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

A. K. Misra[1*], Sunil Kumar[1], T. Kiran Kumar[1], S. Ahmed[1], D. R. Palsaniya[1], P. K. Ghosh[1], M. Louhaichi[3], A. Sarker[2], S. Hassan[3] and S. Ates[3#]

[1]ICAR-Indian Grassland and Fodder Research Institute, Gwalior Road, Jhansi - 284 003, Uttar Pradesh, India
[2] International Center for Agricultural Research in the Dry Areas (ICARDA) South Asia and China Regional Program, New Delhi, India
[3]International Center for Agricultural Research in the Dry Areas (ICARDA), Amman 1195, Jordan
Present Address: Assist Prof. Forage/livestock, Oregon State University, Corvallis, Oregon, USA

Email: *asimkmisra@gmail.com (Corresponding author)

Abstract

The nutritive value of opuntia [(*Opuntia ficus-indica (L.) Mill.*] in conjunction with conventional fodders was assessed on 32 adult sheep (31.00+0.85 kg body weight (BW) and 2 to 3 years in age) divided into four equal experimental groups. The experimental diets consisted of chopped (5-8 cm) Opuntia cladodes to provide 20 percent of dietary DM in conjunction with chopped green Napier (*Pennisetum purpureum*) grass (T1), Berseem (*Trifolium alexandrinum*) hay (T2), lathyrus (*Lathyrus sativus*) straw (T3)and gram (*Cicer arietinum*) straw (T4), *ad libitum*. All experimental animals were supplemented 200 g concentrate supplement per head daily. Total DM intake ranged from 3.39 to 4.35 percent of live weight and it was higher (P<0.01) in experimental groups where berseem hay and lathyrus straw were used as basal feed (T2 and T3). The total tract apparent digestibility of DM, OM and CP were lower (P<0.01) in sheep fed opuntia with gram straw (T4) diet compared to other diets (T1, T2 and T3). Similarly, digestibility of fibre fractions (NDF, ADF and Cellulose) also remained lower (P<0.01) on T4 diet. Intake of digestible DM, OM and TDN were significantly lower in T4 diet, where opuntia was supplemented with gram straw as basal feed, however, it did not differ (P<0.01) with T1 diet. The DCP intake was also lower (P<0.01) in T4 (3.12 g/ kg $W^{0.75}$) than the standard requirements of 5.00 g/ kg $W^{0.75}$ in sheep for maintenance. Intake TDN was over and above (48.74 to 62.10 g/ kg $W^{0.75}$) the prescribed requirements of 36.00 g/ kg $W^{0.75}$ in sheep for maintenance, in all experimental groups. Animals of all experimental groups were in positive nitrogen balance. However, N

intake, balance, absorb and retention (% of intake and % of absorbed) were lower (P<0.01) in T4 diet compared to other diets but the N excretion through faeces and urine was similar in T1 and T4 and T2 & T3. No significant (P<0.01) changes in live weights were observed and animals maintained the live weight throughout the experimental period. It is evident from the results that opuntia is highly palatable and in conjunction with conventional fodder sources can maintain adult sheep during summer in arid and semi arid conditions.

Key words: Cactus, Opuntia, Nutrient utilization, Nutritive value, Sheep

Introduction

Semi-arid and arid regions of South-east Asian countries are prone to drought. During this period, both losses of productivity and animal life occur, mainly due to shortage of feed. Opuntia has been used as a drought feed and as forage for cattle feeding since early 19th century (Griffiths, 1906; Woodward et al., 1915) and in most instances it is still being used as emergency feed during drought. Studies have indicated that the digestibility of opuntia cladodes is comparable with high quality hay (Shoop et al., 1977). The plant is extremely variable in nutritive value depending upon species, variety, age of the plant, sampling season and plant part. However, in general opuntia is high in moisture 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). During summer the harsh agro-climatic condition in 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 feed resource during scarcity.

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 conjunction with conventional green and dry fodders

Materials and Methods

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

Animals and feeding: Thirty two local adult female sheep (31.00+0.85 kg body weight (BW) and 2 to 3 years in age) were fed on four experimental diets in equal groups based on comparable age and BW. The diet consisted of chopped (5-8 cm) Opuntia cladodes to provide 20 percent of dietary DM in conjunction with chopped green Napier (*Pennisetum purpureum*) grass (T1), Berseem (*Trifolium alexandrinum*) hay (T2), lathyrus (*Lathyrus sativus*) straw (T3)and gram (*Cicer arietinum*) straw (T4), *ad libitum*. All experimental animals were supplemented 200 g concentrate supplement (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). Composition of diets is given in Table 1and 2. Animals were housed in stalls, 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 available freely twice a day at 9:30 and 13.30 h. Feeding experiment was continued for 21 days.

Metabolic trial: A metabolic trial was conducted after 21 days of feeding, lasted for 7 day in metabolic cages with facility of 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 feaces samples was determined daily by drying at 70 ^{o}C to a constant weight. The dried samples for 7 day collection were pooled, ground through 1 mm screen and preserved for chemical analysis. Samples of feaces and urine from individual animal were collected every morning for 7 day in a 500 ml Kjehldahl flask containing 25 ml concentrate 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 fiber (NDF) was determined by the procedure of Van Soest et al. (1991) without sodium sulfite or α-amylase, whereas acid detergent fiber (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 of 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

Spineless cactus cladodes contained dry matter (DM) 7.56, crude protein (CP) 6.45 and ash 31.34 percent on DM basis (Table 1). Higher water and ash content in opuntia cladodes has been reported in numerous studies (Ben Salem et al., 1996; 1999, Sirohi etal., 1997 and Misra et al., 2006). 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 (T2) to 14.86 (T1) percent against the target of 20 percent DM in total diet or 150 gm DM per animal daily through opuntia, set under the consideration that total DMI would not exceed beyond 2.5 percent 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 percent 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 ie., napier grass, berseem hay, lathyrus straw and gram straw leading to higher DMI in the experimental groups. Among treatments, intake of total DMI was (Table 2) higher ($P<0.01$) in experimental groups where berseem hay and lathyrus straw were used as basal feed (T2 and T3). It has been observed that increasing the proportion of legume led to significant increases in intake and in N-balance (Mosi & Butterworth., 1985) and this could be the reason for higher ($P<0.01$) total DMI on berseem hay (T2) and lathyrus straw (T3) based basal diets in present experiment.

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 (T4) diet (Table 2) compared to other diets (T1, T2 and T3). Similarly, digestibility of fibre fractions (NDF, ADF and Cellulose) also remained lower ($P<0.01$) on T4 diet. The low dietary CP content (7.46 %, Table 3) coupled with poor protein digestibility (51.98 %) on T4 diet could be attributed to the depressed microbial activity due to lower ruminal NH_3-N results in poor fiber utilization (Preston and Leng, 1987; Ben Salem et al., 1996). In other experimental groups (T1, T2 and T3), the dietary protein level remained above 8 percent, which had ensured sufficient nitrogen supply. Nitrogen supply had probably enhanced microbial activity in rumen and encourages micro-organism to degrade mare feed (Leng, 1990).

Intake of digestible DM, OM and TDN were significantly lower in T4 diet, where opuntia was supplemented with gram straw as basal feed (Table 3), however, it did not differ ($P<0.01$) with T1 diet. The DCP intake was also lower ($P<0.01$) in T4 (3.12 g/ kg $W^{0.75}$) than the standard requirements of 5.00 g/ kg $W^{0.75}$ in sheep for maintenance (ICAR, 2013). Intake of total digestible nutrients (TDN) was (Table 3) over and above (48.74 to 62.10 g/ kg $W^{0.75}$) the prescribed requirements of 36.00 g/ kg $W^{0.75}$ in sheep for maintenance (ICAR, 2013). Higher consumption of TDN widen the ratio with DCP intake particularly on T4 diet. Consumption of TDN and DCP in the ratio of 8.5 to 10.0 would be considered ideal for the sheep (ICAR 2013).

Nitrogen utilization: All animals supplemented 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 T4 diet (Table 4) compared to other diets but the N excretion through faeces and urine was similar in T1 and T4 and T2 & T3. In spite of similar N intake in T1 and T4, the poorer N retention (% of N intake and Absorbed) in T4 could be due to wider TDN/DP ratio (10.85 & 15.50 in T1 & T2, 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 would be considered ideal for the sheep (ICAR, 2013) and to achieve this ratio the dietary protein level should essentially be greater than 8 percent at maintenance level for the sheep. In present experiment, exceptionally greater N balance on the diets having berseem hay as basal fodder (T2) with opuntia was observed. The experimental results are in conformity with the findings of Mosi & Butterworth., 1985, that increasing the proportion of trifolium led to significant increases in intake and in N-balance.

No significant ($P<0.01$) 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. A laxative effect appears when the volume of cactus in the diet is high (>50 to 60 % of total DMI). This problem is easy to solve, feeding of small amount of straw or hay prior to cactus distribution is sufficient to have normal transit (Nefzaoui and Ben Salem, 2002).

Conclusions

It is evident from the results that opuntia is highly palatable and in conjunction with conventional fodder sources can maintain adult sheep during summer in arid and semi arid

conditions. Moreover, opuntia may improve the nutritive value of poor quality roughage due to its high content of soluble carbohydrates, but nutrient intake and utilization on opuntia feeding with fodders having moderate level of protein appears to be more beneficial than the fodders which are either low in protein (<8%) or very rich in protein (>12%). Animals maintained live weight without any digestive disturbances such as diarrhoea and bloating.

Acknowledgement

The financial support for this research provided by International Centre for Agricultural Research in the Dry Areas (ICARDA) and Indian Council of Agricultural Research (ICAR) is thankfully acknowledged.

References

AOAC. 1995. Official methods of analysis. 16th ed., Association of Official Analytical Chemists Washington, DC.

Ben Salem, H., A. Nefzaoui, H. Abdouli and E.R. Orskov. 1996. Effect of increasing level of spineless cactus (*Opuntia ficus indica* Var. *inermis*) on intake and digestion by sheep given straw based diets. *Animal Feed Science and Technology* 62: 293-299.

Duncan, D. B. 1955. Multiple range and multiple 'F' test. *Biometrics* 11: 1-42.

Goering, H.K. and P.J. Van Soest. 1970. Forage fibre analysis (Apparatus, Reagents, Procedures and some applications), ARS U.S.D.A. Handbook No. 379, Washington. D.C.

Griffiths, D. 1906. Feeding prickly pear to stock in Texas. USDA. Animal Ind. Bull. 91.

ICAR. 2013. Nutrient Requirement of Animals- Sheep, Goat and Rabbit (ICAR-NIANP), Indian Council of Agricultural Research, New Delhi, India.

Leng, R.A. 1990. Factors affecting the utilization of poor quality forage by ruminants particularly under tropical conditions. Nutrient Research *Review* 3: 277-303.

Misra, A. K., A. S. Mishra, M. K. Tripathi, O.H. Chaturvedi, S. Vaithiyanathan, R. Prasad and R. C. Jakhmola. 2006. Intake, digestion and microbial protein synthesis in sheep on hay supplemented with prickly pear cactus [*Opuntia ficus - indica* (L.) Mill.] with or without groundnut meal. *Small Ruminant Research* 63:125-134.

Misra, A. K., T., Kiran Kumar, S. Ahmed, Sunil Kumar and P.K. Ghosh. 2017. Nutritional value of Cactus for Livestock Feeding in Arid and Semi-Arid Regions of India. X Biennial conference of animal nutrition association on "newer perspectives in animal

nutrition research for augmenting animal productivity" at College of Veterinary science, Tirupati, 9th to 11th November, 2016. pp.35

Mosi, A .K. and M. H .Butterworth. 1985. The voluntary intake and digestibility of diets containing different proportions of tef (*Eragrostis tef*) straw and *Trifoilium tembense* hay when fed to sheep. *Tropical Animal Production* 10:19-22.

Nefzaoui, A. and H.Ben Salem. 2002. Utilisation of opuntia as forage in United States of America. In: cactus (*Opuntia*) as forage. FAO Plant Production and Protection Paper, 169 (eds. Jackob, C.M and S.P. Gonzalez), FAO, Rome. pp 51-56.

Preston, T. R. and R. A. Leng. 1987. Matching ruminant production systems with available resources in the tropics and sub-tropics. Penambul Books, Armidale.

Rick, A.G. and P. Felker. 1992. Crude protein and phosphorus content of eight contrasting opuntia forage clones. *Journal of Arid Environments* 22: 323-331.

Shoop, M.C., E.J. Alford and H. F. Mayland. 1977. Plains prickly pear is a good forage for cattle. *Journal of Range Management* 30: 12-17.

Sirohi, S. K., S. A. Karim and A. K. Misra. 1997. Nutrient intake and utilization in sheep fed with prickly pear cactus. *Journal of Arid Environments* 36: 161-166.

Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74: 3583-3597.

Woodward, T.E., W.F. Turner and D. Griffiths. 1915. Prickly pear a feed for dairy cow. *Journal of Agricultural Research* 4: 405-450.

Table 1: Chemical composition of feed ingredients (% DM)

Attributes	**Feed ingredients**					
	Opuntia	**Green Napier grass**	**Berssem 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 fiber	25.60	71.72	44.36	63.78	64.78	54.40
Acid detergent fiber[1]	17.43	43.16	36.11	48.40	47.65	16.07
Hemicellulose	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 mix (T1), Opuntia + Berseem hay + Concentrate mix (T2), Opuntia + Lathyrus straw + Concentrate mix (T3) and Opuntia + Gram straw + Concentrate mix (T4), in sheep.

Particulars	**Diets**				**P**	
	T1	**T2**	**T3**	**T4**	**SEm±**	***P***
Body weights (kg)						
Initial	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, g/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 mix	0.19	0.19	0.19	0.19	0.00	0.58
Ratio of opuntia in total diet (% on DM basis)	14.86^{b}	10.83^{a}	11.70^{ab}	14.48^{b}	1.20	0.03
Total dry matter intake						
Total DMI (kg/day)	1.02^{a}	1.40^{bc}	1.30^{bc}	1.13^{a}	0.07	<0.01
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}	100.12^{b}	101.71^{b}	82.25^{a}	5.19	<0.01
Digestibility (%)						
Dry matter	61.50^{a}	62.00^{a}	60.10^{c}	55.95^{d}	0.31	<0.01
Organic matter	57.51^{a}	55.00^{b}	51.49^{c}	49.03^{d}	0.34	<0.01
Crude 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						
% protein in ration	8.96^{a}	15.74^{b}	10.74^{c}	7.46^{d}	0.26	<0.01
Digestible crude protein % in ration	5.74^{a}	11.84^{b}	7.32^{c}	3.88^{d}	0.15	<0.01
TDN % in ration[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 letter in a row differ significantly

Table 3: Plane of nutrition of sheep fed diets containing Opuntia + Green Napier grass + Concentrate mix (T1), Opuntia + Berseem hay + Concentrate mix (T2), Opuntia + Lathyrus straw + Concentrate mix (T3) and Opuntia + Gram straw + Concentrate mix (T4), in sheep.

Attributes	**Diets**				**P**	
	T1	**T2**	**T3**	**T4**	**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 crude protein intake						
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/g DPI	10.85 [a]	5.24 [b]	8.12 [c]	15.50 [d]	0.42	<0.01

Values with different letter in a row differ significantly

Table 4: Nitrogen balance in sheep fed diets containing Opuntia + Green Napier grass + Concentrate mix (T1), Opuntia + Berseem hay + Concentrate mix (T2), Opuntia + Lathyrus straw + Concentrate mix (T3) and Opuntia + Gram straw + Concentrate mix (T4), in sheep.

Particulars	Diets				P	
	T1	T2	T3	T4	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