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Zoo Nutrition for Wild Herbivores: An Examination of Dietary Requirements

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Abstract

Nutritional management of wild herbivores in zoological settings is essential to modern zoo operations, reflecting their role as wildlife conservatories and research facilities. At Sardar Patel Zoological Park (SPZP), dietary practices have evolved from empirical to evidence-based, focusing on the complex needs of captive herbivores. By mimicking natural feeding behaviors—adjusting fodder height, managing feed distribution to prevent overcrowding, and synchronizing feeding times with animals' diurnal patterns—SPZP enhances herbivore welfare. Innovations like chaffed fodder reduce waste and emphasize sustainable feeding strategies. This comprehensive approach ensures the nutritional, behavioral, and physiological health of herbivores, balancing economic and environmental considerations with the well-being of zoo animals. These practices underscore the critical role of precise feed management in advancing zoo animal care.

Keywords: Zoo nutrition, Herbivore captive diet, Nutritional enrichment



Introduction

The nutritional management of wild herbivores in zoological settings has become a cornerstone of modern zoo operations, reflecting zoos' evolving ethos as wildlife conservatories and research facilities. The emphasis on herbivores' dietary requirements—animals that derive their energy and nutrients primarily from plant matter—highlights the difficulty of replicating wild dietary regimes within the constraints of captivity. This article examines the multifaceted approach required to meet the nutritional, behavioural, and physiological needs of captive herbivores, emphasising the shift from empirical to evidence-based dietary practices.

Understanding Wild Dietary Patterns: The foundation of effective nutritional management for herbivores in captivity lies in a comprehensive understanding of their natural dietary preferences and nutritional intake. In their natural ecosystems, herbivores access a wide variety of plant species, each contributing to a nuanced dietary profile that supports their health, reproduction, and survival strategies (Hummel & Clauss, 2011). Transitioning this diversity into a zoo setting challenges caretakers to replicate a diet that not only meets the nutritional benchmarks but also respects the natural feeding behaviours and preferences of each species.

Crafting Species-Specific Diets: The development of species-specific diets requires an interdisciplinary approach, integrating insights from wildlife nutritionists, veterinarians, and field biologists to construct nutritional plans that mirror the complexity of natural diets (Dierenfeld, 1997). This process involves selecting appropriate substitutes from available resources that mimic the nutritional profiles of native plants, considering factors such as seasonal and regional availability, transportation costs, and presentation methods to minimize waste and enhance feeding engagement.

Sardar Patel Zoological Park (SPZP) showcases this approach by assembling a team of experts, including nutrition consultants, to create diets that meet the holistic needs of their herbivorous residents. These diets are designed to ensure nutritional adequacy, stimulate natural foraging and feeding behaviours, and incorporate the diversity and seasonality of the local flora, all of which benefit the animals' physical and psychological well-being.

Enrichment Strategies and Their Role: Beyond the mere provision of nutritionally adequate food, enrichment plays a pivotal role in simulating natural feeding behaviours and promoting mental health among captive herbivores. Enrichment strategies, ranging from physical structures that encourage natural foraging



behaviours to cognitive challenges that engage problem-solving skills, are integral to a well-rounded nutritional management program (Shepherdson, 1998). These strategies not only enhance the well-being of herbivores by providing mental stimulation and physical activity but also contribute to the educational and conservational goals of modern zoos by showcasing animals in more naturalistic and engaging contexts (Fig. 1).

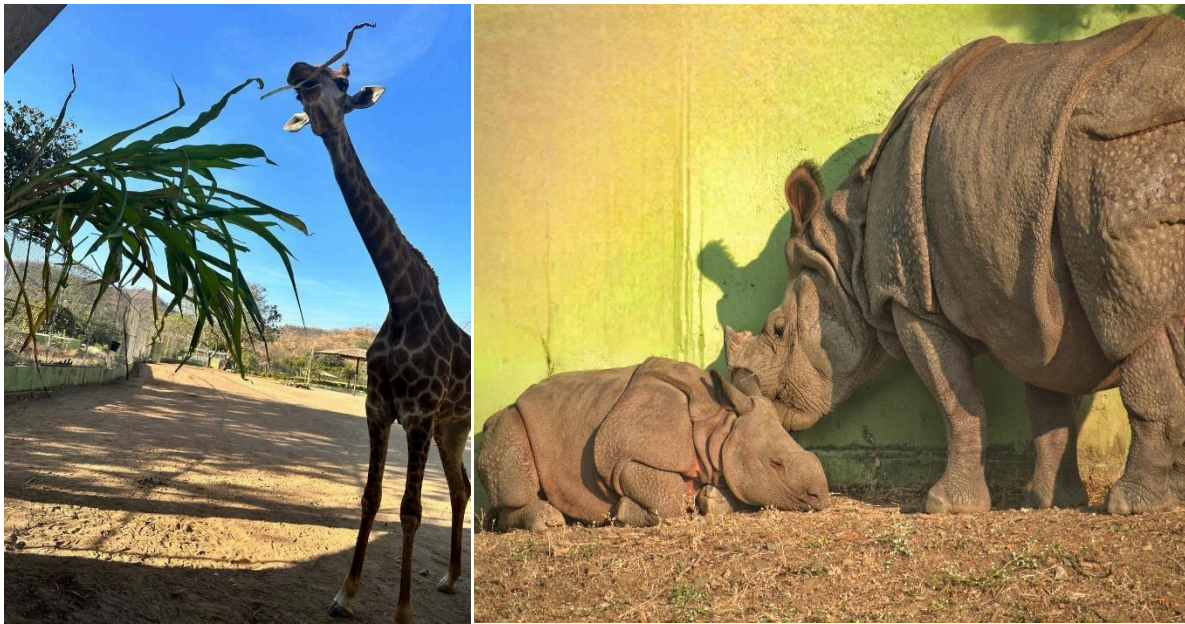


Fig.1: Giraffe enjoying it's feed placed at height. Photograph taken by Ushma Patel.

Fig. 2: Baby Indian One horned Rhinoceros showing a strong bond with her mother. Photograph taken by Darshit Shah.

Challenges and Future Directions: Despite significant advancements in our understanding of zoo animal nutrition, the field remains in its infancy, with much to learn about the specific dietary needs and preferences of the myriad species housed in zoos worldwide. The empirical classification of zoo diets into broad categories like herbivore, carnivore, and omnivore is gradually being supplanted by a more nuanced, species-specific approach that considers the unique nutritional, behavioural, and physiological requirements of each animal (Koutsos, 2003).

As zoos continue to evolve from mere exhibition spaces to centers of conservation and research, the focus on nutrition will increasingly play a critical role in achieving these institutions' broader goals. Future research should aim to deepen our understanding of the nutritional ecology of wild herbivores, improve the precision of



dietary replications in captivity, and explore the impacts of nutrition on animal health and reproductive success.

Conservation breeding and nutrition

Captive breeding programmes represent a critical component of conservation efforts in zoological settings, with nutrition playing a pivotal role in the success of these initiatives. At SPZP, the emphasis on nutrition reflects a comprehensive approach to the management and conservation of herbivorous species, both exotic and native to India. This section elaborates on the relationship between nutrition and reproductive health in captive breeding programmes, highlighting the changes made to dietary provisions and their impact on reproductive success and overall animal welfare (Fig. 2).

Nutritional Status and Reproductive Health: The reproductive health of animals in captivity serves as a vital indicator of their overall nutritional status. SPZP's observation of its diverse herbivore population reveals a direct correlation between nutrition and reproductive outcomes. Instances of abandonment and reduced rates of reproduction often signal underlying nutritional deficiencies. In nature, food scarcity influences reproductive strategies; females may abandon weaker offspring when resources are insufficient to support their survival. In captivity, where animals rely entirely on provided diets, ensuring an adequate and nutritionally balanced intake is essential for supporting both the immediate and future generational needs of the species.

Implementing Scientifically Designed Diets: The introduction of a scientifically designed diet chart at SPZP, which significantly increased the quantity of food provided, marked a turning point in managing reproductive health and offspring survival. This intervention led to a noticeable decrease in the need for hand-raising young animals, suggesting that enhanced nutritional support contributed to better maternal care and offspring viability. While this observation points to a positive outcome of dietary adjustments, it also underscores the complexity of nutritional science in captive breeding programs. Various factors, including diet composition, feeding practices, and individual animal needs, play into the overall health and reproductive success of captive populations.

Challenges of Overnutrition: Conversely, the issue of overnutrition poses its own set of challenges for captive breeding. Overnutrition, manifesting in obesity, acidosis, and laminitis, can adversely affect metabolic processes and, by extension,



reproductive performance (Das, 2018). In zoological settings, diets excessively rich in sugars or proteins have been linked to decreased reproduction rates in certain species. This underscores the necessity for a balanced approach to diet formulation, one that meets the nutritional requirements without tipping into excess.

Scientific Conservation Breeding Programs: SPZP's commitment to conservation is demonstrated by its planning and implementation of scientific conservation breeding programmes for a variety of species, including the Indian rhino, Indian gaur, four-horned antelope, Indian gazelle, wildebeest, and oryx. The nutritional strategy for these programmes is carefully planned to include a variety of dietary components such as green fodder, hay, pellet feed, Bengal gram, tree browse, and supplements (multimineral, calcium, mineral block licks, and multivitamins). This comprehensive approach ensures that each species' dietary needs are met, thereby improving their health and reproductive capacity within the zoo's controlled environment.

Gastrointestinal ailments

The analysis of medical records from zoos has highlighted a recurring issue of gastric ailments among herbivorous species, presenting symptoms such as inappetence, straining, bloat, colic, impaction, and, occasionally, anorexia. These conditions, often treated with conventional methods including antacids, multivitamins, ruminotorics, and symptomatic care, underscore the complexity of managing herbivore health in captivity. Despite these interventions, some animals succumb after prolonged illness, with post-mortem examinations revealing significant gastrointestinal obstructions due to impaction in the abomasum and the formation of phytobezoars, trichobezoars, and polybezoars (Fig. 3,4).



Fig. 3: Complete Intestinal obstruction observed in a Sambar deer. Photograph taken by Mitesh Patel.



Fig. 4: Phytobezoar retrieved from small intestine of Sambar Deer. Photograph taken by Amey Wagh.



The aetiology of these conditions' points to dietary and environmental factors within the captive setting. The presence of bezoars, which are accumulations of indigestible material in the gastrointestinal tract, indicates a dietary imbalance or the ingestion of foreign materials, often stemming from nutritional deficiencies or behavioural issues (Hatt, J.-M., & Clauss, M., 2006). Animals with inadequate nutritional intake may develop pica, a condition characterized by the consumption of non-food items, leading to the ingestion of their own fur and the subsequent formation of trichobezoars (Fig.5).



Fig. 5: Poor skin coat with alopecia due to habitual licking. Photograph by Ushma Patel.



Fig. 6: Provision of mineral blocks to animals. Photograph taken by Jenish Panchal.

Nutritional deficiencies can also trigger abnormal licking behaviours, where animals attempt to supplement their diet by licking inanimate objects or their own fur, further exacerbating the risk of gastrointestinal blockages (Clauss, M., & Hatt, J.-M., 2015). This behaviour underscores the importance of providing a diet that not only meets the nutritional requirements but also mimics the diversity and complexity of their natural food sources, thereby reducing the likelihood of such health issues.

Measures such as providing a cement feeding station or areas that may be free from direct contamination from the ground are important to be provided. For example, Indian rhinoceros have been known to suffer from sand colic if fed directly on the soil.

Addressing these health challenges requires a multifaceted approach, emphasizing the need for comprehensive dietary planning, environmental enrichment, and behavioural studies to mitigate the risks associated with captive feeding practices (Fig. 6). Enhancing the quality and variety of dietary offerings, along with the implementation of enrichment strategies that encourage natural foraging



behaviours, can significantly reduce the incidence of gastrointestinal ailments and improve overall animal welfare (Clauss, M., et al., 2008).

Calculation of feed

The appropriate calculation of feed for each animal in a zoological setting is an essential component in the nuanced science of dietary formulation, requiring a thorough understanding of the various factors that influence dietary requirements. These factors include the animal's body weight, age, physiological status (e.g., pregnancy, lactation), and the physical characteristics of the feed that influence its palatability. The selection of ingredients is a meticulous process, grounded in the practicalities of availability, storage, and distribution within the zoo's enclosures, with each ingredient's nutritional profile assessed on a dry matter basis to ensure dietary balance and adequacy.

Herbivore Feed Classification and Requirements - On Dry Matter Basis							
Concentrates (25-30 % of total feed)				Roughages (70-75 % of total feed Intake)			
Plant Sources				Green Fodder (2/3 rd of Roughages)		Dry Fodder (1/3 rd of Roughages)	
Energy Rich		Protein Rich		Leguminous	Non-leguminous	Hay	Straw
Molasses	Sugar and citrus Molasses	Oil Seed Cakes and Meals	Groundnut Cake. Sunflower seed Cake, Cotton Seed Cake	Lucerne Berseem	Hybrid napier Maize Oat Sorghum	Peanut Alfalfa Meadow Hybrid napier Maize Sorghum	Wheat Straw Rice Straw
Milling by Product	Barley, corn, oats, wheat	Milling by Products	Wheat Bran Rice Bran Soybean hulls				Dongari Grass
Grains and seeds	Bengal Gram Maize Barley Oats	Grains and seeds	Soybean meal Linseeds meal	Tree Fodders as an enrichment: Neem, banyan, mango, moringa, babul, subabool, kachnar, tamarind, mahua, acacia, ber, etc.			
Balanced Feed (Protein Rich as well as energy Rich) Commercial Feeds- Wild Herbivore feed, antelope feed, HP stud Farm feed etc.				Miscellaneous grasses as an enrichment: Lawn Grass, Cowpea, para grass, bamboo etc.			



Concentrates from Animal Sources				Feeding Schedule In General		
Animal Tissue Sources		Marine Sources		Morning	Afternoon	Evening
Bone Meal	Blood Meal	Cuttle bones	Fish Meal	Concentrate Green Fodder (Half Portion)	Dry Fodder Tree Fodder	Green Fodder – Half Portion

The process of calculating feed on a dry matter basis is pivotal for standardizing nutritional analyses, especially for herbivores with diverse dietary inputs. This method facilitates a comparative analysis of different food items, ensuring a consistent approach to meeting the nutritional requirements of zoo animals. For instance, understanding that a feed item contains 20% crude protein on a dry matter basis allows zoo nutritionists to accurately formulate diets that match the specific nutritional needs of each species.

Criteria for Feed Selection

The selection of feed for zoo animals is governed by several key criteria:

1. **Wild Diet Analogues:** Starting with a thorough understanding of an animal's natural diet facilitates the selection of feed items that closely mimic those found in their wild habitats.
2. **Local Availability and Nutrition:** Choosing ingredients that are nutritionally similar and palatable to those in the wild, yet readily available in the region, ensures practicality in feeding regimes.
3. **Seasonal Variability and Storage:** The perennial availability of key ingredients, along with the use of dry ingredients and pellet feeds that can be stored for extended periods, addresses seasonal fluctuations in nutritional content and availability.
4. **Pellet Feed:** Appropriately sized pellet feeds can provide balanced nutrition with high palatability and serve dual purposes in training and medication administration, reducing stress on the animals.
5. **Seasonal Nutritional Optimization:** Making silage from high-nutritive-value green fodder during peak seasons ensures that animals receive quality feed throughout the year, compensating for seasonal variations in fresh feed quality.



- 6. Supplementation:** The inclusion of multi-vitamin and multi-mineral supplements, with a focus on critical nutrients such as Vitamin E and selenium, supports the overall health and physiological demands of the animals, especially those with higher nutritional requirements (Fig. 7,8).
- 7. Economic Considerations:** The cost of feed procurement is a significant aspect of zoo management, necessitating careful budgetary planning and allocation.

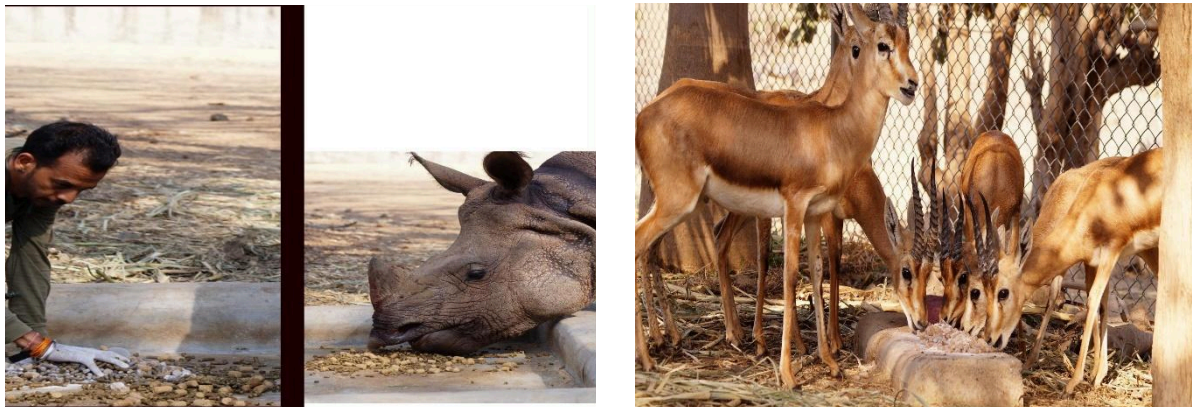


Fig. 7, 8: Provision of specially designed pellet feed with supplements to Indian one horned Rhinoceros and India Gazelle. Photographs taken by Kapil Bariya.

Addressing Nutritional Gaps for Exotic Species

For exotic herbivores, a deeper investigation into their natural diets and the nutritional composition of their native habitats is essential. Soil composition, for instance, plays a crucial role in the nutritional value of plant-based diets. Animals native to regions with selenium-rich soils may suffer deficiencies when fed diets sourced from areas with lower selenium levels, potentially leading to health issues such as dental and gingival problems. This underscores the importance of tailoring diets to address the specific nutritional nuances and requirements of each species, ensuring their long-term health and well-being in captivity.

Presentation of feed

The manner in which feed is presented to captive herbivores at zoos is a critical aspect of their care, significantly influencing their natural behaviours and overall well-being. For browsing animals, it is essential to place fodder at heights that mimic their natural browsing activity, promoting behaviours observed in the wild (Fig.9,10) Implementing grass dispensers or feed stations that replicate these



conditions encourages such naturalistic behaviours. Furthermore, to prevent overcrowding and ensure equitable access to food, the number of active feed stations should be proportionate to the animal population within an enclosure.



Fig. 9: Green fodder presented to four horned antelope and thamin deer through hay manger to imitate act of browsing. Photograph taken by Krunal Trivedi.



Fig. 10: Presentation of Green fodder over wooden logs to Indian Gazelle. Photograph taken by Vaibhav Kansara.

Considering the diurnal nature of many herbivores, aligning feeding times with daylight hours optimizes their dietary intake and behavioural rhythms. Offering concentrates with high protein content, such as pellet feed and Bengal gram, early in the day leverages the animals' peak activity periods. This approach not only facilitates the effective administration of medications via highly palatable feeds but also supports the animals' ability to process and utilize protein-rich diets throughout the day.

At the same time, legumes such as Bengal gram must be soaked for at least 24 hours before offering it to the animals. Paul (2010) established that soaking bengal gram for an extended period of time improved the nutritive value by increase in Vitamin C, E, B-complex and resulted in decreased incidences of flatulence. The author also observed a gradual decrease in the availability of protein but the hydrolysis of proteins into simpler compounds such as polypeptides, peptides and amino acids, heightened its digestibility.

The provision of dry fodder within the enclosures should be carefully managed to meet, but not exceed, the collective nutritional requirements of the inhabitants (Fig. 11). Splitting the total green fodder into two servings, distributed mid-day and early evening, prevents the rapid consumption of the entire day's ration, encouraging sustained feeding behaviours and better mimicry of natural grazing patterns.



Fig. 11: Provision of ad-lib dry fodder (hay) to Blackbuck. Photograph taken by Kapil Bariya.

A notable observation at SPZP highlighted an important consideration in feed management: the presentation of green fodder. It was found that presenting whole stems led to significant wastage, with animals consuming only the leaves and discarding over 30% of the feed's total weight. In contrast, offering chaffed fodder reduced wastage to below 10%, making it a more economical and environmentally sustainable practice (Fig. 12,13). While acceptance of chaffed fodder varies by zoo, depending on specific animal preferences and institutional policies, SPZP's experience highlights the importance of constantly assessing and adapting feed presentation methods to improve efficiency, reduce waste, and promote captive herbivores' health and natural behaviours.



Fig. 12: Chaffed feed consisting of hybrid napier, maize, lucerne and Bengal gram. Photograph by Jenish Panchal.

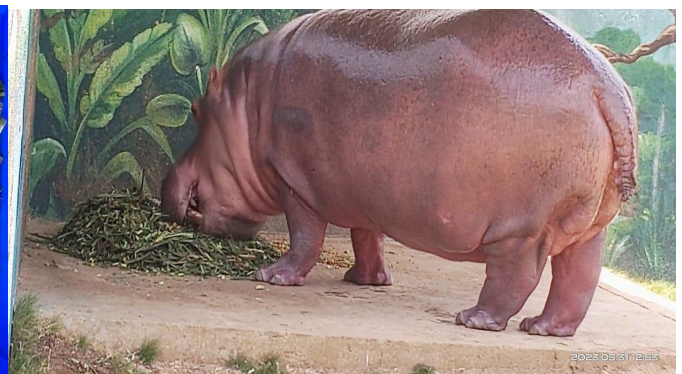


Fig. 13: Hippopotamus being fed chaffed fodder. Photograph by Ushma Patel.



Adapting feeding strategies to closely align with herbivores' natural habits and preferences not only benefits their physiological health but also plays an important role in behavioural enrichment, which is a key component of holistic animal care in zoos. By carefully organising feed presentation, zoos can significantly improve the overall welfare of their herbivore populations, highlighting the complex relationship between nutrition, behaviour, and conservation in captive animal management.

Conclusion

The strategic presentation of feed to captive herbivores at SPZP emphasises the importance of mimicking natural behaviours through tailored feeding techniques. At SPZP, we promote naturalistic behaviours and improve the well-being of its herbivore residents by adjusting the height at which fodder is offered, managing feed distribution to avoid overcrowding, and aligning feeding times with the animals' diurnal nature. The discovery that chaffed fodder significantly reduces waste highlights the importance for zoos to constantly evaluate and adapt their feeding strategies, balancing economic and environmental sustainability with the nutritional and behavioural needs of the animals. This approach not only promotes the physiological health of captive herbivores, but it also improves their overall welfare, emphasising the importance of careful feed management in zoo animal care.



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About the Authors

Chetan Patond is a veterinary surgeon and has been contributing to the rescue of animals involved in human-animal conflict in India, mainly tigers, leopards and sloth bears. He specialises in wildlife anaesthesia and is interested in formulating diets for captive wildlife. He is the curatorial officer at the Sardar Patel Zoological Park, Ekta Nagar, Gujarat.

Ushma Patel is a veterinarian with extensive experience working with native and exotic birds, reptiles and mammals. Beyond her expertise in avian orthopaedics, she is also interested in zoo animal nutrition, education and outreach, and research. In the past she has assisted various NGOs involved in wildlife rescue and rehabilitation.

Soham Mukherjee is a herpetologist and wildlife biologist specialising in crocodiles and venomous snakes. He has worked as a full-time wildlife rehabilitator with a wide range of taxa including reptiles, mammals, birds and arachnids. He has been involved in both in situ and ex situ management projects for the conservation of endangered species. He is particularly interested in conservation breeding, behaviour and cognition, enrichment in captivity and human-wildlife interactions. He is a member of the IUCN-SSC Crocodile Specialist Group, Viper Specialist Group and Snake Specialist Group and has extensive experience in snakebite and human-crocodile conflict mitigation. He currently works as a specialist consultant to zoos and conservation centres.