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Nutrient intake and utilization in sheep fed opuntia [*Opuntia ficus-indica (L.) Mill.*] in combination with conventional green and dry fodders

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Abstract

The nutritive value of opuntia [(*Opuntia ficus-indica* (L.) Mill.] in combination with conventional fodders was assessed on 32 adult sheep, divided into 4 equal groups. The experimental diets consisted of chopped (5-8 cm) green opuntia cladodes (150 g on dry matter basis per head daily) in combination with chopped green napier (*Pennisetum purpureum*) grass (T_1), berseem (*Trifolium alexandrinum*) hay (T_2), lathyrus (*Lathyrus sativus*) straw (T_3) and gram (*Cicer arietinum*) straw (T_4) ad libitum. All experimental animals were supplemented with 200 g concentrate mixture per head daily. Total DM intake ranged from 3.39 to 4.35 per cent of live weight and it was higher (P<0.01) in experimental groups where berseem hay and lathyrus straw were used as basal feed (T_2 and T_3). The total tract apparent digestibility of DM, OM and CP were lower (P<0.01) in sheep fed opuntia with gram straw (T_4) diet compared to other diets (T_1, T_2 and T_3). Similarly digestibility of fibre fractions (NDF, ADF and cellulose) was also lower (P<0.01) on T_4 diet. Intake of digestible DM, OM and TDN were significantly lower in T_4 diet, where opuntia was supplemented with gram straw as basal feed, however, it did not differ (P<0.01) with T_1 diet. The DCP intake was lower (P<0.01) in T_4 (3.12 g/kgW$^{0.75}$) when compared to the standard requirements of 5.00 g/kgW$^{0.75}$ in sheep for maintenance. But intake of TDN was over and above (48.74 to 62.10 g/kgW$^{0.75}$) the prescribed requirements of 36.00 g/kgW$^{0.75}$ in sheep for maintenance when considered for all the groups. Animals of all the experimental groups were in positive nitrogen balance. However, N intake, balance, absorb and retention were lower (P<0.01) in T_4 diet compared to other diets, but the N excretion through faeces and urine was similar in T_1 and T_4; and T_2 and T_3. No significant (P<0.01) changes in live weight were observed and animals maintained the live weight throughout the experimental period. It was evident from the results that opuntia was highly palatable and in combination with conventional fodder sources could maintain adult sheep during summer in semi-arid conditions.

Keywords: Cactus, Nutrient utilization, Nutritive value, Opuntia, Sheep

Introduction

Semi-arid and arid regions of Southeast Asian countries are prone to drought. During drought, both losses in productivity and animal life occur, mainly due to shortage of feed resources. Opuntia has been used as a drought feed (forage) for cattle feeding since early 19th century (Griffiths, 1906; Woodward *et al*., 1915), and in most instances it is still being used as an emergency feed resource during drought. Studies have indicated that the digestibility of opuntia cladodes is comparable to high quality hay (Shoop *et al*., 1977). The opuntia plant is extremely variable in nutritive value depending upon species, variety, age, sampling season and plant parts. However, in general opuntia is high in moisture content and in vitro dry matter digestibility (Misra *et al*., 2017) and can be used as a source of sustenance in drought feeding (Sirohi *et al*., 1997; Misra *et al*., 2006, Mathur *et al*., 2017). During summer, the harsh agro-climatic condition in semiarid/arid regions of the country results in progressive denudation of surface vegetation leading to low energy availability and loss of production. However, the opuntia plant remains green even during summer and can serve as a valuable feed resource. In view of possible importance of opuntia as scarcity feed in hot semi-arid and arid environments, an experiment was undertaken to assess nutrient intake and utilization in sheep fed opuntia in combination with conventional green and dry fodders.

Materials and Methods

***Study site*:** The study was carried out at ICAR-Indian Grassland and Fodder Research Institute, Jhansi, located at 25° 4'N latitude, 78° 6'E longitude and 285 m above sea level. The climate is typically semi-arid with yearly mean minimum and maximum temperatures of 18°C and 32.6°C, respectively. The minimum and maximum ambient temperature and relative humidity of the animal shed during experimental period were 25.5°C, 42.2°C and 35.5%, respectively.

Animals and feeding: Thirty two local adult female sheep (31.00±0.85 kg body weight; 2 to 3 years in age), divided into 4 equal groups based on comparable age and body weights, were fed on 4 experimental diets. The diet consisted of chopped (5-8 cm) green cladodes of spineless opuntia (150 g on dry matter basis per head daily) in combination with chopped green napier (*Pennisetum purpureum*) grass (T_1), berseem (*Trifolium alexandrinum*) hay (T_2), lathyrus (*Lathyrus sativus*) straw (T_3) and gram (*Cicer arietinum*) straw (T_4) *ad libitum*. All the experimental animals were supplemented with 200 g concentrate mixture (58 parts groundnut cake, 40 parts maize grain, 1 part mineral mixture and 1 part common salt) per head daily, to provide adequate protein and other nutrients (ICAR, 2013). Animals were housed in stalls and fodders (hay, straw, napier grass and opuntia) and supplements were fed separately. Animals were permitted 10% fodder refusals. Animals were fed daily at 10.00 h, after discarding the orts of previous day. Water was made available freely twice a day at 9:30h and 13.30 h. Feeding experiment was continued for 21 days.

Metabolic trial: After the feeding experiment, a metabolic trial was conducted for seven days in metabolic cages with facility for quantitative collection of faeces and urine separately. Daily intake of feed and output of faeces and urine were recorded. Samples of feed offered, orts, faeces and urine voided were collected every morning. DM in feed and faeces samples was determined daily by drying at 70°C to a constant weight. The dried samples collected over seven days period were pooled, ground through 1 mm screen and preserved for chemical analysis. Samples of faeces and urine from individual animal were collected every morning for seven days in a 500 ml Kjehldahl flask containing 25 ml concentrated sulfuric acid for N determination.

Chemical analysis: Samples of opuntia, fodders and concentrate supplements, and faeces were analysed for DM, CP and ash as per the standard procedures of AOAC (1995). The neutral detergent fibre (NDF) was determined by the procedure of Van Soest et al. (1991) without sodium sulfite or α-amylase, whereas acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to the method described by Goering and Van Soest (1970).

Statistical analysis: Results obtained for intake, digestibility, plane of nutrition, N balance was subjected to analysis of variance procedure of SPSS Base 13 (SPSS software products, USA), using one way analysis of variance:

$Y_{ij} = \mu + D_i + e_{ij,}$ where: μ= general mean, Di = effect of i^{th} diet (1--4), e_{ij} = random error

The group differences were compared by Duncan's Multiple Range Test (Duncan, 1955).

Results and Discussion

***Chemical composition*:** Spineless cactus cladodes contained 7.56% dry matter (DM), 6.45% crude protein (CP) and 31.34% ash on DM basis (Table 1). Higher water and ash content in opuntia cladodes were also reported earlier in numerous studies (Ben Salem *et al*., 1996; Sirohi *et al*., 1997; Misra *et al*., 2006). However, the CP content of opuntia was within the range of normal variation according to the Rick and Felkar (1992).

Dry matter intake: Opuntia was readily eaten and animals did not allow any ort out of the opuntia quota offered to them. The DM contributed by opuntia in total diet ranged from 10.83 (T_2) to 14.86 (T_1) per cent against the target of 20 per cent DM in total diet or 150 gm DM per animal daily through opuntia, set under the consideration that total DM intake (DMI) would not exceed beyond 2.5 per cent of live weight, which is the normal requirement for maintenance of sheep (ICAR, 2013). However, the total DM intake in the present experiment exceeded this limit and ranged from 3.39 to 4.35 per cent of live weight, which would be considered higher than the normal range for maintenance (ICAR, 2013). This occurred due to more consumption of basal fodder i.e. napier grass, berseem hay, lathyrus straw and gram straw leading to higher DMI in the experimental groups. Among treatments, intake of total DM was (Table 2) higher (P<0.01) in experimental groups where berseem hay and lathyrus straw were used as basal feed (T_2 and T_3). It was observed that increasing the proportion of legume led to significant increase in intake and in N-balance (Mosi and Butterworth, 1985) and this could be the reason for higher (P<0.01) total DMI on berseem hay (T_2) and lathyrus straw (T_3) based basal diets in present experiment.

Table 1. Chemical composition (% DM basis) of feed ingredients

Attributes	Feed ingredients					
	Opuntia	Green napier grass	Berseem hay	Lathyrus straw	Gram straw	Concentrate mixture
Dry matter	7.56	25.04	95.81	94.97	95.57	94.97
Organic matter	68.67	86.68	86.00	92.66	89.47	91.99
Protein (N×6.25)	6.08	5.68	16.22	8.68	3.99	21.20
Neutral detergent fibre	25.60	71.72	44.36	63.78	64.78	54.40
Acid detergent fibre	17.43	43.16	36.11	48.40	47.65	16.07
Hemicellulose[1]	8.17	28.56	8.25	15.38	17.13	38.33
Cellulose	14.79	32.17	29.50	36.47	34.01	9.43
Acid detergent lignin	2.45	5.79	6.43	11.47	9.97	5.38

[1]NDF-ADF

Table 2. Dry matter intake, nutrient digestibility and nutritive value of diets containing opuntia + green napier grass + concentrate mixture (T_1), opuntia + berseem hay + concentrate mixture (T_2), opuntia + lathyrus straw + concentrate mixture (T_3) and opuntia + gram straw + concentrate mixture (T_4) in sheep

Particulars	Diets				P	
	T_1	T_2	T_3	T_4	SEm±	*P*
Body weight (kg)						
Beginning of experiment	30.52	31.48	29.48	32.53	1.62	0.51
After experiment	30.27	33.88	29.86	32.73	1.50	0.14
Dry matter intake (DMI, kg/day)						
Opuntia	0.15	0.15	0.15	0.15		
Green napier grass	0.68	-	-	-		
Berseem hay	-	1.06	-	-		
Lathyrus straw	-	-	0.96	-		
Gram straw	-	-	-	0.78		
Concentrate mixture	0.19	0.19	0.19	0.19	0.00	0.58
Opuntia in total diet (%)	14.86^{b}	10.83^{a}	11.70^{ab}	14.48^{b}	1.20	0.03
Total dry matter intake					0.07	<0.01
Total DMI (kg/day)	1.02^{a}	1.40^{bc}	1.30^{bc}	1.13^{a}		
DMI (kg/100 kg BW)	3.39^{a}	4.16^{b}	4.35^{b}	3.45^{a}	0.23	<0.01
DMI (g/kg $w^{0.75}$)	79.31^{a}	100.1^{b}	101.7^{b}	82.25^{a}	5.19	<0.01
Digestibility (%)					0.31	<0.01
Dry matter	61.50^{a}	62.00^{a}	60.10^{c}	55.95^{d}		
Organic matter	57.51^{a}	55.00^{b}	51.49^{c}	49.03^{d}	0.34	<0.01
Protein	64.10^{a}	75.30^{b}	68.15^{c}	51.98^{d}	0.67	<0.01
Neutral detergent fiber	61.21^{a}	59.83^{ab}	58.47^{b}	52.68^{c}	0.74	<0.01
Acid detergent fiber	57.16^{a}	56.91^{ab}	51.86^{b}	47.33^{c}	0.48	<0.01
Cellulose	65.12^{a}	64.07^{ab}	58.84^{b}	53.59^{c}	0.65	<0.01
Nutritive value					0.26	<0.01
Protein (%)	8.96^{a}	15.74^{b}	10.74^{c}	7.46^{d}		
Digestible protein (%)	5.74^{a}	11.84^{b}	7.32^{c}	3.88^{d}	0.15	<0.01
TDN[1] (%)	62.22^{a}	62.04^{a}	59.38^{b}	59.48^{b}	0.65	<0.01

[1]TDN=87.84 - (0.79*ADF%); Values with different superscripts in a row differ significantly

Apparent digestibility and nutritive value: The total tract apparent digestibility of DM, organic matter (OM) and CP were lower (*P*<0.01) in sheep fed opuntia with gram straw (T_4) diet (Table 2) compared to other diets (T_1, T_2 and T_3). Similarly, digestibility of fibre fractions (NDF, ADF and cellulose) also remained low (P<0.01) on T_4 diet. The low dietary CP content (7.46%, Table 3) coupled with poor protein digestibility (51.98%) on T_4 diet probably attributed to the depressed microbial activity due to lower ruminal NH_3-N resulted in poor fiber utilization (Preston and Leng, 1987; Ben Salem *et al*., 1996). In other experimental groups (T_1, T_2 and T_3), the dietary protein level remained

above 8%, which ensured adequate nitrogen supply. Nitrogen supply probably enhanced microbial activity in the rumen and encouraged micro-organism to degrade more feed resources (Leng, 1990).

Intake of digestible DM, OM and TDN were significantly lower in T_4 diet, where opuntia was supplemented with gram straw as basal feed (Table 3), however, it did not differ (P<0.01) with T_1 diet. The digestible crude protein (DCP) intake was also lower (P<0.01) in T_4 (3.12 g/ kgW$^{0.75}$) than the standard requirements of 5.00 g/kgW$^{0.75}$ in sheep for maintenance (ICAR, 2013). Intake of total digestible nutrients (TDN) was over and above (48.74 to 62.10 g/kgW$^{0.75}$) the prescribed requirements of 36.00 g/kgW$^{0.75}$ in sheep for maintenance (ICAR, 2013). Higher consumption of TDN widened the ratio with DCP intake particularly on T_4 diet. Consumption of TDN and DCP in the ratio of 8.5 to 10.0 was considered ideal for the sheep (ICAR 2013).

Nitrogen utilization: All the animals fed opuntia with different basal fodders were in positive nitrogen balance. However, N intake, balance, absorb and retention (% of intake and % of absorbed) were lower (P<0.01) in T_4 diet (Table 4) compared to other diets, but the N excretion through faeces and urine was similar in T_1 and T_4; and T_2 and T_3. In spite of similar N intake in T_1 and T_4, the poorer N retention (% of N intake and absorbed) in T_4 could be

Table 3. Plane of nutrition of sheep fed diets containing opuntia + green napier grass + concentrate mixture (T_1), opuntia + berseem hay + concentrate mixture (T_2), opuntia + lathyrus straw + concentrate mixture (T_3) and opuntia + gram straw + concentrate mixture (T_4) in sheep

Particulars	Diets				P	
	T_1	T_2	T_3	T_4	SEm±	*P*
Digestible dry matter intake						
g/d	626.45^{a}	868.73^{b}	779.51^{b}	630.87^{a}	43.31	<0.01
g/kg W$^{0.75}$	48.76^{a}	62.07^{b}	61.11^{b}	46.07^{a}	2.99	<0.01
Digestible organic matter intake						
g/d	412.58^{a}	523.01^{b}	419.60^{a}	325.59^{a}	34.25	<0.01
g/kg W$^{0.75}$	32.07^{a}	37.35^{a}	32.87^{a}	23.60^{b}	2.32	<0.01
Digestible protein intake (DPI)						
g/d	58.41^{a}	165.87^{b}	94.90^{c}	42.63^{d}	3.23	<0.01
g/kg W$^{0.75}$	4.55^{a}	11.84^{b}	7.44^{c}	3.12^{d}	0.23	<0.01
TDN intake						
g/d	633.09	869.14	770.37	666.73	42.05	<0.01
g/ kg W$^{0.75}$	49.25^{a}	62.10^{c}	60.41^{bc}	48.74^{ab}	2.89	<0.01
TDN/DP ratio						
TDNI/DPI	10.85^{a}	5.24^{b}	8.12^{c}	15.50^{d}	0.42	<0.01

Values with different superscripts in a row differ significantly

Table 4. Nitrogen balance in sheep fed diets containing opuntia + green napier grass + concentrate mixture (T_1), opuntia + berseem hay + concentrate mixture (T_2), opuntia + lathyrus straw + concentrate mixture (T_3) and opuntia + gram straw + concentrate mixture (T_4) in sheep

Particulars	Diets				P	
	T_1	T_2	T_3	T_4	SEm±	*P*
Nitrogen (g/d)						
Intake	14.58^{a}	35.27^{b}	22.28^{c}	13.11^{a}	0.81	<0.01
Voided in faeces	5.23^{a}	8.73^{b}	7.10^{c}	6.29^{c}	0.37	<0.01
Voided in urine	2.48^{a}	2.55^{b}	3.88^{b}	2.54^{a}	0.69	<0.01
Total N voided	7.71	11.28	10.98	8.83	-	<0.01
N- balance	6.86^{a}	23.99^{b}	11.30^{c}	4.28^{d}	0.74	<0.01
N- absorbed	9.35^{a}	26.54^{b}	15.18^{c}	6.82^{d}	0.52	<0.01
N retention						
(% of intake)	47.33^{a}	67.99^{b}	50.75^{a}	32.31^{c}	2.50	<0.01
(% of absorbed)	73.88^{a}	90.22^{b}	74.57^{a}	62.15^{c}	3.99	<0.01

Values with different letter in a row differ significantly

due to wider TDN/DCP ratio (10.85 and 15.50 in T_1 and T_2, Table 3), which might have resulted in lesser N incorporation in body synthesis. Consumption of TDN and DCP in the ratio of 8.5 to 10.0 were considered ideal for the sheep (ICAR, 2013) and to achieve this ratio the dietary protein level should essentially be greater than 8 per cent at maintenance level for the sheep. In present experiment, exceptionally greater N balance on the diets having berseem hay as basal fodder (T_2) with opuntia was observed. The experimental results were in conformity with the findings of Mosi and Butterworth (1985) that increasing the proportion of trifolium led to significant increase in intake as well as N-balance.

No significant changes in live weights were observed and animals maintained the live weight throughout the experimental period. Problem of laxative effects on opuntia feeding was not observed in present experiment and the faecal DM content remained in between 36.98 to 59.51 percent on different experimental diets. Laxative effects appeared when the volume of cactus in the diet was high (>50 to 60 % of total DM intake). Indeed, this problem was easy to solve as feeding of small amount of straw or hay prior to cactus feeding was sufficient to have normal transit (Nefzaoui and Ben Salem, 2002).

Conclusion

It was evident from the study that opuntia was highly palatable and in combination with conventional fodder resources, it can maintain adult sheep even during summer in semi-arid conditions. Moreover, opuntia might improve the nutritive value of poor quality roughage due to its high content of soluble carbohydrates.

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