Range Management and Agroforestry 46 (2) : 318-323, 2025
ISSN 0971-2070 (Print); 2249-5231 (Online)
https://doi.org/10.59515/rma.2025.v46.i2.18

Research article

Nutrient intake and utilization in crossbred heifers fed opuntia [*Opuntia ficus-indica (L.) Mill.*] supplemented diet

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Received: 24th January, 2025 Accepted: 01st November, 2025

Abstract

The nutritive value of opuntia [(*Opuntia ficus-indica* (L.) Mill.] as a replacer of conventional green fodder M P Chari in the wheat straw-based diet of crossbred (Tharparkar x Jersey) heifers was assessed. The control diet consisted of chopped (2-5 cm) M P Chari green (8.76 kg) plus 1.61 kg concentrate (T_1) and the experimental diet consisted of chopped (5–8 cm) Opuntia cladodes of spineless opuntia (9.24 kg) plus 1.58 kg concentrate (T_2), along with wheat straw *ad libitum* in both groups. DM intake as a percent of body weight or g/kg metabolic body size was similar in both groups, indicating that replacement of MP chari with opuntia did not affect DM intake. The apparent digestibility of DM, OM and CP was lower (p <0.01) in heifers fed opuntia -supplemented diet; however, fiber (NDF and ADF) digestibility was similar in both groups. Digestible dry matter, organic matter, and digestible crude protein intake were significantly (p <0.05) decreased in the treatment group. TDN intake was not affected due to the replacement of MP Chari green with opuntia in the treatment group; however, TDNI(g) per gram of DCP intake was improved significantly (p <0.05) in the treatment group. TDN intake in both groups was sufficient to support a daily gain of 500 g, whereas digestible crude protein intake was sufficient for a gain of 300 g daily. Water intake (lit/d) or (lit/kg DMI) was significantly (p <0.05) higher in the control group than the treated group, indicating that inclusion of opuntia in the diet decreased the water requirement of the heifers. It was evident from the results that opuntia was highly palatable and readily consumed by the animals. Considering the overall performance of the animals in terms of nutrient intake, digestibility, nutrient utilization and water intake, it was concluded that spineless cactus could be a good unconventional and valuable fodder resource for livestock feeding during summer in semiarid conditions.

Keywords: Cactus, Heifers, M P Chari, Nutrient utilization, Nutritive value, Opuntia

Introduction

Livestock plays an important role in the livelihood of the farmers in the dry areas of arid and semiarid regions in India. There is always an acute shortage of green fodder during the summer season. The cultivation of traditional fodder crops has limitations due to the poor soil conditions and water scarcity. Climate change is now one of the biggest challenges worldwide. Prolonged droughts and desertification are among the issues faced by many countries, especially in Africa and Asia, where the rural poor and smallholders are most heavily affected. Being a xerophytic plant cactus pear (*Opuntia ficus indica)* has a great potential as a green fodder in these areas. Cacti have a potential for growing in the worst soil and environmental conditions to provide food, fodder and other economic benefits. The succulent cladodes of spineless cactus are palatable to livestock with a chemical composition of 10% of dry matter (DM), 4 to 10% crude protein (CP) and 30 to 40% neutral detergent fibre (NDF) (FAO, 2001). It also provides a major source of water (89.9 per cent), energy (8.4 MJ ME per kg DM), minerals and vitamin A (Costa *et al*., 2013). The opuntia plant is extremely variable in nutritive value depending upon species, variety, age, sampling season, and plant part.

However, in general, opuntia is high in moisture and *in vitro* dry matter digestibility and can be used as a source of sustenance in drought feeding (Misra *et al*., 2018). Looking at the importance of opuntia as a scarce feed in semiarid and arid environments of India, an experiment was undertaken to assess the effect of feeding opuntia-supplemented diet on nutrient intake and utilization in crossbred heifers.

Materials and Methods

***Study site*:** The study was carried out during summer 2019 at the 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 semiarid with yearly mean minimum and maximum temperatures of 18 and 32.6°C, respectively.

Animals and feeding: Sixteen crossbred (Jersey x Tharparkar) heifers (148.03 ± 5.39 kg body weight and 1.0–1.5 years age) were fed on experimental diets in equal groups based on comparable age and body weights. The diet consisted of chopped (2–5 cm) M P Chari plus concentrate mixture (T_1) and chopped (5–8 cm) Opuntia cladodes of spineless opuntia plus concentrate mixture(T_2), along with wheat straw *ad libitum* in both groups. Concentrate mixture consisted of 58 parts groundnut cake, 40 parts maize grain, 1 part mineral mixture and 1 part common salt, to provide adequate protein and other nutrients (ICAR, 2013). Animals were permitted 10% fodder refusals. Animals were fed daily at 10.00 h, after discarding the orts of the previous day. Water was made available freely twice a day at 9:30 h and 13.30 h. The feeding experiment was continued for 21 days.

Digestion trial: After the feeding experiment, a digestion trial was conducted for seven days. Daily intake of feed offered and output of faeces were recorded. Samples of feed offered, orts, and faeces 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 a seven-day period were pooled, ground through a 1.0 mm screen, and preserved for chemical analysis. Samples of faeces from individual animals were collected every morning for seven days in a 500 mL Kjeldahl flask containing 25 mL concentrated sulfuric acid for N determination.

Chemical analysis: Samples of feed offered, residues, 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: The data obtained for intake, digestibility, and the plan of nutrition were subjected to analysis. Mean data were compared for statistical differences using Student's t-test (Snedecor and Cochran, 1989)

Results and Discussion

Chemical composition: The chemical composition of spineless cactus fed to the experimental heifers indicated that the DM content of spineless cactus was low (7.51%) and the moisture content was high (92.49%), hence it had the advantage of meeting the partial water requirements of the animal (Table 1). Similarly, Kumar *et al*. (2023) also reported the DM content of 2.9 to 6.9% in different accessions of cactus pear. The CP content of spineless cactus was almost similar to the earlier report of Ajith *et al*. (2017), Misra *et al.* (2018), but lower than that reported by Gebremariam *et al*. (2006), Borges *et al*. (2019), and Kumar *et al*. (2023). The variation in CP content may be attributed to the fertility level of the soil, as higher CP content in spineless cactus with nitrogen fertilization of the soil was recorded by De Kock *et al*. (1980) and Karim *et al*. (1996). Similarly, Kumar *et al*. (2021) also recorded the effect of planting time and application of irrigation and fertilizer treatments on different nutrient contents of cactus pear and reported CP content from 4.42 to 6.52% in cactus pear. The CP content of opuntia was within the range of normal variation according to Rick and Felkar (1992). The NDF content (%) in spineless cactus was 34.91 and corroborated the earlier findings of Costa *et al*. (2012) and Gebremariam *et al.* (2006). Costa *et al*. (2016) and Vieira *et al*. (2008) reported a range of 31 to 41% NDF in spineless cactus, whereas Ajith *et al*. (2017) reported lower values. Variation in fiber content could be due to the maturity level of the cladode, soil conditions, and season. The total ash content of spineless cactus in the present experiment was similar to the values reported by Shruthilaya *et al*. (2022), however, Borges *et al*. (2019) reported lower TA values in cactus pear. The variation in TA content might be due to the growth stage of the cactus.

Crude protein content is of utmost importance as it largely determines the palatability and digestibility of forage crops. CP content in M P Chari fodder in the present study was similar to the values reported by Yusriani *et al.* (2023). Similarly, Somegowda *et al*. (2021) also reported the ranges of values for CP (4.75–6.62%), NDF (52–60%) and ADF (37–42%) in sorghum fodder grown under different water availability regimes. However, Karthikeyan *et al*. (2017) reported much higher CP values in different accessions of sorghum genotypes, which might be due to the relative contribution of leaves to total biomass and concentration of protein in dry fodder.

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

Attributes	Opuntia	M P Chari	Wheat straw	Concentrate mixture
Dry matter	7.51	22.88	97.44	98.85
Organic matter	68.50	90.23	91.24	89.20
Protein	6.10	5.90	3.80	17.22
Neutral detergent fibre	34.91	72.69	78.77	37.61
Acid detergent fibre	15.35	40.24	54.01	12.55
Hemicellulose	19.56	32.45	24.76	25.06
Cellulose	13.06	32.84	42.81	7.85
Acid detergent lignin	2.20	4.32	8.48	3.22

Nutrient intake: Opuntia was consumed readily by the heifers and the DM contributed by opuntia in the total diet was 15.14% and corroborated with earlier findings of Misra *et al.* (2018). DM intake as a percent of body weight or g/kg metabolic body size (Table 2) was similar in both groups, indicating that replacement of MP chari with opuntia did not affect DM intake.

Excess moisture content in opuntia cladodes may physically limit DM intake through rumen fill, in treatment group, however, despite of containing a substantial amount of water, opuntia cladodes stand out from other forage sources because of their rapid ruminal degradation rates, which immediately release the water contained and minimize rumen fill which is reflected in similar DM intake in both the groups in the present study. The total DM intake in both groups was sufficient to support the maintenance requirement (ICAR, 2013). Intake (g/d) of CP (424 *vs* 376), NDF (2960 *vs* 2664) and OM (4270 *vs* 3970) was significantly (p <0.05) higher in the control than the treatment group. The reduction in NDF intake is a reflection of the higher NDF content in MP Chari fodder. The NDF levels in the diet of this study did not limit DM intake, since the proportion of NDF in the DM actually consumed varied from 56.94 to 59.23% with the replacement of M P Chari green fodder by the spineless opuntia when the concentration of NDF in the diet is below 50 to 60%, intake is limited by the energy demand in adult animals (physiological regulations). Similarly, Barros *et al*. (2018) reported that the intakes of DM, organic matter, CP, and NDF decreased linearly as a function of the tifton hay replacement by spineless cactus in the diet of post-weaned heifers. Digestible dry matter, organic matter and digestible crude protein intake (Table 3) were also significantly (p <0.05) decreased in the treatment group. TDN intake was not affected due to the replacement of MP chari green with opuntia in the treatment group; however, TDNI (g) per gram of DCP intake was improved significantly (p <0.05) in the treatment group. Similarly, Misra *et al*. (2018) also reported a higher TDN to DCP ratio when opuntia was included with dry roughage compared to chopped green napier

Table 2. Dry matter intake, nutrient digestibility and nutritive value of diets containing M P chari+ wheat straw + concentrate mixture (T_1) and opuntia + wheat straw + concentrate mixture (T_2) in heifers

Particulars	T_1	T_2	T value
Body weight (kg)	150.93	145.38	1.55
Dry matter intake (kg/d)			
Opuntia	-	0.69	-
M P Chari	2.00	-	-
Wheat straw	1.14^a	2.29^b	10.42
Concentrate mixture	1.59	1.57	0.79
Total dry matter intake			
Total DMI (kg/day)	4.74	4.56	1.31
DMI (kg/ 100 kg BW)	3.15	3.15	0.32
DMI (g/kg $w^{0.75}$)	110.10	108.97	0.02
NI(g)/kg DOMI	22.99	22.45	1.42
Nutrient digestibility (%)			
Dry matter	66.15^b	61.83^a	11.82
Organic matter	69.42^b	67.44^a	6.72
Crude protein	76.84^b	72.17^a	7.19
Neutral detergent fibre	65.95^b	64.78^a	1.95
Acid detergent fiber	57.59	59.34	1.54
Cellulose	70.38	70.21	0.17
Nutritive value (%)			
% protein in ration	8.96^b	8.26^a	6.58
DCP	6.89^b	5.96^a	15.23
TDN [1]	61.86	62.15	1.01

[1]TDN = 87.84-(0.79*ADF%); Values with different superscript letters in a row differ significantly (P<0.05); DOMI: Digestible organic matter intake

Table 3. Plane of nutrition of heifers fed diets containing M P chari (green) + wheat straw + Concentrate mix (T_1) and opuntia + wheat straw + concentrate mixture (T_2)

Attributes	Control (T_1)	Treatment (T_2)	T value
Digestible dry matter intake			
kg/d	3.08[b]	2.80[a]	2.75
g/kg $W^{0.75}$	71.75	67.09	1.85
Digestible organic matter intake			
kg/d	2.97[b]	2.68[a]	3.07
g/kg $W^{0.75}$	68.88[b]	64.00[a]	2.14
Digestible crude protein intake			
g/d	326.10[b]	271.69[a]	5.91
g/kg $W^{0.75}$	7.57[b]	6.50[a]	5.33
TDN intake			
kg/d	2.93	2.83	1.30
g/ kg $W^{0.75}$	68.07	67.73	0.18
TDNI (g)/g DCPI	8.99[a]	10.43[b]	25.10
Water intake (lit/d)	14.96[b]	11.69[a]	4.53
Water intake (ml/kg BW)	999	789	5.21
Water intake (lit/kg DMI)	3.23	2.52	7.13

Values with different superscript letters in a row differ significantly (P<0.05)

fodder. In the present study, the N intake (g) values per kg DOM intake in both the groups was similar and indicated its sufficiency for efficient utilization of energy by the rumen microbes and its optimum growth as 2 g of available N per 100 g digestible organic matter has been reported to be required for optimal microbial growth for animals fed forages (Pathak 2008). TDN intake in both groups was sufficient to support a daily gain of 500 g, whereas crude protein intake was sufficient for a gain of 300 g daily (ICAR, 2013).

Apparent digestibility and nutritive value: DM, OM, and CP digestibility were decreased significantly (p <0.05) in treatment groups due to the replacement of MP chari green with opuntia, although fiber (NDF and ADF) digestibility was not affected (Table 2). The lower digestibility in the treatment group might be due to the lower consumption of NDF content in feeds, time available for ruminal microbiota to perform digestion and an increase in the rate of passage of digesta in the rumen (Chen *et al*., 1992). Digestibility values of DM, OM and CP in the present study were similar to earlier reports of Silva *et al*. (2017). However, Barros *et al*. (2018) reported improvement in DM digestibility and no alterations in OM and CP digestibility, and decreased NDF digestibility due to the replacement of tifton hay by spineless cactus in the diet of post-weaned heifers. Similarly, Shruthilaya *et al*. (2022) also reported higher (p <0.05) digestibility of DM, OM, CP, CF, NDF, and ADF in the spineless cactus-supplemented diets in lambs, indicating higher availability of nutrients from spineless cactus. Ajith *et al*. (2017) and Costa *et al*. (2012) also noticed higher digestibility of OM with higher levels of cactus inclusion in the diet of growing Santa lambs, wherein the cactus was replaced 5 by 0% of the corn in the diet. The increased digestibility of DM and OM in cows with progressive inclusion of cactus cladodes as a replacer of corn silage in the diet was explained by improvement in the degradation rates and ruminal fermentation and an increase in CP digestibility was due to the greater digestibility of DM and OM in cows fed cactus cladodes (Medeiros *et al*., 2024).

In the present study, water intake (L/d) or (L/kg DMI) was significantly (p <0.05) higher in the control group than the treated group, indicating that inclusion of opuntia in the diet decreases the water requirement of the heifers during summer. Similarly, Shruthilaya *et al*. (2022) observed reduced water intake when spineless cactus was included as a replacer of super napier in the diet of growing Nellore lambs. Rakotoarivonona *et al*. (2022) also reported that the voluntary water intake decreased with increasing inclusion levels of red cactus containing higher water. Borges *et al*.(2019) also observed that the inclusion of cactus pear in the diet of Holstein/ Zebu cows reduced water consumption by 44.52% in relation to the animal diets based on sorghum silage and elephant grass (p <0.01) and corroborated with the present reduction of 21.86% in heifers. The water in the diet supplied most of the water requirement of animals, thus reducing their voluntary water intake. This response is very important for semiarid regions due to water scarcity. Water consumption at environmental temperature of greater than 20°C was reported to be 3 kg per kg DM (McDonald *et al*., 2002), which corroborates the values on water intake by the animals in the present study. A laxative effect on inclusion of opuntia in the diet was not observed in the present study and the faecal DM content remained between 32.58 and 50.48%. A laxative effect generally appears when the volume of opuntia in the diet is high (>50–60%) of total DM intake, whereas in the present study, it was only 15%.

Conclusion

It was evident from the results that opuntia was highly palatable and readily consumed by the animals. Considering the overall performance of the animals in terms of nutrient intake, digestibility, nutrient utilization, and water intake, it was concluded that spineless cactus could be incorporated at 15% of the total diet as a good unconventional and valuable fodder resource for livestock, especially during summer in semiarid zones.

Acknowledgment

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

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