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Update on Rhinoceros Nutrition

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Human greed and ignorance have led to devastation in dwindling wild populations; basic knowledge of preventative health care is integral when rhinoceros are maintained in managed populations. Although nutrition under human care never replicates the variety and exact composition of wild rhinoceros diets, informed feeding practices will serve to complement behavioral and reproductive health. Several references exist on basic rhinoceros nutrition, including previous iterations of the current text.[1–3] Much nutrition research in the past 5–10 years has focused on the challenges of feeding rhinoceros under human care, characterizing disease issues, and illustrating novel approaches. Researchers strive to make practical connections between nutrient absorption, subsequent physiologic and metabolic interplay, and repercussions on reproduction and disease. Nutrient research in rhinoceros continues to be necessary as the complex interactions of feedstuffs, genetics, and digestive physiologic needs of each species continue to be discovered.

Generalized Recommendations for Feeding Rhinoceros Under Human Care

Rhinoceros consist of five extant species, the black *(Diceros bicornis)*, white *(Ceratotherium simum)*, Sumatran *(Dicerorhinus sumatrensis)*, Indian or greater one-horned rhinoceros *(Rhinoceros unicornis),* and the Javan or lesser one-horned rhinoceros *(Coelodonta antiqitatis).* Rhinoceros are large herbivorous mammals that currently have all species on the International Union for Conservation of Nature Red List of Threatened Species, with three species classified as critically endangered.[4] They are primarily in danger from human poaching for their keratinous horn and habitat loss. Herbivorous feeding strategies vary across species, with Sumatran, Javan, and black rhinoceros as browsers, white rhinoceros as grazers, and Indian rhinoceros classified as intermediate feeders. Current worldwide population estimates (2017) are 60–63 Javan, 100 Sumatran, 3500 Indian, 5042–5455 black, and 19,682–21,077 white rhinoceros.[4] Javan and Sumatran rhinoceros are currently primarily maintained in national parks in Indonesia, and this review will not focus on nutrition of these species under human care.

Although base nutrient recommendations in all extant rhinoceros species have not been significantly altered in recent history, research in the past 10–15 years has added specific knowledge based on species' physiologic idiosyncrasies. Nutrient requirements have not been specifically detailed for each rhinoceros species; however, the horse is considered the closest digestive model used for intake recommendations. Horse digestion and absorption have been compared with rhinoceros species, with most applicability nutritionally for white and greater one-horned rhinoceros, as compared with black or Sumatran.[5] Rhinoceros have been recommended to be fed 1%–3% of their body weight (BW) on an as-fed basis (1%–2% on a dry matter [DM] basis). It must be emphasized that a maximum of one-third of total calories comes from a pelleted concentrate.[1,3,6] Pelleted concentrate may vary in energy (calorie) content, especially compared with hay species, which possibly should be avoided while estimating that pellets themselves should be one-third of the diet. Monitoring of energy intake is critical to maintaining healthy BW in all species.

Good-quality forages (hay and browse) should provide primary nutrients for rhinoceros under human care, with concentrate feeds used to balance energy, protein, mineral, or vitamin needs.[2,6] For browsing or intermediate species, maximizing the amount of browse offered will be ideal; however, replicating natural browse variety consumed in the wild is likely not practical or possible. All rhinoceros are adapted to use energy from fibrous plant material through microbial fermentation. Animals should have ad libitum access to hay, clean water, and salt.[7] Feedings should be at least twice daily due to relatively fast transit time.[1] Trace mineralized salt would not be recommended, especially for iron-sensitive species such as black and Sumatran rhinoceros. Diets should be balanced through prioritizing adequate roughage, limiting pelleted compound feeds, and designing with mineral needs in mind for each species. It should also be emphasized that not all pelleted feeds are the same or interchangeable in terms of nutrients, and use of cereal grain in pellets for all these species should be minimized. Abrasive pellets have been postulated to be connected to dental damage and tooth wear in rhinoceros under managed care, unlike wild counterparts.[8] However,

TABLE 99.1 Mean Serum Mineral and Vitamin Values (±SD; N) for Black Rhinoceros Held Under Human Care or Free Ranging

Parameter	Units	Under Human Care (1999–2016)*	Under Human Care†	Free-Ranging†	Under Human Care[13]
Vitamin E	µg/mL	1.0 (0.9; 198)	0.84 (1.0; 85)	0.6 (0.2; 86)	
Vitamin A	ng/mL	43.2 (28.3; 172)	80 (80; 85)	40 (10.0; 86)	
Vitamin D	nmol/L	174.1 (43.3; 54)	0.24 (0; 2)		
Na	mEq/L	130.3 (14.9; 354)	131.0 (7; 12–34)	145.2 (10.8; 27)	133 (3; 81)
K	mEq/L	4.6 (0.4; 350)	5 (1.0; 12–34)	4.9 (0.6; 27)	4.7 (0.6; 82)
Cl	mEq/L	96.0 (2.7; 125)			96 (0.3; 82)
Ca	mg/dL	12.2 (0.7; 354)	12.7 (2.8; 12–34)	13.9 (2.8; 27)	12.7 (1.0; 90)
P	mg/dL	4.3 (1.2; 352)	4.1 (1.1; 12–34)	3.4 (1.2; 27)	4.8 (1.1; 90)
Mg	mg/dL	2.5 (0.3; 353)	2.1 (0.6; 12–34)	3.0 (0.9; 27)	3.3 (3.5; 27)
Co	ng/mL	1.0 (0.8; 115)			
Cu	µg/mL	1.4 (0.3; 344)	2.1 (0.7; 12–34)	1.5 (0.4; 27)	
Fe	µg/dL	208.1 (54.1; 374)	270.0 (11.1; 12–34)	215 (61.0; 27)	227 (66)
Mn	µg/mL	30.4 (82.6; 115)	0.001 (0.001; 12–34)	0.007 (0.004; 27)	
Mo	ng/mL	16.6 (13.5; 115)	22.1 (13.8; 12–34)	5.5 (4.1; 27)	
Zn	µg/mL	0.9 (0.1; 344)	1.6 (1.3; 12–34)	1.6 (0.4; 27)	
Se	µg/mL	114.7 (12.1; 114)	195.4 (56.1; 12–34)	114.8 (37.4; 27)	

*Unpublished data from black rhinoceros under the care of Disney's Animal Kingdom (1999–2016).
†All vitamin values (see reference 12); all mineral values (see reference 11).

excessive starch and sugar content in some pellets and produce may also be connected to this common issue of severe dental plaque in rhinoceros under human care. Black rhinoceros appear particularly prone to proliferative gingivitis, not always associated with degree of calculus accumulation, also indicating dietary challenges.[3] Therefore forage and browse, dependent on species, are integral to long-term health maintenance. It should be noted that browse silage has been successfully fed to white and black rhinoceros species but may not be a practical production product due to labor and cost.[9,10]

Although supplementation needs are limited in rhinoceros under human care, attention should be paid to mineral and vitamin balance in the diet for these species. For example, vitamin E in circulation appears lower across rhinoceros species compared with other mammals.[1] It should be ensured that total dietary vitamin E levels reach the 150–200 IU/kg diet mark recommended by Dierenfeld for all rhinoceros species.[1] Regular monitoring of vitamin and mineral serum status in rhinoceros may serve to refine recommendations for feeding; however, bioavailability across feed items for these nutrients is often variable. Reference values for animals both under human care and free ranging for minerals and vitamins may serve as guidelines, but regular testing within institutions is critical for individual evaluations (Tables 99.1 and 99.2). Best practices are recommended in the species-specific sections later.

For all species, regular monitoring of BW and condition is also recommended because obesity under human care is well recognized as a risk factor and health detractor across species. Use of body condition scoring (BCS) with a team of animal caretakers with varied exposure to the animal (keeper, veterinarian, nutritionist, manager, etc.) will better maintain health goals during growth, pregnancy, or maintenance. Communication across institutions to standardize BCS would also be beneficial due to its practical application across disciplines.[14]

Rhinoceros milk, as described by Blakeslee and Zuba (2002), describes a low level of total solids, high sugar, low fat, and moderate protein that may be formulated for hand-raising rhinoceros successfully using cows' milk or commercial milk replacer (Zoologic Milk Matrix 20/14, PetAg, Inc. Hampshire, IL).[15] Analysis of milk across three lactation period of a white rhinoceros found similar overall nutrient values for fat and protein but altered fatty acid composition compared with Milk Matrix 20/14, with higher levels of capric, lauric, and myristic acid.[16] Guidelines for colostrum feeding of neonates and subsequent feeding rates are clearly reviewed in the previous edition of this volume and used with success at institutions across white, black, and Indian rhinoceros species.[3]

TABLE 99.2 Mean Serum Mineral and Vitamin Values (±SD; N) for White Rhinoceros Held Under Human Care or Free Ranging

Parameter	Units	Under Human Care (1999–2016)*	Under Human Care†	Free-Ranging†	Under Human Care[13]
Vitamin E	µg/mL	0.9 (0.6; 118)	0.6 (0.48; 57)	0.8 (0.3; 5)	
Vitamin A	ng/mL	60.5 (59.7; 100)	70 (40.0; 57)	60 (20.0; 5)	
Vitamin D	nmol/L	155.6 (50.1; 49)			
Na	mEq/L	131.4 (13.1; 120)	146.7 (28.9; 2–3)	123.8 (4.0; 4)	134 (5; 74)
K	mEq/L	4.3 (0.5; 120)	4.8 (0.5; 2–3)	4.2 (0.3; 4)	4.7 (0.8; 74)
Cl	mEq/L	93.8 (2.6; 79)			95 (4; 74)
Ca	mg/dL	11.5 (1.3; 120)	13.9 (2.2; 2–3)	10.6 (1.6; 4)	11.8 (0.9; 78)
P	mg/dL	4.3 (1.2; 118)	4.0 (1.2; 2–3)	3.6 (0.9; 4)	4.0 (0.9; 76)
Mg	mg/dL	2.7 (0.4; 119)	2.4 (0.4; 2–3)	2.1 (0.4; 4)	
Co	ng/mL	0.5 (0.3; 66)			
Cu	µg/mL	1.4 (0.3; 108)	2.5 (1.3; 2–3)	1.2 (0.2; 4)	
Fe	µg/dL	144.2 (35.8; 113)	166 (23.0; 2–3)	177 (66.0; 4)	
Mn	µg/mL	6.4 (10.2; 60)	0.002 (0.002; 2–3)	0.003 (0.002; 4)	
Mo	ng/mL	19 (7.0; 68)	19 (0; 1)	28.3 (15.4; 4)	
Zn	µg/mL	0.8 (1.1; 108)	1.5 (0.3; 2–3)	1.4 (0.2; 4)	
Se	µg/mL	97.4 (29.5; 68)	232 (144.4; 2–3)	200.8 (46.1; 4)	

*Unpublished data from black rhinoceros under the care of Disney's Animal Kingdom (1999–2016).
†All vitamin values (see reference 12); all mineral values (see reference 11).

White Rhinoceros Nutrition

White rhinoceros should be offered high-quality grass hay (e.g., timothy, Coastal Bermuda grass) as their primary energy source, rather than legume hays (e.g., alfalfa/Lucerne). Horse requirements for nutrients offered apply to this species.[17] White rhinoceros in the wild have been documented consuming a variety of grasses dependent on season, with high levels of crude fiber (~36%) and low to moderate crude protein (4.5%–14.9% DM).[18,19] Monocot grass species available under human care are more limited than the wild. However, fresh grass and dry forage are still necessary as the predominant diet ingredient, rather than a high starch or protein pelleted feed. Produce is commonly used for training and enrichment; however, use of sugary items such as ripe bananas, corn, and melons should be discouraged, especially in excess.[20] All produce and diet items used for training should be tracked and accounted for as part of the animals' diet to avoid unintentional weight gains. White rhinoceros under human care have been documented with reproductive challenges.[21] High levels of digestible sugars and energy in captive diets are speculated to negatively impact energy and glucose response and promote obesity.[20] Lower glycemic index feed items produced similar glucose responses in white rhinoceros, whereas more work is needed to look at the impact of high-sugar training items on metabolic disturbances in this species.[20] White rhinoceros also appear to store vitamin E in adipose tissue rather than liver (as seen in black rhinoceros), potentially indicating antioxidant need in that tissue.[1] The interrelationship of diet impact on health and reproductive status continues to warrant investigation.

A recent study evaluated the impact of phytoestrogenicity of dietary components across multiple zoological institutions on breeding and reproductive success in white rhinoceros.[21] Dietary estrogenicity and fertility of captive-born female southern white rhinoceros had a low to moderate negative correlation across multiple institutions. Bermuda grass and timothy hay appeared to have lower estrogenicity than alfalfa or Sudan hay, or pellet extracts.[21] Limiting estrogenic compounds, although the impact on fertility is unclear, agrees with recommended feeding practices for white rhinoceros in terms of maximizing grass forage, or even fresh forage, without a need for high protein levels common in alfalfa hay or some pelleted diets. However, supplementation with a complete balanced pelleted feed is often needed under human care, especially considering seasonal needs and hay quality. It has been suggested to supplement with forage-based pellets rather than grain-based ones to achieve this balance.[6] An example of a forage-based pelleted diet used in a population with high reproductive success is described in Table 99.3.

TABLE 99.3 **Example of White Rhinoceros Diet Design With Energy Contributions at Disney's Animal Kingdom**

	% Total Diet		% Gross Energy of Total Diet		
Diet Item	Female	Male	Female	Male	Purpose
White Rhinoceros (Year-Round)					
Grass hay (Coastal Bermuda)	77.4	86.4	78.4	87.1	Maintenance
Grass hay–based Pellet*	11.4	9.1	11.0	8.7	Maintenance
Wheat bran/psyllium fiber	0.7	0.1	0.6	0.1	Supplement
Vitamin E—Emcelle Tocopherol†	0.1	0.1	-	—	Supplement
Alfalfa hay	7.2	2.6	7.0	2.5	Training
Timothy/alfalfa cube	1.4	0.9	1.4	1.0	Training
High starch/sugar pellet‡	1.7	0.7	1.6	0.6	Enrichment
Produce (apple/sweet potato)	0.1	0.1	—	—	Enrichment
Body condition score (1–5)	3.5	3.0			
Total weight diet (as fed kg)	27.1	38.2			
Total fed as % BW	1.4	1.7			

*Mazuri Zulife Browser Rhinoceros Cube (5Z1P) Mazuri, Land O'Lakes, St. Louis, MO.
†Stewart Products Inc. Bedford, TX.
‡Omolene; Purina, Land O'Lakes, St. Louis, MO/DAK Mazuri Petting Zoo (5MJZ) Mazuri, Land O'Lakes, St. Louis, MO.
BW, Body weight.

Greater One-horned/Indian Rhinoceros Nutrition

Indian rhinoceros have been found to benefit from more limited intake of no more than 1.1% of BW on a DM basis, due to a propensity for obesity and associated disease states of chronic foot problems and uterine leiomyomas under human care.[22] Even some roughage-only diets without added concentrates exceeded energy needs in a multiinstitutional digestibility study. This would suggest that ad libitum hay access may not be ideal for Indian rhinoceros.[22] Although this study confirmed that Indian rhinoceros diets that meet horse maintenance requirements for minerals are adequate, roughage-only diets will likely need a specific blend of mineral supplementation for balance, without added energy and protein.[23] This may be critical, considering possible connections between unknown excess zinc or biotin needs as they relate to foot issues in this species. Zinc and biotin supplementation has been shown to be integral to a complete mineral balance for hoof health in horses and potentially elephants, although not a cure all.[24,25]

Recent work comparing Indian rhinoceros offered a diet including fresh browse and forage with dried forage found health benefits in circulating nutrients with the diet including fresh herbage.[26] Access to fresh browse and forage is recommended to increase 25-hydroxy vitamin D and alpha tocopherol, although it also increased circulating nonesterified fatty acids, cholesterol, and triglycerides. Also demonstrated was variability in serum mineral levels probably related to bioavailability of minerals in different fresh or dried forage.[26] Work tracking plant species consumption in wildlife reserves in Manas National Park, Assam, India confirms previously reported adaptability of Indian rhinoceros as more of an intermediate feeder than their grazing white rhinoceros counterparts.[27] A total of 139 species of plant from 39 families were documented over 6 years (2008–2013) of observations, with only 24% of diet observed as grasses, and trees, shrubs, herbs aquatic plants, and agricultural products also represented.[27] This wide variety of diet emphasizes that, although Indian rhinoceros under human care are often considered primarily grazers, varying the forage and browse options may better optimize health, while keeping in mind the need to limit total dietary energy offered to this species. More work determining optimal balance of minerals and vitamins and impact on foot issues, as well as successful controlled diet plans to combat obesity, is recommended.

Black Rhinoceros Nutrition

Although diets offered to black rhinoceros under human care vary among institutions, recommendations about nutrient and diet specifics have been made specifically for black rhinoceros.[28] The captive diet appears to be a poor replica of the nutrient and antinutrient composition found in wild browse.[6] Compared with an all fresh browse diet in the wild, with more than 240 species of plants documented as consumed, most managed care institutions cannot offer

TABLE 99.4 Example of Black Rhinoceros Diet Design With Energy Contributions at Disney's Animal Kingdom

Diet Item	% Total Diet		% Gross Energy of Total Diet		Purpose
	Winter	Summer	Winter	Summer	
Male—Body Condition Score 3					
Browse*	26.8	30.6	14.3	11.6	Maintenance
Timothy hay	30.9	30.7	40.7	42.0	Maintenance
Coastal Bermuda grass hay	13.7	13.6	18.6	19.2	Maintenance
Grass hay–based pellet†	19.6	19.4	25.3	26.1	Maintenance
Wheat bran	1.0	1.0	—	—	Supplement
Vitamin E—Emcelle Tocopherol‡	0.1	0.1	—	—	Supplement
Sodium phosphate monobasic	0.1	0.1	—	—	Supplement
Greens§	4.1	4.1	0.2	0.2	Enrichment
Produce¶	3.0	2.9	0.5	0.5	Training
Other training items**	0.8	0.8	0.4	0.4	Training
Total weight diet (as fed kg)	31.3	31.5			
Total fed as % BW	2.5	2.5			

*Browse consists of three species in the winter (*Elaeagnus* and *Acacia* spp.) and three in summer (*Willow, Banana,* and *Pennisetum* spp.).
†Mazuri ZuLife Browser Rhinoceros Cube (5Z1P); Mazuri, Land O'Lakes, St. Louis, MO.
‡Stuart Products Inc. Bedford, TX.
§Greens include bok choy, romaine, kale, endive, and green leaf Lettuce.
¶Produce includes squash, celery, green beans, sweet potato, carrots, cauliflower, cucumber, zucchini, and bean paste.
**Other training items include pinecones, low-starch primate biscuit, and herbivore gel.
BW, Body weight.

substantial quantities of browse.[29] Black rhinoceros diets under human care may consist of pelleted feed, alfalfa and grass-legume mixes, browse, and ideally a minority of enrichment such as produce.[28] Alfalfa hay should be limited, due to high protein, calcium, and iron in many harvests, as well as creating diarrhea and colic.[2,3,28] Black rhinoceros develop iron overload disorder (IOD) under human care, where there is an excess of iron in circulation, measured repeatedly by iron biomarkers, and excessively stored, causing damage to tissues as demonstrated by necropsy.[28,30,31] There also may be a recently found mechanism of iron absorption in play in black rhinoceros, which uses plant ferritin, a protein holding up to 4500 atoms of iron, which exists only in legumes such as alfalfa and absorbs it whole through clathrin-mediated endocytosis.[32] The possibility that legume iron stores may be absorbed outside of typically understood regulated absorption in the gut may be a key factor in contributing to IOD in this species with a need for further study. As previously reviewed, excess generalized mineral supplementation should be avoided.[5] Although a well-formulated pellet should provide adequate phosphorus and not overly high calcium, extra supplementation as monosodium phosphate may be necessary, based on serum evaluations and for preventative reasons.

Essential in formulating complete diets under human care is limitation of high sugar and high vitamin C produce, both for concerns with obesity and metabolic syndrome, as well as increasing bioavailability of iron. Caution and tracking should be exercised to limit training items, as well as high sugar and high iron items like molasses. Pellet formulations for black rhinoceros are recommended to be low in starch and soluble sugars, with NDF values from 40%–60%.[28] An example of a successful diet for black rhinoceros under human care that improved measures of iron stores, primarily ferritin, is shown in Table 99.4.[33] Based on the practical limitations and availability of feed items such as low-iron pelleted feed and browse, iron concentration in the diet was recommended to not exceed 300 mg/kg DM or approximately 6 g of iron per day for a 1300 kg black rhinoceros fed 1.5% BW in DM.[2,28] The commercial process of milling grains produces high-iron pelleted commercial feeds, even in grain that is moderate in iron concentration.[17,34] There have been positive correlations found between amount of grain-based products in the diets of European-held black rhinoceros and omega-6 polyunsaturated fatty acids.[35] Excess levels of omega-6 fatty acids are established precursors to proinflammatory pathways, which could exacerbate inflammation in an already oxidant-sensitive species.

Much work has focused on diseases of unknown etiology in the black rhinoceros, many of which may be tied to inability to replicate wild nutrition for this species under human care. This appears to include the interplay of stress (both oxidant and environmental), improper fatty acid balance, lack of antioxidant, lack of polyphenolic antinutrients, excess of dietary iron, excess of starch and other glucose supplies, and inadequate fiber in a diet under human care.[11,28,35] Antioxidant and phosphate supplementation appear to be preventative diet supplements for black rhinoceros.[1] Physiologic findings indicate rhinoceros have a reduced capacity to neutralize oxidants, especially black rhinoceros.[36] Genetic testing of the black rhinoceros genome has identified specific mutations that may begin to explain the fragility of black rhinoceros red blood cells due to a mutation in their adenosine coding.[37]

Theories exist on interconnection of obesity, insulin/glucose metabolism, metabolic dysregulation, and connection to iron loading and inflammation in black rhinoceros under human care.[38] Baseline assays on banked samples from zoo-managed (n = 86) and free-ranging (n = 120) black rhinoceros were assessed for biomarkers of inflammation; with TNFα, serum amyloid A, insulin, insulin to glucose ratio, and ferritin found statistically higher in zoo-managed versus free-ranging populations.[38] This supports the need for investigation via longitudinal serial sampling in zoo-managed black rhinoceros into factors impacting inflammation, including nutrient and diet impact, as well as body condition and activity levels of these animals. Fluctuations of vitamin D with seasonal exposure to sunlight (highest in summer) have been seen, despite vitamin D supplementation in a pelleted feed year-round.[39] Vitamin D, a known genetic regulator across species, also may fit into the complicated picture of metabolic regulation in this species.

Comparisons between human iron overload and black rhinoceros IOD indicate that black rhinoceros IOD appears multifactorial, with both dietary iron intoxication and intrinsic metabolic dysregulation as possible contributors.[40,41] Although lowering dietary iron and increasing natural dietary chelators to combat IOD in black rhinoceros may be a valid preventative approach to one aspect of this disorder, classical human treatments of phlebotomy and iron-targeted synthetic chelation are equally valid options with varied success.[33,42] Measurements of iron biomarkers in free-ranging black rhinoceros ($n = 194$) found circulating ferritin values, the only known marker of iron storage in the liver, to be 290 ng/mL ± 18 ng/mL (mean ± SEM), markedly lower than common under human care.[43] A black rhinoceros ferritin species-specific test is currently under development based on a fully sequenced ferritin gene; however, assessment of iron load should be made using ferritin and transferrin saturation (serum iron/total iron-binding capacity).[44]

Chelators as a dietary therapy for IOD have been investigated. Condensed tannins (proanthocyanidins) are one of a larger array of phenolic compound classes, which may work to decrease iron absorption in the digestive tract.[45] It has been demonstrated that inclusion at 0.5%–1.5% of diet DM as quebracho (a proanthocyanidin), but not tannic acid (a hydrolysable tannin), increased total antioxidant capacity but did not affect the apparent absorption of iron.[46,47] Using natural sources of tannins, such as grape pomace or tea leaves, there is doubt on the ability to supplement enough phenolic compounds to mimic levels observed in wild diets.[6] Grape seed extract was added as a form of natural chelator to both horse and black rhinoceros fecal continuous culture, analyzing impact on the fecal microbial population.[48] Grape seed extract did not change nutrient digestibility or fermentation, and similar microbial populations were found between species; the increased inclusion of the extract did increase condensed tannins and iron-binding capacity and stimulated microbial growth.[48] Although there were no negative effects on the hindgut in vitro, more research is warranted to understand in vivo effects, including possibly binding and limiting absorption of microminerals. Recent work examined the use of an iron-specific drug chelator, known as HBED (N,N′-Bis(2-hydroxybenzyl) ethylenediamine-N,N′-diacetic acid), for oral use to increase iron excretion in black rhinoceros under human care.[42] The chelator was effective in increasing iron excretion through urinary output; however, due to one study, animal's post study health crisis, administration of HBED is not recommended for black rhinoceros with documented health problems.[42] Iron-specific synthetic chelators may still provide a future for preventative solutions, perhaps at lower or tapered doses.[42] Although IOD is not the only chronic disease state affecting black rhinoceros long term under human care, understanding the interplay between inflammatory pathways and disease progressions may lead to more concrete diet design for black rhinoceros. Future research must integrate practical husbandry concerns with epidemiologic perspective. Veterinarians, nutritionists, and husbandry professionals may then approach IOD preventative measures with a similar mindset that emphasizes sharing and centralizing information.

Nutrition Moving Forward

Taking a preventative approach and trying to think long term in nutritional care serve to minimize nutritionally related disease states. Working across disciplines and thinking of how nutrition, reproduction, behavior, and genetics are integrated in rhinoceros metabolism are necessary to move to sustainable populations. Practical diet guidelines serve as a starting off point for balancing rhinoceros diets to maximize animal health.

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