HORNBILL DIETS AT SAN DIEGO ZOO GLOBAL: A REVIEW

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Abstract

Hornbills (Bucerotidae) are a family of birds that include 14 genera and 54 species spanning sub-Saharan Africa and Southeast Asia.[7] They are easily identified by their long decurved bill and casque.[7] The smallest hornbills range in body weight from 83-135 g (Black dwarf-hornbill, *Tockus hartlaubi*; Red-billed dwarf hornbill, *Tockus camurus*) while the largest can reach body weights of 2230-4580 g (Northern, *Bucorvus abyssinicus*, and Southern, *Bucorvus leadbeateri*, ground-hornbills).[7] Additionally, hornbills span the range of feeding ecology from highly frugivorous to highly carnivorous.[6]

San Diego Zoo Global (SDZG) currently houses 15 species of hornbills at the San Diego Zoo and San Diego Zoo Safari Park with representative African and Asian species and those that span from highly frugivorous to highly carnivorous. Gamble et al., reviewed 486 hornbill necropsy records and documented 12% with iron storage diseases as the cause of death.[5] A recent mortality review of 14 hornbill species in the SDZG collection identified 10 species which had individuals with iron storage disease as a contributing factor or the cause of death of 14-60% of the individuals (Burns, personal communication). With this incidence of iron storage disease a review of the SDZG hornbill diets was warranted.

Of the 15 hornbill species housed at SDZG, seven unique diets were identified (Table 1). The nutrient composition of those diets were determined using an in-house diet evaluation program (Table 3) and compared to recommended nutrient concentrations for psittacines and passerines.[1]

Comparing the diets fed to the most frugivorous hornbills at SDZG to the survey information by Foeken et al. (Table 2), the SDZG Diets 1-3 contained less in fruit and vegetables and greater in concentrates, meat, rodents and insects.[3] All seven diets (Table 3) had adequate crude protein (CP) content compared to psittacines and passerines requirements and greater than the 10.8% dietary CP determined to be sufficient to meet nitrogen balance.[1,2] The predominantly carnivorous diets (Diets 6 and 7) had more than 150% of the protein requirement of cats at maintenance, gestation and lactation.[9]

Iron content in all seven diets (Table 3) was greater than the suggested 50-100 ppm DM for hornbills to prevent iron storage diesese.[4] Manganese of all diets was below the recommended 65 ppm for psittacines and passerines.[1] Vitamin K was below the recommended concentrations in Diets 6 and 7 (Table 4). Vitamin K can be synthesized in the intestines and birds that have access to their feces decreases the dietary need.[8] Choline was deficient in Diets 1 and 3. The majority of the choline in the other diets was being supplied by the Zoo Carnivore Diet. Biotin was deficient in Diet 3. This is in part due to the lack of information on the biotin concentration of the produce items in the diet. There are some fruits that are particularly good sources of

biotin.[8] Folic acid was deficient in Diet 3. The other diets are adequate in folic acid due to the addition of the Zoo Carnivore Diet in the diets.

For the diets that are being fed to the most frugivorous birds (Diets 1-3), reformulation of the diets need to be done to reduce the iron content to less than 100 ppm. Although dietary iron is important to reduce the risk of iron storage disease, there is a need to improve manganese concentrations in all diets and ensure that all nutrient requirements are met.

Literature cited

1. Association of American Feed Control Officials. 1998. Nutrition expert panel review: new rules for feeding pet birds. Feed Management 49(2): 23-25.
2. Foeken, S.G., M. de Vries, E. Hudson, C.D. Sheppard, and E.S. Dierenfeld. 2008. Determining nitrogen requirements of *Aceros* and *Buceros* hornbills. Zoo Biol. 27:282-293.
3. Foeken, S.G., M. de Vries, and T.R. Huisman. 2006. An overview of captive Aceros and Buceros hornbill diets in some Dutch and US facilities. In: Zoo Animal Nutrition vol. III, A. Fidgett, M. Clauss, K. Eulenberger, J-M. Hatt, I. Hume, G. Janssens, and J. Nijboer, eds. Filander Verlag, Furth, Federal Republic of Germany. Pp 49-53.
4. Galama, W., C. King, and K. Brouwer. 2002. EAZA Hornbill Management and Husbandry Guidelines, 1st ed. The EAZA Hornbill TAG. http://www.coraciiformestag.com/Research/Hornbill/EAZA_Hornbill_Management. pdf.
5. Gamble, K.C., M. Garner, and C. Wolf. 2012. Iron storage disease susceptibility profiles in Asian hornbills. Proc. AAZV Conf. 2012:187-189.
6. Kemp, A.C. 1995. The Hornbills. Oxford University Press, New York.
7. Kemp, A.C. 2001. Family Bucerotidae (Hornbills). In: Handbook of the Birds of the World, vol. 6. Mousebirds to Hornbills. J. del Hoyo, A. Elliott, and J. Sargatal, (eds.). Lynx Edicions, Barcelona.
8. Klasing, K.C. 2000. Comparative Avian Nutrition. CABI Publishing, New York.
9. National Research Council. 2006. Nutrient Requirements of Dogs and Cats. The National Academies Press. Washington, DC.

Table 1. Ingredients of hornbill diets fed at San Diego Zoo Global.

	Hornbill Diets[1]						
Diet ingredients (as-fed)	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Weight Control for Dogs, soaked, g[2]	68	12	0	12	48	0	130
Scenic, Mixed Jungle pellets, soaked, g[3]	47	16	61	16	32	0	0
Zoo Carnivore Diet 5, g[4]	32	46	0	46	46	227	227
Hornbill Fruit Mixture, g[5]	180	15	90	15	15	0	0
Banana, without peel, g	53	12	15	12	18	0	0
Grapes, g	36	12	12	12	15	30	0
Fig, dried, g	30	0	0	0	31	0	0
Fig, dried, ground, g	30	15	15	0	15	0	0
Yams, chopped, steamed, g	60	15	15	15	15	0	0
Mouse, fuzzie, g	4	8.6[8]	0	8.6[8]	12	162.4	101.5
Cricket, adult, g[6]	3	8	8	8	8	1.4	1.4
Mealworm, larvae, regular, g[7]	1.6	1.6	2	1.6	1.6	0.8	0.8
Total, g as-fed/d	544.6	156.3	218.0	141.3	256.6	421.6	460.7

[1]Diet 1: Wreathed (*Rhyticeros undulatus*), Papuan (*Rhyticeros plicatus*), Yellow-casqued (*Ceratogymna elata*), Great (*Buceros bicornis*), Red-knobbed (*Aceros cassidix*), Wrinkled (*Aceros corrugatus*), Javan Rhinoceros (*Buceros rhinoceros silvestris*); Diet 2: Black-casqued (*Ceratogymna atrata*), Southern Sulawesi Tarictic (*Penelopides exarhatus sanford*), Black (*Anthracoceros malayanus*); Diet 3: Trumpter (*Bycanistes bucinator*); Diet 4: Eastern Yellow-billed (*Tockus flavirostris*); Diet 5: West African Long-tailed (*Tropicranus albocristatus albocristatus*); Diet 6: Abyssinian Ground Hornbill (*Bucorvus abyssinicus*); Diet 7: Southern Ground Hornbill (*Bucorvus leadbeateri*).
[2]Iams ProActive Health Adult Weight Control, 45% dog food, 55% water.
[3]Marion Zoological, Plymouth, MN 55441, 68% Mixed Jungle, 32% water.
[4]Dick Van Patten's Natural Balance Pet Foods Inc., Pacoima, CA 91331.
[5]Apples, pears, honeydew melon, and papaya.
[6]*Acheta domesticus*.
[7]*Tenebrio molitor*.
[8]Offered 3 d/wk.

Table 2. Ingredient type in hornbill diets fed at San Diego Zoo Global.

Item, % of total as-fed weight	Hornbill Diets[1]							Average	Aceros and Buceros species[2]
	1	2	3	4	5	6	7		
Fruit[3]	60.4	34.6	60.6	27.6	36.6	7.1	0.0	32.4	60.6
Vegetables[4]	11.0	9.6	6.9	10.6	5.8	0.0	0.0	6.3	16.6
Concentrates[5]	21.1	17.9	28.0	19.8	31.2	0.0	28.2	20.9	18.1
Meat[6]	5.9	29.4	0.0	32.6	17.9	53.8	49.3	27.0	7.8
Rodents	0.7	2.4	0.0	2.6	4.7	38.5	22.0	10.1	-
Insects[7]	0.8	6.1	4.6	6.8	3.7	0.5	0.5	3.3	1.8
Eggs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7
Supplements[8]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Miscellaneous[9]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2

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[2]Foeken et al., 2006.
[3]Hornbill fruit mixture, banana, grapes, and figs.
[4]Yams.
[5]Dog food and Scenic mixed jungle pellets.
[6]Zoo Carnivore Diet.
[7]Crickets and mealworms.
[8]Foeken et al., 2006 included mineral and vitamin supplements.
[9]Foeken et al, 2006 included tofu, rice, gelatin and pig lard.

Table 3. Proximate nutrients and mineral composition of hornbill diets fed at San Diego Zoo Global.

Diet Nutrients (DM basis)	Hornbill Diets[1]							Recommended concentrations[2]	
	1	2	3	4	5	6	7	Psittacine	Passerines
Protein, %	16.67	30.96	18.48	32.87	26.78	55.72	45.75	12	14
Lysine, %	0.91	1.83	0.96	1.95	1.46	2.28	2.29	0.65	0.75
Methionine, %	0.34	0.62	0.37	0.67	0.53	0.74	0.8	0.3	0.35
Methionine and Cystein, %	0.56	1.01	0.65	1.08	0.86	1.18	1.24	0.5	0.58
Fat, %	6.28	12.81	6.09	13.6	10.51	24.69	19.81	NR[3]	NR
Ash, %	5.0	6.04	4.69	6.24	6.07	9.53	8.79	NR	NR
Ca, %	0.69	1.14	0.69	1.21	1.11	2.46	2.04	0.3-1.2	0.5-1.2
P, %	0.51	0.78	0.54	0.83	0.78	1.6	1.35	0.3	0.5
Ca:P ratio	1.35	1.46	1.28	1.46	1.42	1.54	1.51	1:1-2:1	1:1-2:1
K, %	1.32	1.17	1.15	1.17	1.07	1.03	0.97	0.4	0.4
Mg, %	0.10	0.11	0.12	0.11	0.11	0.11	0.11	0.06	0.06
Na, %	0.17	0.31	0.16	0.33	0.28	0.56	0.5	0.12	0.12
S, %	0.10	0.27	0.15	0.29	0.21	0.68	0.44	NR	NR
Fe, ppm	134.0	144.6	116.6	153.4	184.5	150.1	249.4	80	80
Zn, ppm	90.4	108.4	99.0	115.5	125.6	109.9	157.0	50	50
Mn, ppm	32.9	34.4	40.4	36.4	40.0	14.7	34.4	65	65
Cu, ppm	10.5	12.9	11.9	13.5	13.3	12.1	15.5	8	8
I, ppm	1.83	1.67	1.89	1.79	2.31	0.77	2.54	0.4	0.4
Se, ppm	0.19	0.31	0.2	0.33	0.28	0.36	0.41	0.1	0.1

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[2]Association of American Feed Control Officials, 1998.

[3]No requirement established.

Table 4. Vitamin composition of hornbill diets fed at San Diego Zoo Global.

Diet Nutrient (DM basis)	Hornbill Diets[1]							Recommended concentrations[2]	
	1	2	3	4	5	6	7	Psittacine	Passerines
Vit. A, kIU/kg	17.66	11.37	14.70	11.69	13.06	8.90	15.74	8.00	8.00
Vit. E, IU/kg	104	186	136	199	155	279	245	50	50
Vit. K, ppm	1.0	1.3	2.5	1.3	1.3	0.6	0.5	1	1
Vit. C, ppm	683	630	648	668	410	754	607	NR[3]	NR
Thiamin, ppm	6	8	4	9	8	9	12	4	4
Riboflavin, ppm	8	17	9	18	14	15	18	6	6
Pantothenic acid, ppm	24	35	20	36	32	36	45	20	20
Niacin, ppm	56	121	46	128	88	178	161	50	50
Choline, ppm	1254	2287	1107	2431	1887	2707	2932	1500	1500
Vit. B6, ppm	6.08	9.76	5.56	10.06	7.13	11.07	8.94	6	6
Biotin, ppb	278.6	650.2	124.3	695.7	494.8	1076.8	1049.0	250	250
Folic acid, ppm	3.46	11.52	0.67	12.31	7.03	21.62	17.84	1.50	1.50
Vitamin B12, ppb	73.7	137.5	18.9	147.1	121.9	197.6	258.1	10	10

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