 70% below global standards of optimum performance when fed on guar straw alone. CS increased the POI by 5 and 35% more than optimum level in lambs and pregnant ewes. Performance of yearlings and lactating ewes on CS needed 14 and 50% more improvement to make it comparable with standards.

Key words: Growth, Lactation, Nutrition deficiency, Pregnancy, Sheep, Supplement

Tropical semi-arid regions, where large population of sheep habitated are facing the problem of crop failures in successive years due to extreme weather and animals are also physically near their limits of heat tolerance. Protein shortage is very chronic problem at least for 6 to 7 months in a year (Leng 1990). Feeding concentrate supplements (CS) in little quantities mitigates nutritional deficiency but seldom followed by sheep farmers due to low income, poor input management and limited resource availability (Srinivas *et al*. 2008). Poor knowledge and sociological taboos in these regions are also causing hindrances in propagating the scientific and economical methods in livestock rearing (Srinivas *et al.* 2004). Often inefficiency in livestock production systems in semiarid regions is highlighted imprecisely in quantitative terms with reference to globally accepted standards (ARC 1998, NRC 2000). Quantitative production of microbial nitrogen in rumen of sheep is important to substantiate meager endogenous N recycling (Djouvinov 1999) and chronic deficiency in diet and, its contribution in the total protein requirements in semi arid regions is also less known in sheep during different physiological stages. This study was undertaken to measure quantitative difference in comparison to global measures of nutrition sustenance and microbial N production in lambs, yearlings, pregnant and lactating ewes on guar straw as sole feed or with CS.

Present address: (e mails[1,2,3]: bandla_srinivas@rediffmail.com; narendranath.swain@rediffmail.com; npsingh2005@yahoo.com), Southern campus, National Dairy Research Institute, Bangaluru 560 030.

MATERIALS AND METHODS

Geography and environmental conditions: Study conducted in semiarid region of eastern Rajasthan of India. It lies between 75°25’ to 75°28’E longitude and 26°15’ to 26°25’N latitude with 326 m elevation above mean sea level. Topography is flat with mild slope interspersed with deep gullies of narrow to medium bottom width. Sand dunes are also prevailing in certain locations. Soil is sandy loam with infiltration ranging from medium to high. Experiments on lambs and lactating ewes were carried out during the months of mid January to end of the April and, on yearlings and pregnant ewes were conducted during mid October to December. Average humidity during this period was 62% , temperature ranged between 90 and 57 °F, wind speed was 3.4 km/h and, evaporation was 7% . Maximum, minimum and average heat index was 91°, 63° and 79 °F, respectively and was far below the stressful index of 113 °F. Average sunshine hours were 9 with surface soil temperature ranged 25 to 50 °C with average of 37±0.7 °C.

Animals, diets and metabolism trial: Twenty replicates in each physiological stage, such as female lambs (age 3.08±0.08 month and body weight 10.8±0.4 kg), yearlings (age 12.6±0.4 M and BW 21.7±0.4 kg), pregnant ewes (age 24.8±0.9 M, BW 25.2±0.78 kg) and lactating ewes (age 28.3±1.2 M, BW 29.0±0.86 kg, milk yield 130±16 g d^{-1}) were randomly divided into 2 equal groups of 10 each. Guar straw (1 kg) was offered to yearlings, pregnant ewes and lactating ewes but only 500 g was offered to lambs. Control groups (CG) was solely maintained on roughage without CS and experimental groups (EG) were fed CS @ 25 g/kg $W^{0.75}$ during each physiological stage. CS, on fed basis, consisted groundnut cake 25, maize 30, wheat bran 40, mineral mixture 3 and common salt 2% and fortified with vitablend 300 g/tonne. Sheep were housed in well ventilated 3 × 4 ft individual pens. Samples of feed offered and orts were collected every day, oven dried and total DM intake (DMI) was calculated. Clean drinking water offered to sheep for 4 times in a day without measurement. Sheep were under personal human care, maintained, fed and treated according to good practices for experimentation on sheep as per institute's animal ethics committee pro-guidelines of CPCSEA (1998).

After preliminary period of feeding sheep in each physiological stage for 6 wks, metabolism trial for 7 days was conducted with 2 d of acclimatization. Urine collection bucket acidified by adding 10% H_2SO_4 (v/v) to prevent ammonia volatilisation. Feed intake was measured and samples of feed offered and left were pooled for 5 days. Total faeces and urine collected once daily at 08:30 h. Feces was sampled to 1/20th part in two quantities. One part kept for oven drying at 100±5°C for 12 h and other part acidified with addition of 25% H_2SO_4 (v/v) in a glass bottle and kept for N estimation. Total urine was diluted uniformly to 2 L with tap water, mixed thoroughly and part of it filtered through glass wool. A sample of 50 ml was taken in polypropylene bottles and stored at –20 °C.

Laboratory analysis: DM content, proximate (AOAC 1995) and cell wall constituents (Van Soest *et al.* 1991) were analysed in feed, ort and faecal samples. NDF and ADF estimations were completed sequentially. Gross (GE) and digestible energy (DE) was estimated by adiabatic bomb calorimeter.Metabolizable energy (ME), heat increment (HI) and energy efficiency were calculated based on empirical models recommended by ARC (1998).

Microbial protein production (MBP) was quantified from the purine derivatives excreted in urine (Chen *et al.* 1995). Urine samples stored at –20 °C were diluted 10 times to maintain the concentration of allantoin and uric acid within the range of 5–50 mg/l. Allantoin standards (A-7878) were prepared in the range of 10 to 60 mg/l with 10 mg increment and its concentration in the samples was determined using colorimetric method by reading the varying intensity of pink colour developed at 522 nm using UV- visible spectrometer. Xanthin and hypoxanthin were estimated by enzymatic method using xanthin oxidase by degrading to uric acid. Standards of uric acid were prepared in the concentration of 20 to 100 mg/l with 20 mg increment. Uric acid content was measured by uricase method with working standard concentrations of 5, 10, 20, 30 and 40 mg/l and absorbance was read at 293 nm. Based on the urinary excretion of purine derivatives (PD), outflow of microbial-N was calculated. Microbial-N flow from rumen was quantified based on the digestibility of microbial purines, N content of purines and ratio of purine N to total N in mixed rumen microbes as 0.83, 70 mg N/mmol, and 11.6:100, respectively. Digestible organic matter (DOM) apparently fermented in the rumen (DOMR) was considered as 65% of the DOM intake.

Quantification of nutrition sustenance: Total DMI, total protein and ME and efficiency of their utilization were compared with standards recommended by ARC (1998) for sheep during growth, pregnancy and lactation, respectively. Optimum efficiency of absorbed CP was taken as 60, 70 and 80% and, energy efficiency as 65, 20 and 62% for growth, pregnancy and lactation, respectively. Optimum MBP was taken as 30 g/kg DOMR. Differences in the observed and standard values were calculated and simple index of deficiency/ sufficiency or efficiency/inefficiency derived as (Observed value - Standard Recommendation/ Standard–Recommendation) ×100.

Mathematical and statistical analysis: Comparison between physiological stages was done using the 'metabolic body weight' as uniform scale (Schmidt-Nielson 1984). Statistical significance of various parameters between lambs, yearlings, pregnant and lactating ewes was taken as factor α and diets with and without CS was taken as factor ß as split plot on factor α. Variation among means with $0.001<P<0.05$ were accepted as representing tendencies to differences among the groups. These analyses used the standard procedures of SPSS, Version- 14.0 for Windows.

Performance output index (POI) was derived as function of efficiency (output/input). Output was taken as a product of input × efficiency. Since deficiency/sufficiency or efficiency/inefficiency was derived as deviation from standard recommendations, these optimum levels were given a value of 1 and relative values were derived. Any value exceeding 1 was an indicative of performance exceeding the optimum value while less than 1 was an indication of below optimum performance.

POI = (1+X)×(1+Y), which on simplification becomes [1+(X+Y+XY)], where,

X = aggregate fractional deficiency or sufficiency of nutrients intake e.g, DM, CP, ME

Y = aggregate fractional efficiency or inefficiency in the nutrients use e.g., CP, ME, microbial N.

RESULTS AND DISCUSSION

Diet intake and digestibility: Chemical composition of CS and guar straw is presented in Table 1. Irrespective of physiological stage of sheep, deficiency in DM, CP and energy intake was common in semi arid regions due to their poor quality. CS intake during different physiological stages was between 20 to 25 g/kg $W^{0.75}$. Proportion of CS in total diet was 30 to 37% . No significant difference in DMI (g/kg $W^{0.75}$) was observed between lambs, yearlings and pregnant ewes with or without CS (Table 2). DMI of sheep was improved after CS to guar straw by 60 and 80% , respectively in growing and pregnant sheep but only 20% in lactating ewes. Improvement observed in DMI and digestibility of nutrients with CS to guar straw was an obvious distinction that has been ascertained from many studies conducted earlier due to its positive associate affect (Archimede *et al.* 1997, Orden *et al.* 2000, Srinivas *et al*. 2002). This affect was more with growing than mature animals. Total DMI was 47% higher ($P< 0.01$) in lactating ewes than during growth or pregnancy may be because the nutrient demand during this physiological stage is more due to active synthetic processes those require rapid circulation and partition of nutrients in mammary tissue (Ingvertsen 2006). Energy efficiency of CG was negative irrespective of physiological stage of the sheep. Both energy efficiency and protein intake were improved with CS ($P< 0.01$). When CS intake was 20 to 25 g/kg$W^{0.75}$, the stipulated intake of CS in growing and pregnant sheep was about 26, 30 and 29%, respectively, and in lactating ewes was 39%. Archimede *et al.* (1997) suggested from meta-analysis that 30 to 40% CS in the diet for optimum nutrient usage and rumen fermentation.

Digestibility of DM ($P< 0.001$), OM ($P< 0.001$), CP ($P< 0.05$) and energy differed significantly ($P< 0.001$) between different physiological stages with or without CS. Digestibility of nutrients was significantly ($P < 0.001$) higher in lambs, yearlings and pregnant ewes than lactating ewes. Improvement in nutrient digestibility irrespective of physiological stage was eventual to reduce their deficiency from limited feed resources available in these regions. Digestibility of DM, OM, CP and energy was more in growing than mature animals with and without CS in the

Table 1. Chemical composition of diet (% on DM basis)

Parameter	Concentrate mixture	Roughage
Dry matter	92.61±0.61	91.94±1.05
Organic matter	88.67±0.45	90.36±0.51
Crude protein	17.70±0.31	10.42±0.94
Ether extract	4.04±0.50	1.82±0.20
Crude fiber	11.39±1.09	32.28±0.73
Nitrogen free extract	55.54±1.06	41.83±1.58
Total ash	11.33±0.45	9.64±0.51
Acid insoluble ash	2.32±0.13	4.64±0.53
Neutral detergent fibre	37.52±1.90	68.92±0.67
Acid detergent fibre	16.11±1.35	47.40±1.13
Hemicellulose	21.41±2.92	21.52±1.30
Cellulose	10.41±0.75	30.27±1.37
Lignin	4.12±0.61	9.4±1.20

Table 2. Intake and digestibility of nutrients during different physiological conditions

Parameter	Without concentrate supplement					With concentrate supplement				
	Lambs	Yearlings	Reproduction	Lactation	SE_M	Lambs	Yearlings	Reproduction	Lactation	SE_M
Initial body weight (kg)	10.77^{a}	21.67^{b}	25.32^{b}	29.33^{c}	0.58***	10.80^{a}	21.67^{a}	25.05^{bc}	28.67^{c}	1.93***
(Met. B. Wt)	5.94^{a}	10.04^{b}	11.28^{b}	12.60^{c}	0.19***	5.95^{a}	10.04^{a}	11.19^{bc}	12.39^{c}	0.19***
Final body weight (kg)	11.00^{a}	22.33^{b}	27.53^{c}	29.67^{c}	0.64***	12.50^{a}	23.00^{a}	27.90^{c}	29.17^{c}	0.42***
(Met. B. Wt)	6.03^{a}	10.27^{b}	12.01^{c}	12.71^{c}	0.20***	6.65^{a}	10.50^{a}	12.14^{c}	12.55^{c}	0.12***
Concentrate intake (g d^{-1})	–	–	–	–	–	136^{a}	232^{a}	280^{c}	322^{d}	3.56***
(g $kg^{-1}W^{0.75}$)	–	–	–	–	–	20.56^{a}	22.08^{ab}	23.05^{b}	24.70^{c}	0.34**
Roughage intake (g d^{-1})	216^{a}	397^{a}	429^{a}	892^{b}	34.68***	234^{a}	429^{ab}	506^{b}	739^{c}	35.69**
(g $kg^{-1}W^{0.75}$)	35.67^{a}	38.92^{a}	35.95^{a}	69.97^{b}	2.70**	35.30^{a}	40.88^{ab}	41.66^{ab}	60.37^{b}	3.10
Total DM intake (g d^{-1})	216^{a}	397^{a}	429^{a}	892^{b}	34.68***	370^{a}	660^{b}	785^{b}	1062^{c}	32.44***
(g $kg^{-1}W^{0.75}$)	35.67^{a}	38.92^{a}	35.95^{a}	69.96^{b}	2.77**	55.87^{a}	62.96^{a}	64.71^{a}	85.06^{b}	2.98*
DM digestibility (%)	51.11^{a}	67.06^{b}	58.56^{c}	41.90^{d}	0.83***	70.82^{a}	74.48^{a}	66.44^{a}	42.82^{b}	1.62***
OM intake (g $kg^{-1}W^{0.75}$)	32.23^{a}	35.17^{a}	32.48^{a}	63.22^{b}	2.44**	50.01^{a}	57.91^{a}	58.08^{a}	76.43^{b}	2.73*
OM digestibility (%)	55.63^{a}	70.10^{b}	60.45^{a}	41.55^{c}	0.79***	73.87^{a}	77.15^{a}	70.00^{a}	43.06^{b}	1.45***
DCPI (g $kg^{-1}W^{0.75}$)	2.39^{a}	2.86^{a}	2.10^{a}	3.65^{b}	0.12**	5.64	6.73	5.87	6.48	0.28
CP digestibility (%)	64.35^{a}	70.85^{a}	56.89^{ab}	43.74^{b}	2.09**	77.63^{a}	80.28^{a}	69.88^{ab}	52.25^{b}	3.01*
Dig. energy, MJ $kg^{-1}W^{0.75}$	0.33^{a}	0.45^{ab}	0.36^{a}	0.50^{b}	0.02	0.70	0.81	0.77	0.66	0.03
Energy digestibility (%)	59.47^{a}	72.68^{b}	65.00^{a}	45.88^{c}	0.99***	79.66^{a}	81.01^{a}	75.67^{a}	48.57^{b}	1.56***
Energy efficiency (%)	-15.67	-0.33	–9.25	–0.33	0.02	18.61	21.68	27.21	13.71	0.02
Cell wall digestibility (%)	61.59^{a}	74.10^{b}	62.40^{a}	54.20^{c}	1.02***	69.56^{a}	73.97^{a}	66.87^{ab}	54.84^{b}	2.11

[abc] Values bearing different superscripts in a row differ significantly between physiological stages of similar treatment. *$P< 0.05$, **$P< 0.01$ and ***$P< 0.001$.

Table 3. Nitrogen and energy balance during different physiological stages

Parameter	Without concentrate supplement					With concentrate supplement				
	Lambs	Yearlings	Reproduction	Lactation	SE_M	Lambs	Yearlings	Reproduction	Lactation	SE_M
Nitrogen balance (g/kg $W^{0.075}$)										
Total intake***	0.59^a	0.65^a	0.54^a	1.17^b	0.04**	1.17^a	1.31^a	1.25^a	1.72^b	0.05*
Fecal output**	0.21^a	0.16^a	0.26^a	0.66^b	0.03***	0.26^a	0.26^a	0.41^a	0.82^b	0.05*
Absorbed***	0.38^a	0.49^b	0.28^a	0.51^b	0.02**	0.90	1.05	0.84	0.90	0.05
Urinary excretion*	0.11^a	0.11^a	0.37^c	0.26^b	0.01***	0.15^a	0.12^a	0.47^b	0.37^c	0.01***
Metabolizable***	0.27^{ab}	0.39^b	-0.10^c	0.19^a	0.02***	0.76^{ab}	0.93^a	0.38^c	0.48^{bc}	0.05*
Energy balance (MJ/kg $W^{0.75}$)										
Gross***	0.56^a	0.61^a	0.57^a	1.10^b	0.04**	0.88^a	1.00^a	1.02^a	1.35^b	0.05*
Metabolizable***	0.28	0.38	0.33	0.43	0.02	0.61	0.70	0.54	0.57	0.03
Retained***	–0.04	0.00	–0.03	0.003	0.01	0.11	0.15	0.15	0.09	0.01
Heat increment***	0.33^a	0.38^{ab}	0.36^{ab}	0.42^b	0.01*	0.49^{ab}	0.55^a	0.40^b	0.48^{ab}	0.02*

[abc] Values bearing different superscripts in a row differ significantly between physiological stages for same treatment. Significance specified for a parameter indicate level of significance between two means of same physiological stage across treatments. *$P< 0.05$, **$P< 0.01$ and ***$P< 0.001$.

prevailing environment because ewes during pregnancy and lactation were more sensitive to the external environment due to changes occurring in putative metabolic cycles with hormonal changes call for simultaneously adjustment with internal environment for nutrient partition between multiple tissues and functional systems (Bauman 2000). Ewes have to depend largely on the maternal body reserves during pregnancy and lactation due to nutritional inadequacy on sole feeding of guar straw (Srinivas and Sankhyan 2010).

Nutrient balance: N and energy balance were significantly different between physiological stages between CG and EG (Table 3). Significant difference in the urinary N excretion among growing, pregnant and lactating ewes indicated possible difference in the metabolic regulation of N due to their biological needs during different physiological stages. Variation in N retention during different physiological stages was good indication of interaction between nutrient supply and tissue metabolism. Metabolizable N balance was positive in growing lambs, yearlings and lactating animals. N retention per kg of metabolic body weight was higher with lambs and yearlings than either pregnant or lactating ewes. N deficiency on sole feeding of guar straw also affected energy utilization in sheep during all physiological stages. However, in pregnant ewes both N and energy were deficit without CS. Since N retention is a quadratic function of both energy and protein intake (ARC 1998), either negative or substantially low metabolizable N was indicative of poor tissue metabolism during pregnancy and lactation. Substantial improvement in the N retention in pregnant ewes with CS to guar straw indicated its definite requirement. Any negligence in feeding CS during pregnancy may cause physiological deterioration that may even affect their subsequent productivity (McNeil *et al.* 1997). Negative energy and N balance of sheep in semiarid regions on low quality roughages without CS was lead to mobilization of body reserves and loss of body weight (Srinivas and Sankhyan 2010). Ryan *et al.* (1993) reported a change in body condition score by 0.5 to 1 during unfavorable seasons which is equivalent to approximately 6 to 12 kg. CS improved N utilization efficiency in growing sheep but not in the pregnant or lactating ewes. Kebreab *et al.* (2002) observed restriction in energy utilization due to N deficiency decreases voluntary intake and, on the other hand, excess N intake causes nonproductive use of energy in N excretion. Even without CS, only growing sheep has been reported to meet their total energy demand by altering endogenous energy loss in response to dietary energy and protein supply (Chowdhury *et al.* 1997). N absorption across gut improved with CS however, it was constant with metabolic body size irrespective of physiological stage. Even after fulfilling nutrient deficiency with CS, still inefficiency of energy during growth and lactation may probably an indication of asynchrony in their availability (Chumpawadee *et al.* 2006). Particularly during pregnancy and lactation, ewes were reported to be very sensitive to protein and energy asynchrony (Bell *et al.* 2005). Increase in HI ($P< 0.05$) with CS was higher in growing sheep rather than pregnant or lactating ewes. Although feeding CS resulted in additional heat increment of 0.10 MJ/kg $W^{0.75}$, some trade-offs among disadvantage are inevitable over many advantageous accrued from it (Forbes 2001).

MBP during different physiological stages: Allantoin excretion was significantly more ($P< 0.001$) in lambs than yearlings, pregnant and lactating ewes (Table 4). During pregnancy, uric acid excretion (mM/ d/kg $W^{0.75}$) was significantly low ($P< 0.05$) compared to growth or lactation both in CG and EG. Purine derivatives excreted in the urine of adult sheep was lesser than lambs or yearlings and indicated inverse relationship with body size of sheep. Level of DMI of sheep may not have any effect on the ratio of purine derivatives (Singh *et al.* 2007). MBP or microbial N (g/d/kg $W^{0.75}$) production and efficiency was declined with age with or without CS and accounted 2 to 4 times lesser than it was reported on different type of diets (Verbic 2002). MBP and microbial N were higher in growing lambs and yearlings than mature animals during pregnancy or lactation. MBP decreased 0.16 and 0.15 g/d/kg $W^{0.75}$ after CS in lambs and lactating ewes however, increased by 0.22 and 0.02 g/d/kg $W^{0.75}$ in yearlings and pregnant ewes. Negligible increase in MBP in pregnant and decrease in either lambs or lactating ewes with simultaneous gain in metabolizable N with CS indicated likely increase in the rumen bypass protein per unit of CP consumed. MBP efficiency (g/kg DOMR) was also significantly ($P < 0.001$) greater in lambs followed by yearlings and lactating ewes than pregnant ewes. Efficiency of MBP in semiarid regions was much lesser than recommended standards (ARC 1998) and its improvement was not possible by supplementing CS to enhance

Table 4. Purine derivatives (PD) excretion in urine and microbial-N production in sheep during different physiological stages

Parameter	Without concentrate supplement					With concentrate supplement				
	Lambs	Yearlings	Reproduction	Lactation	SE_M	Lambs	Yearlings	Reproduction	Lactation	SE_M
Allontoin (mM/ d/kg $W^{0.75}$)	1.11	0.49	0.35	0.48	0.10	1.03^a	0.67^b	0.36^c	0.39^c	0.03***
Xanthin+hypoxanthin (mM/d/kg$W^{0.75}$)	0.16^a	0.10^b	0.08^{bc}	0.04^c	0.01*	0.09	0.10	0.08	0.04	0.01
Uric acid (mM/ d/kg $W^{0.75}$)	0.15^a	0.13^{ab}	0.03^b	0.20^a	0.02*	0.17^a	0.17^a	0.03^b	0.17^a	0.01*
Total PD (mM/ d/kg $W^{0.75}$)	1.42^a	0.73^b	$0.46^{\mathbf{b}}$	0.72^b	0.06**	1.30^a	0.94^b	0.48^c	0.60^c	0.04***
Allontoin (%)	77.26	67.45	75.83	72.25	2.17	79.46	71.70	74.68	65.50	1.67
Xanthin+hypoxan (%)	11.88	14.22	17.62	6.32	1.62	6.87^a	10.77^{ab}	17.99^b	6.58^a	1.20*
Uric acid (%)	10.86^{ab}	18.33^{ac}	6.56^b	26.39^c	2.65*	13.67^a	17.53^a	7.33^a	27.91^b	1.57**
Total PD absorbed (g/d/kg$W^{0.75}$)	1.68^a	0.85^b	0.51^b	0.85^b	0.14**	1.52^a	1.11^b	0.53^c	0.70^c	0.05***
Microbial-N (g /d/kg $W^{0.75}$)	1.22^a	0.62^b	0.37^b	0.61^b	0.10**	1.11^a	0.81^b	0.38^c	0.51^c	0.03***
MBP* (g / kg DOMI)	93.95^a	34.64^b	26.62^b	34.66^b	8.52**	41.41^a	25.40^b	13.61^c	22.00^b	1.15***
MBP* (g / kg DOMR)	61.07^a	22.52^b	17.30^b	22.52^b	5.54**	26.92^a	16.51^b	8.55^c	14.30^b	0.75***

[abc] Values bearing different superscripts in a row differ significantly between physiological stages for same treatment. Significance specified for a parameter indicate level of significance between 2 means of same physiological stage across treatments. *P< 0.05, **P< 0.01 and ***P< 0.001.

Table 5. Relative nutritional deficiency (%) and inefficiency (%) in sheep during different physiological stages

Parameter	Lambs	Yearlings	Reproduction	Lactation	SE_M
Without concentrate supplement					
DM	-33^a	-39^{ab}	-44^b	4^c	3.36***
Total CP deficiency/sufficiency	-35^a	-41^a	28^b	-7^c	4.56***
Metabolizable energy deficiency	-38^a	-31^a	-8^b	-40^c	2.35***
Average deficiency	-35^a	-37^b	-8^c	-14^c	2.57**
Energy inefficiency	-135^a	-102^b	-154^a	-100^b	4.42**
Nitrogen inefficiency/efficiency	17^a	31^a	-158^b	$- 46^c$	11.35***
MBP inefficiency/efficiency	-25^a	-45^b	-54^a	-40^b	2.31***
Average inefficiency	-48^a	-39^b	-122^c	-62^d	5.10***
Aggregate POI	0.35^a	0.39^a	-0.18^b	0.32^a	0.04*
With concentrate supplement					
DM	13^a	0^b	4^b	28^C	2.84***
Total CP sufficiency	39^a	22^b	201^c	39^a	11.22***
Metabolizable energy sufficiency	45^a	30^b	57^c	-19^d	5.27***
Average sufficiency	32^a	18^b	87^c	16^c	5.12**
Energy inefficiency/efficiency	-71^a	-67^a	41^b	-78^a	7.27**
Nitrogen inefficiency/efficiency	40^a	46^a	-43^b	-29^c	6.33***
MBP inefficiency	-31^a	-60^a	-78^b	-61^c	2.68***
Average inefficiency	-21^a	-27^b	-27^b	-56^C	2.23***
Aggregate POI	1.05^a	0.86^b	1.37^c	0.51^d	0.05***

[abc] Values bearing different superscripts in a row differ significantly between physiological stages. *P< 0.05, **P< 0.01 and, ***P< 0.001.

digestibility or supplementing CP and OM. Chumpawadee *et al*. (2006) suggested synchronizing CP and energy degradation in rumen could be more effective on MBP. While assessing inefficiency in the nutrient utilization in these regions, discomfort faced by animals from extreme weather conditions should not be discounted (Dynes *et al.* 2005).

Nutritional sustenance: Differences in DM, CP and energy during different physiological stages between actual intakes and recommended levels are presented in Table 5. DM, CP and energy intake were deficient significantly (P< 0.01) without CS during all physiological stages except CP in pregnancy. Contrary was true after CS (P< 0.01) except energy in lactating ewes. ME utilization was significantly inefficient during growth, pregnancy and lactation both in CG and EG compared to optimum efficiency reported (ARC 1998). N utilization was efficient in growing animals even without CS however, inefficient during pregnancy or lactation even after CS also. MBP was also inefficient in sheep during all the physiological stages in CG and EG. POI was 0.30 to 0.40 for growing or lactating sheep without CS which was 60 to 70% less than optimum value. It was negative for pregnant ewes when fed guar straw without CS. Negative POI of pregnant ewes without CS indicated probable stress on maternal reserves and may affect ewe's subsequent productivity. CS however, improved performance of pregnant ewes by 37% higher than the optimum level of output after CS. This indicated utmost necessity of CS during later half of the pregnancy. POI of lactating ewes was 0.50 less than the optimum even with CS. Aggregate POI indicated that the growing and lactating sheep without CS could able to perform only 1/3rd of optimum levels reported by ARC (1998) but improved to 2/3rd with CS. POI showed that CS had better impact on lambs and pregnant ewes and, to little less extent on yearlings.

Efficiency of utilization of CS was higher in growing sheep however, CS was essential for pregnant ewes. Aggregate POI indicated that the sheep without CS performed 60–70% below the optimum suggested by ARC (1998). Performance of lambs and pregnant ewes in semiarid regions was more than optimum when provided CS to guar straw. Performance of yearlings and lactating ewes in semiarid regions need 14 and 50% more improvement to make it comparable with optimum (ARC 1998). Quantitative improvement in MBP production 2 to 4 times and 60% increase in efficiency was needed for better production performance.

ACKNOWLEDGEMENT

Authors are thankful to the Director, Central Sheep and Wool Research Institute (Indian Council of Agricultural Research) for financial support and extending the facilities.

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