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ORIGINAL RESEARCH

Effect of roughage to concentrate ratio of sweet sorghum (*Sorghum biclor* L. Moench) bagasse-based complete diet on nutrient utilization and microbial N supply in lambs

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Abstract An experiment was conducted to study the effect of roughage to the concentrate ratio of complete diets containing sweet sorghum bagasse (SSB), an agro-industrial by product, as sole roughage source on nutrient utilization in ram lambs. Twenty-four Nellore × Deccani cross ram lambs aged about 3 months (average body wt. 10.62±0.03 kg) were randomly allotted into four groups fed with CR-I (60R:40C), CR-II (50R:50C), CR-III (40R:60C), and CR-IV (30R:70C) complete diets. The roughage to concentrate ratio did not affect the dry matter intake (in grams/day or grams/kilogram weight$^{0.75}$). The crude protein ($P<0.01$) and ether extract ($P<0.05$) digestibility of ration CR-IV was higher than CR-I and CR-II rations, whereas, the digestibility of nitrogen-free extract and fiber fractions was similar among all the rations. Experimental diets were different ($P<0.01$) in digestible crude protein (DCP) content, in which the CR-I ration contained lower DCP value whereas CR-IV ration contained higher DCP value. The total digestible nutrients (TDN) and metabolizable energy (ME) values were comparable among all the experimental rations. The daily DCP intake (in grams/day) was lower ($P<0.05$) in lambs fed with CR-I ration compared to CR-III and CR-IV rations and it was comparable with CR-II ration. The TDN intake (in grams/day), digestible energy, and ME intakes (in megajoules/day) were similar among the lambs fed experimental rations with different SSB to concentrate ratios. The average daily DCP intake of lambs fed with CR-II, CR-III, and CR-IV rations met the requirements whereas, the daily TDN and ME intake was met by all the lambs. The lambs on all the diets were in positive nitrogen retention. The nitrogen balance expressed as grams/day was higher ($P<0.05$) in lambs fed with CR-III and CR-IV ration than those fed with CR-I ration. The daily calcium and phosphorus intake and balance were comparable on all the experimental rations. The total purine derivatives (in millimoles/day) were higher ($P<0.05$) in CR-III than CR-I and comparable with CR-II and CR-IV diets. The higher ($P<0.01$) microbial N supply (in grams/day) was observed in CR-III ration compared to other three rations and the efficiency of microbial synthesis was comparable among all the rations. It is concluded that

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sweet sorghum bagasse can be included in the complete rations at maximum level of 50 % as roughage source for rearing of ram lambs.

Keywords Sweet sorghum bagasse · Roughage/concentrate ratio · Complete diet · Nutrient utilization · Efficiency of microbial synthesis · Sheep

Introduction

Sweet sorghum (*Sorghum bicolor* (L) Moench) is well adapted to the "semi-arid" tropics and is one of the most efficient dry land crops to convert atmospheric CO_2 into sugar. The crop is therefore gaining rapid importance as an alternative feedstock for bioethanol production. It is grown in areas with an annual rainfall range of 400–750 mm worldwide on about 44 million hectares (m ha) in almost 100 different countries. It is therefore the fifth most important cereal crop in the world. The major producers are the USA, India, Nigeria, China, Mexico, Sudan, and Argentina. Sudan (8.95 mha) is the largest sorghum grower in the world followed by India (8.45 mha) and Nigeria (7.81 m ha). India is the third largest producer after USA and Nigeria with 7.15 million tons (FAO 2007). Sweet sorghum is a multipurpose crop that is cropped also for grain production for human consumption and fodder for livestock feeding. While the demand for sweet sorghum for ethanol production increases, it diverts biomass away from livestock, thus adding to the feed scarcity problem. A crop yielding 40 ton fresh stalk/ha and 60 % extractability would yield about 12–15 ton/ha stalk residue. The residue left after extracting the juice from stalks can compensate the fodder loss.

The nutritive value of by-products and the waste materials is low and when fed as such cannot maintain the livestock. Therefore, incorporation of concentrate in animal diets is needed to overcome nutrients requirements such as protein, mineral, and vitamins and optimize the efficiency of feed utilization for growth, gestation, or milk production (Reddy et al. 2005). Moreover, concentrate diets are generally provided because dry matter intake (DMI) and volatile fatty acids (VFA) are higher than with diets based only on roughage (Suarez et al. 2007). To maximize the production, roughage and concentrate should be mixed to reduce the feed cost, labor cost, and wastage.

Processed fibrous crop residue could be successfully used as the sole source of roughage in complete feed for optimum growth and milk production (Reddy et al. 2003). Moreover, the level of roughage and concentrate in the complete feed is apparently of major importance for efficient utilization of dietary nutrients for production. Characteristics and level of roughage in ruminant rations are crucial for maintaining desirable VFA patterns in the rumen and could influence animal performance. Microbial protein has a good balance of essential amino acids, and its synthesis in the rumen should be optimized (Brito et al. 2006). Optimization of microbial protein synthesis should increase the efficiency of nitrogen (N) utilization and reduce N urinary excretion, which constitutes a major source of N pollution from livestock farms.

The present study was planned to utilize the sweet sorghum bagasse as sole roughage source in the complete diets for growing lambs. The nutrient utilization and microbial N supply of complete diets with different proportions of sweet sorghum bagasse (SSB) were studied to determine the optimum roughage to concentrate ratio for meat production in the country.

Material and methods

Cropping conditions of sweet sorghum

Sweet sorghum is a warm-season crop that matures earlier under high temperatures and short days. It tolerates drought temperature stress better than many crops, but it does not grow well, under low temperatures. It can be grown on soils ranging from heavy clay to light sand. Rainfall of 500–600 mm distributed ideally across growing period is the best, unless the soil can hold much water. Seed rate is 7–8 kg seeds/ha with a recommended density about 7,000 plants/ha. Most of the sweet sorghum varieties mature between 115–125 days during rainy season. Sweet sorghum yields 25–75 ton/ha green matter, according to soil fertility and rainfall.

Site of study

The experiment was carried out at the College of Veterinary Science of S V Veterinary University, Rajendranagar, Hyderabad (17° 12′ N, 78° 18′ E, 545 m above sea level) in India. The ambient temperature and relative humidity values during the period of study were in the ranges of 28–42 °C and 28–32 %, respectively.

Animals and diets

Twenty-four growing Nellore × Deccani ram lambs aged about 3 months were randomly distributed into four groups of six animals each in a completely randomized block design for conducting a 180-day growth trial. All animals were kept in well-ventilated pens (4×3 m). In the pens, hygienic conditions were maintained by draining appropriately to allow the water to run off and they were regularly cleaned. The spoiled or discarded feed was regularly removed. Four lambs (initial body weight 21.28±0.68 kg) from each treatment were kept in metabolic cages at the end of the growth trial. Experimental rations containing SSB and concentrate ingredients were processed into mash with SSB to concentrate ratio of 60:40 (CR-I), 50:50 (CR-II), 40:60 (CR-III), and 30:70 (CR-IV) and offered in the form of complete feed to the lambs during the experimental period. The ingredient composition of experimental rations is presented in Table 1.

Metabolism study

A metabolism study was conducted at the end of the growth trial using Nellore × Deccani ram lambs to assess the nutrient utilization and energy, N, calcium (Ca), and phosphorus (P) balance of experimental complete rations with different SSB/concentrate ratios. Animals were kept in hygienic, well-ventilated individual metabolism cages where feces and urine were separately collected. Animals had free access to water throughout the experiment. Prior to collection period, experimental lambs were acclimatized to metabolic cages for 5 days.

During the 7-day collection period, the amounts of feed distributed and individual refusals, feces, and urine were weighed daily. During the period of metabolism trial, 24-h collection of feces was made using fecal bags harnessed to the ram lambs. Urine was collected in glass bottles kept at the bottom of the metabolic cages, which were added with 50 ml of 5 % sulfuric acid daily to avoid nitrogen loss. Representative samples of each feed offered, refusals, and feces were collected for 7 days and composited. After estimation of dry matter (DM), the samples of all the experimental feeds, refusals, and feces were ground separately in a laboratory Wiley mill through 1-mm screen and preserved in air tight bottles for subsequent analysis. For balance studies, 5 % total urine voided daily by each animal, after thorough mixing, was composited and preserved in glass bottles and kept in refrigerator till analyzed for nitrogen content.

Table 1 Ingredient composition (in grams/kilogram) of experimental rations

Ingredient	Ration			
	CR-I	CR-II	CR-III	CR-IV
Sweet sorghum bagasse	600.0	500.0	400.0	300.0
Maize	124.0	155.0	186.0	217.0
Groundnut cake	66.0	82.5	99.0	115.5
Sunflower cake	80.0	100.0	120.0	140.0
Deoiled rice bran	92.0	115.0	138.0	161.0
Molasses	20.0	25.0	30.0	35.0
Urea	6.0	7.5	9.0	10.5
Mineral mixture	8.0	10.0	12.0	14.0
Salt	4.0	5.0	6.0	7.0
Vitamin A, D_3	0.1	0.1	0.1	0.1

CR-I SSB 60/concentrate 40, *CR-II* SSB 50/concentrate 50, *CR-III* SSB 40/concentrate 60, *CR-IV* SSB 30/concentrate 70

Microbial N flow

The daily intestinal flow of microbial N (in grams/day) from total urinary purine derivatives (PD) (in millimoles/day) was calculated (IAEA-TECDOC-945 1997) using the PD work software of IAEA (2001). The preserved diluted urine samples were thawed and ultrasonicated for 20 min to break the urinary precipitates, if any, and further diluted for estimation of PD of allantoin ten times, xanthine and hypoxanthine for five times before analysis. The equation used to relate absorption of microbial purines (X, in millimoles/liter) and excretion of PD in urine (in millimoles/liter) was $Y=0.84+(0.150\mathrm{W}^{0.75}\ e^{-0.25X})$. The calculation of X from Y was performed by Newton–Raphton iteration process.

Chemical analysis

Feed, feces, and urine samples were analyzed for N using "Terbotherm" and "Vapodest" (Gerhard, Germany) analyzers based on the micro-Kjeldhal method (AOAC 1997). DM, ether extract (EE), and total ash were determined according to procedures described by AOAC (1997). Cell wall constituents in feeds, feces, and residues were performed as per the method described by Van Soest et al. (1991). Ca was estimated as per the method described by Talapatra et al. (1940). P was determined colorimetrically as per the method of Ward and Johnston (1962). The metabolizable energy (ME) of the diets was estimated from gross energy (GE). The GE or heat of combustion of feed, feed refusals, feces, and urine was estimated as per the procedure described in the manual of Gallenkamp Automatic Ballistic Bomb Calorimeter. Methane production was calculated by using the equation suggested by Blaxter and Clapperton (1965) basing on digestibility coefficient of energy (D).

$$\mathrm{CH_4(inkilocalories/100kilocaloriesGE)} = 3.67 + 0.062D$$

Statistical analysis

Statistical analysis of the data was carried out according to the procedures suggested by Snedecor and Cochran (1994). Least-square analysis of variance was used to test the significance of various treatments, and the difference between treatments means was tested for significance by Duncan's new multiple range and F test (Duncan 1955).

Results and discussion

Chemical composition of the diets

There was an increase in the crude protein (CP) content of the rations as the concentrate proportion increased from 40 to 70 %, respectively (Table 2). An increase in the proportion of SSB from 30 to 60 % in complete ration increased neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents and decreased EE, nitrogen-free extract (NFE), Ca, and P contents. The GE content of the diet varied from 18.07 to 18.98 MJ/kg DM, the lowest and highest values being in diets containing 60 % SSB and 30 % SSB, respectively, due to higher proportion of concentrate. The findings of the present study were in agreement with Bakshi et al. (2004) with either high roughage or low roughage containing 30:70 or 70:30 concentrate to roughage ratio of wheat straw. The NDF content was decreased proportionally as the forage to concentrate ratio decreased in the diets (Lechartier and Peyraud 2010; Sterk et al. 2011). Dhuria et al. (2008) also reported similar results with bajra straw.

Voluntary feed intake

The variation in the roughage to concentrate ratio in complete diets could not influence the DMI (in grams/weight$^{0.75}$) of ram lambs (Table 3). In the present study, no significant difference was observed among the rations in DMI of lambs, whereas the DMI of lambs fed with CR-IV ration was 6.65 % lower than the CR-I ration. This might be due to high-energy content of the diet. Feed intake by lambs fed the high-concentrate diet is controlled by energy demands of the animals (Dinius and Baumgardt 1969). The result obtained in the present study was in agreement with the findings of Dhuria et al. (2007a) in sheep fed with bajra straw-based complete feeds with roughage to concentrate ratio of 40:60 to 60:40. Generally in ruminants, DMI increases within limits as concentrate to roughage ratio increases (Santra and Pathak 1999; Haddad 2005). DMI response was not affected when forage to concentrate ratio decreased to 20:80 (Lechartier and Peyraud 2010).

Table 2 Chemical composition (percent DM unless indicated) of rations with different ratios of SSB and concentrate

Nutrient	Ration			
	CR-I	CR-II	CR-III	CR-IV
Dry matter (%)	92.5±0.48	92.2±0.42	92.0±0.58	92.0±0.53
Organic matter	90.2±0.53	90.2±0.61	90.2±0.33	90.1±0.47
Crude protein	10.2±0.50	11.7±0.38	13.1±0.37	14.4±0.46
Ether extract	1.9±0.26	2.0±0.32	2.0±0.36	2.1±0.30
Nitrogen free extract	48.9±1.00	49.5±0.75	50.2±0.55	50.8±0.76
Neutral detergent fiber	56.9±0.61	52.6±0.60	48.1±0.81	43.1±0.92
Acid detergent fiber	32.5±0.56	30.2±0.69	27.1±0.52	24.4±0.42
Acid detergent lignin	3.7±0.29	3.9±0.32	3.2±0.23	3.1±0.15
Calcium	1.05±0.05	1.12±0.04	1.18±0.05	1.19±0.04
Phosphorus	0.53±0.04	0.56±0.03	0.61±0.03	0.65±0.03
Gross energy (MJ/kg)	18.1±0.29	18.5±0.26	18.7±0.20	19.0±0.29

On DM basis except for DM

CR-I SSB 60/concentrate 40, *CR-II* SSB 50/concentrate 50, *CR-III* SSB 40/concentrate 60, *CR-IV* SSB 30/concentrate 70

Table 3 Effect of feeding complete rations with different SSB to concentrate ratios on dry matter intake, nutrient digestibility, and nutritive value in growing Nellore × Deccani ram lambs

Parameter	Ration				
	CR-I	CR-II	CR-III	CR-IV	SEM
Body wt. (kg)	22.15	21.10	22.40	20.93	0.74
DMI (g/kg w$^{0.75}$)	87.89	87.64	87.62	81.07	1.67
Diet digestibility (%)					
OM	59.3	63.4	66.4	63.7	1.00
CP*	59.0c	62.9bc	67.2ab	71.1a	1.36
EE**	74.8b	78.2ab	81.1a	82.9a	1.10
NFE	60.6	64.7	68.0	64.3	1.27
NDF	56.0	60.5	63.1	59.3	1.12
ADF	53.7	54.1	56.7	52.4	0.98
Nutritive value					
DCP (g/kg DM)*	60.26d	73.3c	88.21b	102.11a	4.15
TDN(g/kg DM)	552.79	591.4	619.31	594.68	9.26
DE (MJ/kg DM)*	11.04c	11.67b	12.39a	12.40a	0.17
ME (MJ/kg DM)	9.12	9.55	10.17	10.14	0.20

Mean values in the same row that have different letters are significantly different from each other

SEM standard error of the mean, *DM* dry matter, *DMI* dry matter intake, *OM* organic matter, *CP* crude protein, *EE* ether extract, *NFE* nitrogen free extract, *NDF* neutral detergent fiber, *ADF* acid detergent fiber, *DCP* digestible organic matter, *TDN* total digestible nutrients, *DE* digestible energy, *ME* metabolizable energy, *CR-I* SSB 60/concentrate 40, *CR-II* SSB 50/concentrate 50, *CR-III* SSB 40/concentrate 60, *CR-IV* SSB 30/concentrate 70

*$P<0.01$; **$P<0.05$

Nutrient digestibility

None of the diets with different SSB to concentrate ratio exhibited any significant difference in the digestibility of organic matter and NFE in ram lambs (Table 3). As the concentrate proportion increased in the rations, a progressive increase was observed in the CP digestibility. The CP digestibility of ration CR-IV was higher ($P<0.01$) than CR-I and CR-II rations, whereas there was numerical increase observed from CR-III to CR-IV ration. The lambs fed with

CR-I digested CP similar to lambs fed with CR-II ration, and CR-III was similar to that of CR-II ration. The ether extract digestibility was lower ($P<0.05$) in lambs fed with CR-I ration than those fed with CR-III and CR-IV rations, but it was similar to the digestibility of CR-II ration. The results of CP and EE digestibility of the present study were in agreement with the findings of Haddad (2005) in baladi kids who reported that CP digestibilities increased ($P<0.05$) with increasing of the concentrate proportion in the diets. The high-concentrate diets had greater CP digestibilities compared with high-forage diets in sheep (Ramos et al. 2009; Lechartier and Peyraud 2010). Shahjalal et al. (2000) noticed that goats receiving high-protein diets had significantly higher CP digestibility compared to those receiving low-protein diets. Similar observations were reported by Bhatta et al. (2007), Santra and Karim (2002, 2009) in lambs and kids. The different ratios of SSB and concentrate in complete rations could not affect the digestibility of fiber fractions in growing ram lambs (Table 3). The addition of high levels of concentrate did not decrease either NDF or ADF apparent digestibility ($P>0.05$), perhaps because ruminal pH was not low enough to negatively affect fiber digestion. Similar findings were reported in earlier studies (Heinrichs et al. 2008; Cantalapiedra et al. 2009; Ramos et al. 2009).

Nutritive value and plane of nutrition

The digestible crude protein (DCP) value was different ($P<0.01$) in the diets in which the CR-I ration contained lower DCP value whereas CR-IV ration contained higher DCP value (Table 3). The DCP content of the diets increased ($P<0.01$) with increased proportion of concentrate in the diet. Chandramoni et al. (1999) reported higher DCP in high-concentrate-fed animals. The total digestible nutrients (TDN) values were comparable among the experimental rations. Energy balance study revealed that the CR-I ration contained lower ($P<0.01$) digestible energy (DE) than CR-II, CR-III, and CR-IV rations whereas the ME content of the rations was comparable among the diets (Table 3). The increased DE and ME values of the CR-II, CR-III, and CR-IV rations compared to CR-I might be due to increase in the proportion of concentrate in the complete rations. These results were in agreement with the reports of Mcleod and Baldwin (2000) and Haddad (2005), who reported higher ME in the high-concentrate diets than low-concentrate diets.

The daily DCP intake was lower (in grams/day, $P<0.05$; in grams/kilograms weight$^{0.75}$, $P<0.01$) in lambs fed with CR-I ration compared with CR-III and CR-IV rations, and it was comparable with CR-II ration. The DCP intake increased with increasing level of concentrate (Gaafar et al. 2009). The daily intakes of TDN either per animal or per unit metabolic body size did not differ among the lambs on various diets. The lambs consumed more DM in all the groups than requirements stipulated by ICAR (1998). The lambs fed with CR-II, CR-III, and CR-IV rations met the average daily DCP intake requirements at 20 kg body weight growing at 100 g/day. All the lambs met the daily TDN intake at 20 kg body weight growing at 100 g/day.

Energy balance

The average daily gross energy intake was similar among the ram lambs fed with different experimental rations. The GE digestibility was lower ($P<0.05$) in CR-I ration and it was comparable among CR-II, CR-III, and CR-IV rations (Table 4). The increased GE digestibility with high levels of concentrate (70 %) was reported in goats by Cantalapiedra et al. (2009) with grass and alfalfa hay. Energy losses in feces (Table 4) were linearly less ($P>0.05$) for high- than

Table 4 Effect of feeding complete rations with different SSB to concentrate ratios on energy balance in growing Nellore × Deccani ram lambs

Parameter	Ration				
	CR-I	CR-II	CR-III	CR-IV	SEM
Gross energy intake (MJ/day)	16.25	15.98	16.87	15.10	0.61
Fecal energy (MJ/day)	6.29	5.91	5.68	5.19	0.23
Digestible energy intake (MJ/day)	9.96	10.06	11.19	9.91	0.43
Gross energy digestibility (%)	61.09b	63.06ab	66.34a	65.35a	0.71
Urinary energy (MJ/day)	0.51	0.64	0.73	0.56	0.09
Methane loss (MJ/day)	1.21	1.21	1.31	1.17	0.05
Methane loss as % of GE	7.46b	7.58ab	7.78a	7.72a	0.04
Metabolizable energy intake (MJ/day)	8.24	8.22	9.14	8.18	0.37

Mean values in the same row that have different letters are significantly different from each other, ($P<0.05$). CH_4 (in kilocalories/100 kcal GE) was calculated using the formula $3.67+0.062D$ (Blaxter and Clapperton 1965)

SEM standard error of the mean, *GE* gross energy, *CR-I* SSB 60/concentrate 40, *CR-II* SSB 50/concentrate 50, *CR-III* SSB 40/concentrate 60, *CR-IV* SSB 30/concentrate 70

Table 5 Effect of feeding complete ration with different SSB and concentrate ratios on nitrogen, calcium and phosphorus balance in growing Nellore × Deccani ram lambs

Parameter	Ration				
	CR-I	CR-II	CR-III	CR-IV	SEM
N intake (g/day)	14.69	16.10	18.97	18.29	0.76
Fecal N (g/day)	5.96	5.97	6.26	5.23	0.23
Urinary N (g/day)	2.98	3.49	4.11	4.08	0.32
N balance (g/day)	5.74b	6.65ab	8.60a	8.98a	0.48
Ca intake (g/day)	9.44	9.67	10.66	9.47	0.38
Fecal Ca (g/day)	4.66	4.45	5.09	4.01	0.18
Urinary Ca (g/day)	1.06	1.41	1.03	1.60	0.14
Ca balance (g/day)	3.72	3.80	4.54	3.86	0.26
P intake (g/day)	4.76	4.83	5.51	5.17	0.20
Fecal P (g/day)	2.19	1.81	2.50	2.03	0.12
Urinary P (g/day)	0.97	1.42	0.99	1.12	0.11
P balance (g/day)	1.60	1.60	2.03	2.03	0.15

Mean values in the same row that have different letters are significantly different from each other, ($P<0.05$)

SEM standard error of the mean, *CR-I* SSB 60/concentrate 40, *CR-II* SSB 50/concentrate 50, *CR-III* SSB 40/concentrate 60, *CR-IV* SSB 30/concentrate 70

low-concentrate diets, as reported by Molina et al. (2000) in goats. The methane loss as percent of GE was lower ($P<0.05$) on ration CR-I, which reflected the lower digestibility coefficient of GE. The daily intakes of DE and ME (in megajoules/day) did not differ among the lambs on various diets (Table 4). But the intakes of DE and ME by lambs fed with CR-II and CR-III were numerically higher than those fed with CR-I ration which might be due to increased rate of fermentation of structural carbohydrates, which was reflected in increased digestibility of fiber fractions. The ME intakes when expressed as percentage of GE and DE intakes were also comparable among the rations with different SSB to concentrate ratios. ME intake requirements (ICAR 1998) were met by all the lambs at 20 and 25 kg body weight growing at 100 g/day.

Nitrogen, calcium, and phosphorus balance

The lambs on all the diets were in positive N balance. The daily N intake and fecal and urinary losses were comparable in lambs fed on experimental rations CR-I, CR-II, CR-III, and CR-IV, respectively (Table 5). The N balance expressed as grams/day was higher ($P<0.05$) in lambs fed with CR-III and CR-IV rations than those fed with CR-I ration. The lambs were on positive Ca and P balance. The results of the present investigation were in agreement with the findings of Chandramoni et al. (1999). Increase in the proportion of concentrate in the diet increased significantly N digestibility in sheep. Digestibility of N depends on the availability of fermentable energy in the rumen. On high-concentrate diet, more fermentable energy is available, which helps rumen microbes to capture N leading to its increased digestibility. Santra and Karim (2002) reported

Table 6 Effect of feeding complete ration with different SSB and concentrate ratios on daily urinary purine derivatives excretion and microbial N flow in Nellore × Deccani ram lambs

Parameter	Ration				
	CR-I	CR-II	CR-III	CR-IV	SEM
DOMI (g/day)	483.8	490.6	540.6	458.1	21.78
PD excreted in urine (mmol/day)					
Allantoin*	8.41b	9.54b	10.88a	9.39b	0.29
Uric acid	1.71	1.79	1.92	1.90	0.08
Xanthine and hypoxanthine**	0.25b	0.29ab	0.36a	0.37a	0.02
Total PD excreted in urine					
mmol/day**	10.37b	11.62ab	13.15a	11.65ab	0.36
μmol/kg $w^{0.75}$	1042.38	1183.5	1288.04	1189.79	39.31
PD absorbed (mmol/day)**	12.20b	13.78ab	15.62a	13.82ab	0.44
Microbial N supply (g/day)*	8.87b	10.02b	12.16a	10.05b	0.39
Microbial N supply (g/kg DOM)	19.51	20.53	21.28	22.34	0.95
Microbial CP (g) per MJ of ME	6.76	7.60	6.92	7.86	0.26

Mean values in the same row that have different letters are significantly different from each other

SEM standard error of the mean, *DOMI* digestible organic matter intake, *PD* purine derivatives, *CP* crude protein, *DOM* digestible organic matter, *ME* metabolizable energy, *CR-I* SSB 60/concentrate 40, *CR-II* SSB 50/concentrate 50, *CR-III* SSB 40/concentrate 60, *CR-IV* SSB 30/concentrate 70

*$P<0.01$; **$P<0.05$

an increase in total N retention with increase in concentrate proportion in the diet from 0 to 85 % in steers and lambs, respectively. Fecal and urinary N excretion and N retention were not affected in sheep fed diets differing in forage to concentrate ratio (Zanton and Heinrichs 2009; Ramos et al. 2009). The daily Ca and P intake and balance were comparable on all the experimental rations (Table 5). The results were in agreement with the findings of Dhuria et al. (2007a) in sheep fed with bajra straw-based complete feeds with roughage to concentrate ratio of 40:60 to 60:40 and with mustard straw-based complete diets (Dhuria et al. 2007b).

Microbial N flow

The total PD (in millimoles/day) were higher ($P<0.05$) in lambs fed with CR-III diet than those fed with CR-I diet and it was comparable with CR-II and CR-IV diets (Table 6). Cantalapiedra et al. (2009) reported greater urinary PD excretion with high- than low-concentrate diets. The allantoin excretion was higher ($P<0.01$) in CR-III diet-fed lambs, whereas uric acid excretion was comparable among all the diets, but xanthine plus hypoxanthine excretion was lower ($P<0.05$) in lambs fed with CR-I ration compared to CR-III and CR-IV rations. The total PD excreted (in micromoles) per kilograms weight$^{0.75}$ was comparable among all the rations. PD absorbed was higher ($P<0.05$) in CR-III-fed lambs compared to those fed with CR-I ration, whereas it was comparable with CR-II and CR-IV rations. As the daily excretion of PD is largely determined by the absorption of microbial purines, the relationship between total PD excretion and microbial purine absorption is linear. The PD excretion seemed to depend not only on digestible organic matter intake (DOMI) ($P>0.05$) (Table 6) but also on N intake ($P>0.05$) (Table 5).

The higher ($P<0.01$) microbial N supply (in grams/day) was observed in CR-III ration with increasing DOMI ($P>0.05$) and N intake ($P>0.05$) compared to other three rations. The decreased microbial N production found in low-concentrate diets compared with high-concentrate diets could be partially explained by the decreased intakes of energy and N, and the yield of microbial biomass is related to the amount of available energy and N (Flachowsky et al. 2006; Ramos et al. 2009). Similar finding was reported by Seresinhe and Pathirana (2008); the higher DOMI boosted the microbial N supply in bull calves on straw-based diets. However, the efficiency of microbial synthesis was comparable among all the rations. There was numerically increase observed in the microbial efficiency (in grams/kilogram of digestible organic matter) in the diets as the proportion of the concentrate increased from 40 to 70 %. High concentrate in diet did not modify ($P>0.05$) microbial synthesis efficiency likely because greater protozoa numbers result in more bacterial predation (Harrison et al. 1979; Nienaber 2008). Most of the values obtained were below the mean value (32 gN/kg of rumen digestible organic matter) established by the ARC (1984) for sheep fed with different diets since the diets were crop residue-based diets. The microbial CP (in grams) per megajoules of ME fermented in the rumen of the experimental diets was lower than the values recommended by AFRC (1993) for growth in sheep (Table 6).

Conclusions

This study showed that lambs fed with complete diets containing increasing levels of SSB exhibited similar voluntary feed intake, nutrient utilization, nutrient intake, microbial efficiency and N, energy, and Ca and P balances. However, lambs receiving the highest level of SSB (60 %) would be exposed to a protein shortage. Therefore, it is recommended to include no more than 50 % of SSB in diets for growing lambs and to provide a protein source to ensure optimal microbial activity.

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