

EVALUATING THE NUTRITION OF A FLOCK OF NON-BREEDING GREATER FLAMINGOS (*PHOENICOPTERUS RUBER ROSEUS*) AT THE SAN DIEGO ZOO SAFARI PARK

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Abstract

A flock of 150 greater flamingos (*Phoenicopterus ruber roseus*) at the San Diego Zoo Safari Park were moved to a new enclosure in 2010 to provide them a larger exhibit and to promote the breeding of lesser flamingos (*Phoeniconaias minor*) that shared the previous exhibit. Since the greater flamingos moved, they have not laid eggs through June 2015. A nutrition review of the greater flamingos was conducted in 2014 and 2015 and included an evaluation of the nutrient composition of the diet, diet disappearance studies, body weight monitoring, and review of blood minerals and vitamins. The greater flamingos received a fine-grounded custom-manufactured diet that has been fed for more than 15 yr without changes in nutrient specifications. The diet was lower in vitamin A and E than desired and higher in Se than needed. The two diet disappearance studies suggested that an adequate amount of food was disappearing to meet the birds' energy needs. The greater flamingos had lost an average 13.8% of their body weight between 2010 and 2014 and continued to lose weight in 2015. The serum minerals and vitamins were within reference values except, whole blood selenium was greater. This nutrition review suggested that the current dietary concentrations of vitamin A, vitamin E, and selenium should be evaluated.

Introduction

In January and February, 2010, the 150 bird flock of greater flamingos (*Phoenicopterus ruber roseus*) at the San Diego Zoo Safari Park were moved from an enclosure (~3531 m², 0.35 ha, 0.87 ac) they shared with ~ 100 lesser flamingos (*Phoeniconaias minor*) to a new and larger (~18,635 m², 1.86 ha, 4.6 ac) exhibit. The goals of moving the greater flamingos were to provide them a larger exhibit and to promote the breeding of the lesser flamingos. The lesser flamingos did start to breed in 2010 and have produced chicks each year through 2014.

From 1998 to 2009 the greater flamingo flock produced 173 chicks. Since the birds moved, they have not produced any eggs or chicks from 2010 to June 2015. The plan for this nutrition review was to 1) evaluate the nutrient content of the diet fed, 2) conduct a diet disappearance study, 3) monitor body weights, and 4) collect blood samples to evaluate nutrients.

Materials and Methods

Diet Review

The greater flamingo flock received a diet of 91.5% San Diego Zoo Global (SDZG) Flamingo 24 Fine (Western Milling, Goshen, CA 93227) and 8.5% Mazuri Waterfowl Maintenance/Breeder (Purina Mills, LLC., St. Louis, MO 63116). The waterfowl floating diet was provided to attract the birds and to get them close enough for daily visual evaluations. Samples of SDZG Flamingo

24 fine diets were collected (May and December, 2014) for nutrient analysis at commercial laboratories (Dairy One, Ithaca, NY 14850; Michigan State University DCPAH, East Lansing, MI, 48910). The results were compared to the product specifications and the Flamingo Husbandry Manual recommendations (Brown and King, 2005).

Diet Disappearance Study

Because there had been some weight loss recorded in a few birds that had been handled for medical or other reasons, two diet disappearance studies were conducted. During the first week (Study 1, 7 d), Animal Care staff fed the SDZG Flamingo 24 Fine diet in the building attached to the exhibit as they usually do and tossed the waterfowl diet on the water near shore. To determine if the birds did not like going into the building to eat, in Study 2, the flamingos were fed in 10 grey plastic tubs on the shoreline for 7 d and again the waterfowl diet was tossed on the water near shore. The diet offered was weighed daily and Animal Care staff collected and weighed the remaining diet, or the next day prior to feeding. The amount of food that disappeared was compared to a suggested DM intake of 2-4% of body weight (Brown and King, 2005) and to maintenance energy requirements for zoo (ME kcal/d = $115 \times \text{BW, kg}^{0.729}$; Robbins, 1993) and free-ranging (ME, kcal/d = $2.51 \times \text{BW, g}^{0.681}$, all birds equation; Nagy et al., 1999) birds.

Body Weight Monitoring

With the heightened concern that the greater flamingo flock had not been reproductive for more than 4 yr, three pairs of birds were removed from the new exhibit and returned to their old exhibit with the lesser flamingos in March 2014. In the process of moving the birds, it was realized that 2.2 birds had an average weight loss of 25% compared to January/February 2010. Opportunistic weights and weights during medical procedures were collected in December 2014 and May 2015 and compared to 2010 when the birds were moved to the new exhibit. Additionally, 15 (6.9) greater flamingos were introduced into the flock in 2011 to try to stimulate breeding. For 6 birds that were weighed 2015 plus 2 resident birds, weights collected in 2011 were used for calculate changes in body weight.

Serum Nutrient Evaluation

To evaluate the nutritional health of the birds, an initial three (0.3) greater flamingos had blood collected when they were moved back to their old exhibit in March 2014. Additional samples were collected from three (2.1) greater flamingos (vitamins only) in November 2014 and 13 (4.9) greater flamingos in December 2014. Blood was collected into acid-washed tubes (Becton, Dickinson, and Co., Franklin Lakes, NJ, 07417 USA) for serum mineral (Ca, Cu, Fe, Mg, P, K, Na, Se, Zn) and vitamin analysis (A and E) and K2 EDTA tubes (Becton, Dickinson, and Co., Franklin Lakes, NJ, 07417 USA) for whole blood selenium analysis. Banked serum samples from 30 flamingos collected in 2010 were analyzed for vitamin A (13 samples) and vitamin E (26 samples) to compare with samples collected in 2014.

Blood samples were analyzed at a commercial laboratory (CAHFS, Davis, CA 95617). Blood nutrient concentrations were compared to previous results of SDZG flamingos (unpublished data) and to those in the literature for flamingos (Benato et al., 2013; Brown and King, 2005; Dierenfeld, 1989; Schlegel et al., 2005; Teare, 2013a,b) and poultry (Puls, 1988). A paired t-test

(MS Excel) was used to determine if serum vitamin concentrations had changed over the 4 yr since the birds were in the new exhibit (2010 versus 2014) using the banked serum samples.

Results and Discussion

Diet Review

The custom SDZG Flamingo 24 diet is being fed to the greater flamingos and three other species of flamingos (Caribbean, *Phoenicopterus ruber ruber*; Chilean, *Phoenicopterus chilensis*; and Lesser) at the San Diego Zoo and San Diego Zoo Safari Park. The greater and lesser flamingos receive the fine particle-size product and the Caribbean and Chilean flamingos receive the product in a pelleted form. All but the greater flamingos have been reproductive in the last 4 yr. The SDZG Flamingo 24 diet specifications meet, exceed, or are within the range of nutrient concentrations recommended by the husbandry manual (Brown and King, 2005) except vitamin A (Table 1). The vitamin A specification (11,111 IU/kg DM) is 45% less than suggested by the husbandry manual (20,000 IU/kg DM) and has been formulated this way for more than 10 yr. Vitamin A deficiencies have not been a significant finding on flamingo necropsies. The lots of SDZG Flamingo 24 diet tested (Table 1) were slightly below product specifications for protein, calcium and phosphorus, but were within ranges suggested by Brown and King (2005). The sample analyzed for vitamin E (162.2 IU/kg) was more than 50% below the product specification (333 IU/kg) and below the suggested concentration by Brown and King (2005). The selenium concentration of the one sample analyzed (1.01 mg/kg DM) was 3 times the product specification (0.33 mg Se /kg DM), but toxicity starts at 5 mg Se/kg DM (NRC, 1994). Analysis of B vitamins in 2013 met or exceeded the product specifications, but vitamin A concentrations were lower than product specifications (data not shown). Based on husbandry manual guidelines, there are areas in the product specifications that need to be adjusted.

Diet Disappearance Study

Ninety-seven percent and 72% of the flamingo diet that was fed disappeared when offered in the barn or on the shore, respectively (Table 2). The birds readily consumed the waterfowl diet when tossed to them on the water. When the birds were fed in the building, 22% more feed disappeared than when fed on the shore. Based on the diet disappearing, the amount of dry matter consumed per bird was 7.5% and 6.1% of body weight for a 3-kg flamingo. This consumption is higher than the suggested 2-4% in the husbandry manual (Brown and King, 2005). Estimated energy consumption of both diet disappearance studies suggests that more than adequate amounts of diet were consumed to support the maintenance energy requirement of a 3-kg bird at a zoo or free-ranging (Table 2). It should be noted that these studies could not account for consumption by native wildlife (mallards, *Anas platyrhynchos*; and coots, *Fulica americana*) or the feed that got pushed out of the feeders and dropped in the water and not consumed.

Body Weight Monitoring

Three of the greater flamingos that were returned to their old exhibit in March 2014 were weighed again in November 2014 and had averaged a 21.1% body weight gain. In December 2014, when the main flock was being manually restrained for blood collection, 4.9 birds were weighed and the average weight loss was 13.8% (range 26.8% loss to 1.7% gain) compared to 2010. A female greater flamingo that arrived in 2011 to stimulate the flock to breed lost 18.5% from its arrival weight to 2014. To try to promote weight gain, the waterfowl breeder that was used previously, was replaced with Mazuri Flamingo Breeder (Purina Mills, LLC., St. Louis,

MO 63116) and 25% of the SDZG Flamingo 24 fine was replaced with the flamingo breeder increasing the crude protein 9%, the fat 13.6%, with a 1.8% increase in total energy. In May 2015, 40 greater flamingos were weighed again to see the effect of the diet change. Of the 30 (11.19) birds that moved in 2010 and had weights recorded in 2015, the average weight loss was 14.4% (range 28.1% loss to 7.4% gain). Of the 6 (3.3) birds that joined the flock in 2011 plus two resident (0.2) birds, the average weight loss was 6% (range: 18.5% loss to 6.5% gain) from 2011 to 2015. Two (0.2) birds that were weighed in May 2015 had not been weighed in 2010 or 2011 to allow similar comparisons.

Serum Nutrient Evaluation

The initial three (0.3) greater flamingos, sampled in April 2014, had greater serum P and K, compared to greater flamingo reference ranges (Teare, 2013a; Table 3). Selenium concentrations were higher in whole blood from both groups of Safari Park greater flamingos than the greater flamingos in the study by Benato et al. (2013) from the United Arab Emirates (UAE) and domestic poultry (Puls, 1988). The higher Se concentrations can be explained by the higher dietary Se. Serum Ca, Cu, Mg, Na, and Zn from the Safari Park flamingos were similar to reference values (Puls, 1988; Teare, 2013a,b).

The vitamin A concentrations in the serum from the three (0.3) flamingos bled in April 2014 were lower than those collected in November and December and lower than serum collected in 2010, but as a group, the vitamin A concentrations from 2014 were similar to 2010 and the reference values (Table 4). The serum vitamin E concentrations in all of the samples collected in 2014 were similar to 2010 and the reference values. Thirteen (3.10) flamingos had serum vitamin A and E samples from 2010 and 2014 to allow direct comparisons. There were no differences ($P = 0.23$) in vitamin A concentrations between 2010 and 2014 (0.59 mg/L versus 0.63 mg/L, respectively). The vitamin E concentration in the serum from 2014 (30.8 mg/L) was 15% greater ($P = 0.02$) than the serum from 2010 (26.5 mg/L).

Next Steps

It has been difficult to explain why, given the apparently adequate diet disappearance and appropriate serum nutrient profiles, the birds continued to lose weight. One explanation for the weight loss is due to increased activity. The greater flamingos were moved to an exhibit that was more than five times larger and the flamingos are spending more time swimming thus increasing their energy expenditure. The greater flamingos that moved back to their old exhibit regained most of the lost weight. The current SDZG Flamingo 24 diet appears to meet the nutritional needs of the Caribbean, Chilean and lesser flamingos as evidence by reproductive successes. Historically, the greater flamingos had reproductive success on the SDZG Flamingo 24 diet, but this nutrition review suggests that the current concentrations of vitamin A, vitamin E, and selenium should be evaluated.

Acknowledgements

The authors would like to thank bird keepers at the Safari Park for assisting in the catch-up and weighing of the flamingos and collecting data for the diet disappearance study, the Safari Park Veterinary Services and Clinical Laboratory team for collecting and processing the blood samples, and to David Granados in Nutritional Services for collecting feed samples for analysis.

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Table 1. Nutrient recommendations, product specifications and recent laboratory analysis of San Diego Zoo Global Flamingo 24 fine.

Nutrient	Husbandry	SDZG Flamingo 24 Fine		
	Manual Recommendations ¹	Specifications	Sample 2014.080	Sample 2014.212
Crude Protein, %	20-40	> 26.67	25.5	25.9
Lysine, %	NR ²	1.3	- ³	-
Methionine, %	NR	0.6	-	-
Methionine + Cystine, %	NR	1.0	-	-
Acid Detergent Fiber, %	NR	< 2.2	5.4	9.7
Crude Fat, %	NR	> 4.4	4.7	4.2
Linoleic acid, %	> 1	> 1.22	-	-
Ash, %	NR	< 11.1	10.7	9.5
Energy, ME, kcal/g	3.00	2.96 ⁴	-	-
Calcium, %	1-3	2.33-2.77	2.09	1.87
Phosphorus, %	0.5-1	> 0.94	0.79	0.73
Chloride ion, %	0.2	NS ⁵	0.63	0.26
Magnesium, %	0.1	> 0.28	0.28	0.25
Potassium, %	0.2	> 1.11	1.29	1.11
Sodium, %	0.2	> 0.28	0.35	0.22
Cobalt, mg/kg	0.2	NS	0.71	-
Copper, mg/kg	15	> 16.7	23	29
Iodine, mg/kg	0.5-1.0	> 1.11	-	2.27
Iron, mg/kg	50-100	> 111	320	268
Manganese, mg/kg	50-75	> 77.8	156	132
Selenium, mg/kg	0.2-0.3	> 0.33	-	1.01
Zinc, mg/kg	50-100	> 111	173	165
Vitamin A, IU/kg	20,000	> 11,111	-	-
Vitamin D, IU/kg	2000	> 2440	-	-
Vitamin E, IU/kg	200	> 333	-	162.2
Vitamin K, mg/kg	1	> 2.22	-	-
Thiamin, mg/kg	5-10	>5.6	-	-
Riboflavin, mg/kg	10-20	>8.9	-	-
Niacin, mg/kg	25-35	>111	-	-
Pyridoxine, mg/kg	10-20	>6.7	-	-
Vitamin B12, mg/kg	4	>33.4	-	-
Pantothenic Acid, mg/kg	10-20	>22.2	-	-
Folic acid, ppm	NR	NS	-	-
Biotin, ppb	NR	>278	-	-
Choline, ppm	NR	>1667	-	-

¹Brown and King (2005), ²No recommendations given, ³Not analyzed, ⁴Calculated using domestic poultry (NRC, 1994), ⁵No specification given.

Table 2. Food disappearance and intake of dry matter and energy from a flock of greater flamingos (*Phoenicopterus ruber roseus*) when fed in the barn or on the exhibit shoreline at the San Diego Zoo Safari Park.

Item	Study 1: Building	Study 2: Shore
SDZG Flamingo 24 fine		
Offered, kg	36.44	39.35
Orts, kg	1.00	10.85
Consumed, kg	35.44	28.50
Mazuri Waterfowl Breeder		
Offered, kg	3.54	3.62
Orts, kg	0	0
Consumed, kg	3.54	3.62
Intake per bird (157 birds in the flock)		
As-fed intake, kg	0.248	0.204
DM intake, kg ¹	0.223	0.184
DM intake, % of body weight ²	7.45	6.14
Energy intake, kcal ME ³	672	566
Requirement, Zoo, kcal ME/d ^{2,4}		253
Requirement, Free-ranging, kcal ME/d ^{2,5}		585

¹Assumes 90% DM.

²Based on a 3.0 kg flamingo.

³SDZG Flamingo 24 Fine, 2.66 kcal ME/g as-fed; Mazuri Waterfowl Breeder, 3.22 kcal ME/g as-fed.

⁴ME kcal/d = 115 x BW, kg^{0.729} (Robbins, 1993).

⁵ME, kcal/d = 2.51 x BW, g^{0.681} (all birds, Nagy et al., 1999).

Table 3. Blood mineral concentrations of San Diego Zoo Safari Park greater flamingos (*Phoenicopterus ruber roseus*) sampled in 2014 compared to concentrations found in the literature.

Element	SP 0.3 Greater Flamingos ¹ 3-4 April 2014		SP 4.9 Greater Flamingos ¹ 9 December 2014		UAE 21.15 Greater flamingos ²		Reference values
	mean	range	mean	range	mean	range	
Ca, ppm ³	98.7	91-110	116	98-130	- ⁵	-	102-180 ⁶
Cu, ppm ³	0.37	0-0.67	0.33	0.26-0.48	0.36	0.21-0.52	0.20-0.45 ⁷
Fe, ppm ³	1.07	0.6-1.8	1.02	0.65-2.30	-	-	NR ⁸
Mg, ppm ³	22.3	20-24	26.2	22-29	-	-	20.5-43.5 ⁹
P, ppm ³	77.7	65-91	47.5	22-78	-	-	21-60.9 ⁶
K, meq/L ³	5.3	2.6-6.9	3.28	2.2-4.0	-	-	1.8-3.2 ⁶
Na, meq/L ³	143.3	140-150	160.8	150-180	-	-	145-161 ⁶
Se, ppm ⁴	0.65	0.62-0.69	0.78	0.67-1.30	0.21	0.12-0.32	0.13-0.20 ⁷
Zn, ppm ³	1.80	1.1-2.2	2.40	2.0-3.3	2.08	1.39-2.71	1.85-3.40 ⁷

¹San Diego Zoo Safari Park.

²United Arab Emirates, Benato et al., 2013; conversions used: copper $\mu\text{M} \times 0.063546 = \text{mg/L}$; selenium $\mu\text{M} \times 0.07896 = \text{mg/L}$; zinc $\mu\text{M} \times 0.06538 = \text{mg/L}$.

³Serum.

⁴Whole blood.

⁵Not analyzed.

⁶Teare, 2013a.

⁷Puls, 1988.

⁸No reference value available.

⁹Teare, 2013b.

Table 4. Serum vitamin A and E concentrations of greater flamingos (*Phoenicopterus ruber roseus*) at the San Diego Zoo Safari Park sampled in 2010 and 2014 compared to concentrations previously analyzed at San Diego Zoo Global and those in the literature.

Species	Vitamin A, mg/L			Vitamin E, mg/L		
	<i>n</i>	mean	range	<i>n</i>	mean	range
SP Greater Flamingos (3-4Apr14) ¹	0.3	0.43	0.28-0.54	0.3	31.3	30-33
SP Greater Flamingos (29Nov14) ¹	2.1	0.78	0.68-0.90	2.1	22.0	21-24
SP Greater Flamingos (9Dec14) ¹	4.9	0.63	0.45-0.77	4.9	31.3	21-41
SP Greater Flamingos (2010) ¹	3.10	0.59	0.43-0.81	9.14	24.6	12-40
Referene values						
SP Greater Flamingos (1999-2002) ¹	4	0.58	0.51-0.62	4	24.2	18.4-28.7
DAK Greater Flamingos (1999-2003) ²	- ⁶	-	-	31	12.2	5.3-27.3
DAK Greater Flamingos (2004-2005) ²	-	-	-	26	46.3	13.2-110.8
UAE Greater Flamingo, males ³	21	0.46	0.26-0.77	21	12.8	4.6-19.1
UAE Greater Flamingo, females ³	15	0.47	0.32-0.72	15	14.6	9.4-26.7
Flamingo (2 <i>Phoenicopterus</i> spp.) ⁴	-	-	-	-	-	10.7-34.0
SDZG Lesser Flamingos (1995-1997)	-	-	-	27	22.4	1.3-57.7
UAE Lesser Flamingo, both ³	14	0.39	0.32-0.52	14	12.7	7.1-18.0
Lesser Flamingos ⁵	6	0.73	0.45-0.92	6	13.2	10.0-15.4
SDZ Caribbean Flamingos (1996)	-	-	-	28	46.8	16.8-73.1
Semi-free ranging Caribbean Flamingos ⁵	53	0.046	0.00312-1.443	53	19.0	4.3-38.9
Caribbean Flamingos ⁵	15	0.44	0.12-0.77	15	15.4	0.8-25
SP Chilean Flamingos (2003-2004)	50	0.82	0.45-1.47	50	58.2	24.9-140
Chilean Flamingos ⁵	55	1.23	0.16-2.29	55	21.2	0.5-34.3

¹San Diego Zoo Safari Park

²Disney's Animal Kingdom, Schlegel et al., 2005.

³United Arab Emirates; Benato et al., 2013; conversions used: vitamin A $\mu\text{M} \times 0.28645 = \text{mg/L}$; vitamin E $\mu\text{M} \times 0.43071 = \text{mg/L}$.

⁴Dierenfeld, 1989.

⁵Brown and King, 2005.

⁶Not analyzed.