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Spineless cactus an alternative source of forage for different livestock: A review

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Abstract

Spineless cactus (*Opuntia ficus-indica*), a drought-tolerant xerophyte, has gained importance as an alternative forage resource in arid and semi-arid regions where conventional fodder production is severely constrained by water scarcity, poor soils and erratic rainfall. Its high adaptability, efficient water-use mechanism and ability to thrive under harsh climatic conditions make it a reliable green fodder source for livestock during periods of scarcity. Cactus cladodes are rich in water, soluble carbohydrates, calcium, potassium and vitamins A and C, but low in crude protein, fiber and phosphorus. When included in ruminant diets, cactus improves feed intake, enhances palatability and reduces drinking water requirements by up to 35%. Studies in sheep, goats, cattle and buffaloes have shown improvements in body weight gain, milk yield, milk quality and feed efficiency when cactus is supplemented with protein- and fiber-rich feeds. Moreover, cactus contributes to climate resilience by providing year-round fodder, mitigating enteric methane emissions and reducing production costs. However, its nutritional limitations, particularly low protein and fiber content, necessitate complementary feeding strategies such as combination with legumes or oilseed cakes. This review highlights the agronomic adaptability, nutritional profile, feeding value, environmental significance and future prospects of spineless cactus as a sustainable fodder resource for climate-smart livestock production systems.

Keywords: Spineless cactus, *Opuntia ficus-indica*, livestock nutrition, drought resilience, fodder scarcity, sustainable feeding

1. Introduction

Context of Fodder Scarcity in Arid and Semi-Arid Regions

Livestock farming in arid and semi-arid regions is constantly challenged by scarcity of quality green fodder. More than 50% of India's geographical area falls under these zones, characterized by extreme temperatures, erratic and low rainfall (25-450 mm annually), high evapotranspiration, poor soil fertility and recurrent droughts (FAO & ICARDA, 2017) ^[10]. Under such conditions, the cultivation of conventional fodder crops like sorghum, maize and legumes is severely restricted due to high water requirements and soil limitations. This leads to seasonal feed deficits, poor livestock productivity and economic insecurity for farmers dependent on animal husbandry.



Rationale for Cactus as Alternative Forage

Spineless cactus (*Opuntia ficus-indica*), a xerophytic plant, has emerged as a promising alternative fodder source because of its exceptional ability to thrive in degraded soils with minimal water. Its crassulacean acid metabolism (CAM) photosynthetic pathway enables water-use efficiency four to five times greater than grasses (Makkar, 2017) ^[17]. It produces substantial biomass (20–200 t DM/ha/year), remains green year-round and serves as both feed and water source for livestock. Nutritionally, cactus cladodes are rich in moisture, soluble carbohydrates, minerals and vitamins, making them highly palatable. Although protein and fiber content are low, cactus can serve as a sustainable supplement to improve feed intake, reduce water consumption and enhance livestock performance in drought-prone regions.

Objectives of the Review

This review aims to:

1. Summarize the agronomic adaptability and nutritional composition of spineless cactus
2. Compare its feeding value with conventional fodder crops
3. Evaluate its role in livestock feeding and performance across species
4. Highlight environmental benefits, challenges and future research needs

By consolidating available scientific evidence, this article emphasizes the potential of spineless cactus as a climate-resilient fodder resource for sustainable livestock production.

2. Agronomic Adaptability of Spineless Cactus:

2.1 Climatic and Soil Adaptability

Spineless cactus (*Opuntia ficus-indica*) is a hardy xerophyte well suited to arid and semi-arid ecosystems. It tolerates extreme temperatures ranging from –10°C to 50°C, survives under annual rainfall as low as 250 mm and thrives in soils with low organic matter and high salinity (FAO & ICARDA, 2017) ^[10]. Unlike conventional fodder crops, cactus does not require fertile or well-drained soils and can establish in degraded lands prone to erosion. Its crassulacean acid metabolism (CAM) photosynthetic pathway allows it to open stomata at night, minimizing water loss while maximizing carbon fixation, making it a climate-resilient crop for water-limited environments.

2.2 Water-Use Efficiency and Productivity

One of the most important traits of cactus is its superior water-use efficiency, reported to be four to five times greater than that of tropical grasses (Degu *et al.*, 2009; Guevara *et al.*, 2011) ^[9, 13]. It can produce 20–200 tonnes dry matter (DM)/ha/year depending on soil fertility and irrigation conditions (FAO, 2017) ^[11]. This biomass yield is significantly higher than that of natural rangelands in arid areas, enabling sustainable fodder supply for livestock throughout the year. In addition, cladodes act as a natural water source for animals, helping to reduce reliance on scarce drinking water resources.

2.3 Global and Indian Scenario of Cultivation

Globally, cactus is extensively cultivated in Latin America, Africa, West Asia and parts of Europe. Mexico is the center of origin and maintains over 3 million ha under cactus, largely for fruit, fodder and cochineal dye production (Makkar, 2017)

^[17]. Brazil has approximately 500,000 ha of cactus plantations, while Ethiopia (360,000 ha), Morocco (120,000 ha) and Tunisia (600,000 ha) represent major African producers. In West Asia, Jordan, Israel and Gulf countries also cultivate cactus for food and fodder.

In India, commercial adoption of cactus as a fodder crop is still at an early stage. Research trials by ICAR-Central Arid Zone Research Institute (CAZRI), Jodhpur and BAIF Development Research Foundation, Pune, have demonstrated its suitability under arid and semi-arid conditions. Field trials in Rajasthan, Gujarat, Maharashtra and Haryana confirm its high biomass productivity, drought tolerance and acceptance by small ruminants and dairy animals (Kauthale *et al.*, 2017) ^[15].

2.4 Improved Clones and Varieties

Significant progress has been made in the development of spineless cactus clones adapted to diverse environments. Improved accessions such as 1269, 1270, 1271, 1280, 1308, AHCP-2 and CAZRI Botanical Garden have shown promise in Indian trials (Soni *et al.*, 2015) ^[23]. Among these, clone 1271 exhibited the highest survival rate (67%), while clone 1270 demonstrated faster sprouting and better growth under irrigated conditions (Singh *et al.*, 2014) ^[22]. Clone 1280 performed well under saline soils, maintaining plant height and cladode formation. Such genetic diversity offers opportunities for large-scale deployment of location-specific accessions to support livestock farming in drought-prone regions.

3. Nutritional Composition of Cactus Cladodes:

3.1 Proximate Composition

Cactus cladodes are characterized by exceptionally high moisture content (75–90%), which provides animals with an internal water source, particularly valuable during droughts (Le Houérou, 1996) ^[16]. On a dry matter (DM) basis, crude protein (CP) content is generally low, ranging from 4–6% DM (Ben Salem *et al.*, 1996; Batista *et al.*, 2003) ^[7, 5]. Fiber fractions are moderate, with neutral detergent fiber (NDF) ranging between 18–30% and acid detergent fiber (ADF) between 12–20% (FAO, 2017) ^[11]. Crude fat content is minimal (<1%), while carbohydrate levels are high (up to 60% DM), largely in the form of soluble sugars and mucilage.

3.2 Vitamins and Minerals

Cactus cladodes are rich in β -carotene (pro-vitamin A), vitamin C (10–20 mg/100 g FW) and small quantities of B-complex vitamins such as thiamine (B1) and riboflavin (B2) (Ayadi *et al.*, 2009) ^[3]. Mineral composition is dominated by calcium (200–300 mg/100 g FW) and potassium (>500 mg/100 g FW), while phosphorus is relatively low (50–100 mg/100 g FW), resulting in a high Ca:P ratio (Sawyer *et al.*, 2001) ^[21]. Magnesium and sodium are present in moderate amounts. The mineral richness contributes to animal bone health, electrolyte balance and overall metabolic functions.

3.3 Functional Components

Cactus cladodes contain mucilage (6–13 g/kg FW), a hydrocolloid polysaccharide that enhances rumen fermentation, improves digestibility of fibrous feeds and stabilizes rumen pH by slowing fermentation rates (Abidi *et al.*, 2009) ^[1]. High levels of malic acid contribute to its CAM metabolism and diurnal fluctuations in acidity, which also influence rumen fermentation dynamics (FAO, 2017) ^[11].

3.4 Nutritional Limitations

Despite its advantages, cactus has some limitations as livestock feed. Its low CP and fiber content make it unsuitable as a sole feed. Excessive consumption of cladodes can result in digestive disturbances such as diarrhea and rapid rumen passage due to their high moisture content (Ben Salem *et al.*, 2004) ^[6]. Additionally, the high Ca:P ratio and oxalate content may reduce phosphorus availability and affect calcium utilization in animals (Nefzaoui & Ben Salem, 2001) ^[18]. These challenges highlight the need for dietary balancing through supplementation with protein-rich and fibrous feeds such as legumes, crop residues or oilseed cakes.

4. Comparison with Conventional Fodder Crops:

Cactus fodder differs markedly from conventional grasses and legumes in terms of agronomic requirements, nutritional

composition and utility. Traditional fodder crops such as sorghum, maize and alfalfa require fertile soils, frequent irrigation and significant nutrient inputs, making them less sustainable in arid and semi-arid regions. In contrast, spineless cactus thrives in degraded soils with minimal water and fertilizer requirements.

From a nutritional standpoint, conventional fodders are generally richer in crude protein (10–20% DM) and fiber (25–30% DM) compared to cactus (4–6% CP, 10–20% fiber). However, cactus has the advantage of higher moisture content (75–90%), soluble carbohydrates, vitamin C and minerals such as calcium and potassium. Thus, while it cannot fully replace conventional forages, cactus serves as a valuable supplementary feed that enhances diet palatability, improves water balance and reduces feeding costs during drought periods.

Table 1: Nutritional comparison of spineless cactus and conventional fodder crops

Parameter	Spineless Cactus (<i>Opuntia ficus-indica</i>)	Conventional Fodder (Grasses/Legumes)
Moisture (%)	75–90	60–70
Crude Protein (% DM)	4–6	10–20
Crude Fiber (% DM)	10–20	25–30
Ash (% DM)	10–25	8–12
Calcium (mg/100 g FW)	200–300	100–150
Phosphorus (mg/100 g FW)	50–100	200–300
Potassium (mg/100 g FW)	500+	300–400
Vitamin C (mg/100 g FW)	10–20	2–5

FW = Fresh weight; DM = Dry matter

Overall, cactus excels in climatic resilience and water provision, while conventional fodders provide higher protein and energy. A strategic combination of both can ensure balanced nutrition, particularly in drought-prone regions where cactus acts as a sustainable buffer against fodder scarcity.

5. Cactus as Livestock Feed

Spineless cactus has been widely studied as a livestock feed, particularly in drought-prone areas where conventional fodder is scarce. Its high palatability, water content and digestibility make it suitable as a dietary supplement. However, due to its low crude protein and fiber content, cactus should be combined with fibrous and protein-rich feeds to ensure balanced nutrition.

5.1 Sheep and Goats

Feeding trials in small ruminants have shown encouraging results. Inclusion of cactus up to 50% of diet dry matter (DM) increased feed intake, body weight gain and carcass yield (Gebremariam *et al.*, 2006; Degu *et al.*, 2009) ^[12, 9]. Cactus-legume diets produced performance comparable to commercial diets and supplementation with cottonseed cake or peanut cake improved growth and slaughter weights (Gusha *et al.*, 2015) ^[14]. Moreover, cactus-fed ewes accumulated more colostrum and produced higher milk yields compared to those fed barley-based diets (Rekik *et al.*, 2010) ^[20].

5.2 Cattle

In dairy cattle, cactus supplementation (20–30% DM) improved feed intake, nutrient digestibility and daily body

weight gain (Kauthale *et al.*, 2017) ^[15]. Studies in Brazil and Mexico reported increased milk yield (by 7–15%) and higher protein and solids-not-fat content in milk, although milk fat percentage often declined slightly (Costa *et al.*, 2010) ^[8]. Cactus feeding also reduced animals' drinking water intake due to its high internal water content.

Raut *et al.*, (2024) ^[19], studied the experimental crossbred heifers exhibited significant weight gain and improved body measurements when 10 per cent of green fodder was replaced with forages cactus. This finding suggests that forage cactus holds promise as a beneficial fodder option for crossbred heifers, controlling to a well-balanced nutrient intake.

5.3 Buffaloes

Field trials in India demonstrated that supplementation with 8 kg cactus per buffalo per day improved average daily weight gain by 95 g compared to 49 g in controls (BAIF, 2021) ^[4]. Milk yield was not significantly altered, but water intake was reduced by 35%. These results highlight cactus as a water-efficient supplement that maintains production under feed scarcity conditions.

5.4 Nutritional Challenges

Despite these benefits, excessive feeding of cactus can lead to digestive problems such as diarrhea due to its high water and soluble sugar content (Ben Salem *et al.*, 2004) ^[6]. Its low crude protein and high Ca:P ratio also limit its role as a complete feed. Therefore, cactus should be integrated into rations with fibrous crop residues (e.g., straw) and protein-rich supplements (e.g., oilseed cakes, legumes) to balance the diet. Ensiling cactus with legumes has been suggested as a practical solution for smallholder farmers.

Table 2: Summary of livestock performance trials with cactus inclusion

Species	Level of Cactus Inclusion	Key Outcomes	Reference
Sheep (Tef straw diet)	Up to 50% DM	Improved BW gain, higher feed intake, no digestive problems	Gebremariam <i>et al.</i> , 2006 ^[12]
Sheep (With oilseed cakes)	20–30% DM + cottonseed/peanut cake	Higher slaughter weight, dressing%, growth rate	Degu <i>et al.</i> , 2009 ^[9]
Ewes (Tunisia)	Barley vs. cactus-based diets	Greater colostrum yield, higher milk yield at 10–30 days postpartum	Rekik <i>et al.</i> , 2010 ^[20]
Dairy cows	20–30% DM	Increased milk yield (7–15%), improved protein & SNF, slight fat reduction	Costa <i>et al.</i> , 2010 ^[8]
Cows (India)	8 kg/day/cow (25% cereal fodder replacement)	Improved feed intake, BW gain (660 g/day vs. 608 g/day), stable milk fat	Kauthale <i>et al.</i> , 2017 ^[15]
Goats (India)	1.6 kg/day/goat	Higher BW gain (75 g/day vs. 31 g/day in controls); reduced water intake 33%	Kauthale <i>et al.</i> , 2017 ^[15]
Buffaloes (India)	8 kg/day/buffalo	Higher BW gain (95 g/day vs. 49 g/day), water intake reduced by 35%, no change in milk yield	BAIF, 2021 ^[4]

BW = Body weight; DM = Dry matter; SNF = Solids-not-fat

6. Environmental and Health Benefits

The use of spineless cactus as livestock feed extends beyond nutritional advantages. Its adaptability and functional properties contribute to environmental sustainability, climate resilience and improved animal health and product quality.

6.1 Drought Resilience and Water-Saving Role

Cactus is uniquely suited to arid and semi-arid regions due to its crassulacean acid metabolism (CAM) pathway, which minimizes water loss by opening stomata at night. Its high cladode water content (75–90%) allows animals to meet part of their hydration requirements, thereby reducing dependence on scarce water resources. Feeding trials in goats and buffaloes have shown reductions of 30–35% in drinking water intake when cactus was included in the diet (Kauthale *et al.*, 2017) ^[15]. This feature makes cactus invaluable during prolonged droughts when both feed and water are limited.

6.2 Contribution to Sustainable Livestock Production

The ability of cactus to thrive on degraded soils and marginal lands reduces the pressure on arable land and irrigation resources otherwise needed for fodder crops. Its perennial nature allows repeated harvests over several years, lowering cultivation costs and improving fodder security. By integrating cactus plantations into livestock systems, farmers can ensure year-round availability of green forage, particularly in regions where seasonal deficits are common.

6.3 Methane Mitigation Potential

Ruminant livestock are significant contributors to enteric methane emissions, a potent greenhouse gas. Several studies indicate that diets supplemented with cactus reduce methane emissions due to its soluble carbohydrate profile and positive effects on rumen fermentation efficiency (Australia and Mexico trials, 2010–2015). This suggests that cactus-based feeding systems can play a role in lowering the carbon footprint of livestock production while maintaining animal performance.

6.4 Animal Health and Product Quality

Cactus feeding has been associated with improved rumen fermentation, stabilization of pH and enhanced digestibility of fibrous feeds (Abidi *et al.*, 2009) ^[1]. Ewes fed cactus-based diets showed higher colostrum production, which benefits neonatal survival and immunity (Rekik *et al.*, 2010) ^[20]. Milk composition studies reveal that cactus diets increase conjugated linoleic acid (CLA) and polyunsaturated fatty acids (PUFA), improving the nutritional quality of milk and meat for human consumers (Atti *et al.*, 2006) ^[2]. These benefits position cactus as not only a drought-resilient fodder

but also as a feed ingredient that can improve animal health and product value.

7. Challenges and Future Prospects

7.1 Nutritional Limitations

Despite its potential, spineless cactus has notable nutritional constraints. Its crude protein content (4–6% DM) is much lower than that of conventional fodders (10–20% DM), which can lead to protein deficiencies if cactus is used as the sole feed. Similarly, its low fiber content accelerates rumen passage, reducing nutrient utilization and sometimes causing diarrhea (Ben Salem *et al.*, 2004) ^[6]. The high calcium-to-phosphorus ratio and presence of oxalates may impair mineral balance and bioavailability (Nefzaoui & Ben Salem, 2001) ^[18]. Therefore, cactus must be complemented with protein- and fiber-rich feeds such as legumes, oilseed cakes or crop residues to form a balanced ration.

7.2 Digestive and Feeding Challenges

Feeding large quantities of cactus may result in laxative effects due to its high water and soluble sugar content. While these effects are generally not harmful, they can reduce feed efficiency if not managed properly. Gradual introduction of cactus into the diet, ensiling with fibrous materials or mixing with dry roughages are practical strategies to overcome these issues.

7.3 Farmer Adoption and Awareness

In India, the adoption of cactus as a fodder crop remains limited, mainly due to lack of awareness, unavailability of planting material and traditional preference for conventional crops. Although research trials at institutions such as CAZRI and BAIF have demonstrated its suitability, large-scale extension efforts are needed to promote its benefits among smallholder farmers.

7.4 Research Gaps

Several areas require further investigation:

- Optimal feeding levels for different livestock species under varied production systems.
- Economic analysis of cactus-based feeding compared to conventional fodder systems.
- Value addition technologies, including cactus-legume silages, pelleted feed blocks and incorporation into total mixed rations.
- Genetic improvement for higher protein content, improved palatability and better pest resistance.
- Long-term effects of cactus feeding on animal health, reproduction and product quality.

7.5 Future Prospects

Spineless cactus has immense potential as a climate-resilient fodder crop in arid and semi-arid regions. With targeted research, farmer training and policy support, cactus can be mainstreamed into sustainable livestock production systems. Its role in ensuring fodder security, reducing water demand and mitigating greenhouse gas emissions aligns with global goals for climate-smart agriculture. Scaling up cactus cultivation through community-based nurseries, government-backed extension programs and integration with watershed management initiatives can transform it into a strategic fodder resource for future livestock farming.

8. Conclusion

Spineless cactus (*Opuntia ficus-indica*) represents a promising solution to the persistent fodder shortages in arid and semi-arid regions. Its exceptional adaptability to heat, drought, salinity and poor soils makes it a reliable year-round source of green forage where conventional crops often fail. Nutritionally, cactus cladodes are rich in water, soluble carbohydrates, minerals and vitamins, offering both feed and hydration to livestock. However, its low crude protein, limited fiber content and imbalanced Ca:P ratio restrict its use as a sole feed, underscoring the need for supplementation with protein- and fiber-rich sources.

Feeding trials across sheep, goats, cattle and buffaloes consistently demonstrate improvements in feed intake, growth performance and milk yield, alongside reductions in drinking water requirements. Beyond its nutritional role, cactus contributes to climate-smart livestock production by conserving water, improving rumen function, reducing enteric methane emissions and enhancing the nutritional quality of milk and meat.

Challenges such as digestive disturbances, low farmer awareness and limited availability of planting material must be addressed through research, extension and policy interventions. Future strategies should focus on integrating cactus into mixed farming systems, developing value-added feed products and promoting region-specific high-yielding clones.

In conclusion, spineless cactus offers a sustainable, low-input and climate-resilient forage resource that can strengthen livestock productivity and resilience in water-scarce regions, contributing significantly to food and livelihood security under changing climatic conditions.

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10. Conflict of Interest

The authors state that there is no conflict of interest. All the authors revised the manuscript.

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