A simple and effective egg-based hand-rearing diet for flamingos

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Abstract

An egg-based diet, composed of whole, peeled hard-boiled chicken eggs, with added hard-boiled yolks, water, and supplemental minerals, vitamins, and fat, was developed to duplicate the nutrient composition of crop milks fed to flamingo chicks. Dietary intake and growth were recorded in 44 Caribbean (*Phoenicopterus ruber*) and 21 Chilean (*P. chilensis*) flamingo chicks housed at four US zoological facilities. Feeding protocols, amounts fed, and significant developmental milestones are detailed. Diets made from fresh eggs, as well as dried egg product powders, appeared equally palatable and resulted in similar chick responses. Transition to adult diets was uneventful; this diet represents a practical, nutritionally balanced, and successful formula for hand-rearing flamingos.

Keywords

avian, crop milk, Ciconiiformes, growth

Introduction

Flamingos feed their young for up to six months of age with crop "milk", originating from esophageal glands (Studer-Thiersch, 1975). Along with several species of Columbiformes and some penguins, both sexes produce a prolactin-mediated secretion associated with brooding activities. Lipid droplets are

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incorporated into tissues lining the crop, and epithelial cells subsequently detach into the lumen if the crop, thus producing liquid nourishment for feeding chicks. Limited published information on flamingo crop secretions obtained from fed chicks aged approx 1 to 2.5 wks (reported in Van Bocxstaele 1974) to 6—10 wks of age (Ward et al. 2001) describes flamingo crop milk to be somewhat similar in proximate chemical composition to early pigeon milks (albeit much more variable): high in fat and protein, and low in carbohydrates (Table 1). Composition of crop milk likely varies with stage of development, but has not been examined in detail for flamingos. Nonetheless, a series of handrearing diets for transition to adult flamingo diets has historically been implemented in US zoo practices (Brown et al. 2005), often containing multiple ingredients and dilutions at different stages of growth; a typical example is found in Table 2. We describe here a simple, practical diet regimen that was used to raise both Caribbean (*Phoenicopterus ruber*) and Chilean (*P. chilensis*) flamingo chicks at four US zoological facilities, variously from hatch to ∼80 days of age.

Table 1: Crop milk composition from American flamingo chicks and pigeon squabs (average value; range in parentheses). Data from: Van Bocxstaele 1974, Ward et al. 2001, and Kirk-Baer and Thomas 1996.

	% Water	**% Fat** ←	**% Crude Protein** DM basis →
Flamingo (ages 1–10 wk)	85 (78–91)	58 (30–75)	35 (23–51)
Pigeon (age 1–3 da)	74 (73–74)	46 (46–47)	48 (47–49)

Methods

Diet An egg-based diet, with a single-batch recipe comprising 60 g hard-boiled whole eggs (without shell; 1 whole egg), 90 g hard-boiled egg yolks (4 yolks), 6 g corn oil, 2 g calcium carbonate ($CaCO_3$), 30 IU vitamin E, and 147.5 ml water, was blended into a liquid and stored under refrigeration for up to 24 hr prior to warming (35–37.8 °C) and tube-feeding. Although all facilities initially started with fresh eggs, due to logistical considerations, dry whole egg and egg yolk powders with additional water were substituted in feeding programs at

Table 2: Example historical formula(s) for hand-rearing flamingo chicks in US institutions (Pribble et al. 2003).

Flamingo Chick Rearing Diets Ingredient	**Diet 1 1–21 days % as fed**	**Diet 2 21–28 days**	**Diet 3 until weaned**
Silversides (*Menidia beryllina*)	7.5 (110 g)	7.5 (110 g)	5.5 (110 g)
Krill	5.5 (80 g)	5.4 (80 g)	5.4 (80 g)
Cooked egg yolk	4.4 (64 g)	2.2 (32 g)	
Human baby cereal	2.0 (29 g)	1.0 (15 g)	
Ground flamingo breeder pellet	1.9 (28 g)	5.1 (75 g)	8.4 (122 g)
Brewer's yeast	1.1 (16 g)	1.1 (16 g)	1.1 (16 g)
Vionate[1] vitamin supplement	0.3 (4.8 g)	0.3 (4.8 g)	0.3 (4.8 g)
Calcium carbonate	0.2 (2.4 g)	0.2 (2.4 g)	0.2 (2.4 g)
Water	77.1 (1125 g)	77.1 (1125 g)	77.1 (1125 g)

[1]Gimborn/Rich Health, Atlanta, GA
Mix in a blender to the consistency of latex paint.

both Riverbanks and Saint Louis Zoos to duplicate this formulation: 12.5 g dry whole eggs, 50 g dry egg yolk, 6 g corn oil, 2 g $CaCO_3$, 30 IU vitamin E, 237.5 ml water. The dry ingredients can be mixed in bulk and stored in the freezer. To mix a batch (or multiple batches), add liquids (oil, water) and allow to hydrate overnight in refrigerator before feeding. Mix well before and during feeding.

Samples of the final dry mixture were analyzed for proximate nutrient composition at Dairy One Forage Lab (Ithaca, NY), and amino acids were evaluated at the Amino Acid Laboratory (University of California, Davis, CA).

Animals and Rearing Protocols Daily intake and growth data of Caribbean flamingo chicks successfully raised on this formula were summarized from Riverbanks Zoo (Columbia, SC; $n = 15$), Birmingham Zoo (Birmingham, AL; $n = 14$); Saint Louis Zoo (St. Louis, MO; $n = 12$) and Bronx Zoo (Bronx, NY; $n = 3$). Chilean chicks reared included 18 birds from Birmingham Zoo and 3 from Bronx Zoo.

General husbandry protocols for all facilities followed those outlined in the Flamingo Husbandry Guidelines (Brown et al. 2005). In summary the husbandry included the following procedures:

Days 1-6: after chicks hatched, they remained in the hatcher until dried and fluffed out, then were placed into a warm brooder (temperature 36-37° C).

The umbilicus was treated with disinfectant for two days, and the first feeding occurred 24 hours post-hatch.

Feedings were spaced at 3-hour intervals for a total of 5 feedings/day: 0700, 1000, 1300, 1600 and 1900 hrs, with target weight gains no more than 10% of chick body weight per day. Birds were fed using syringes with catheter tips with flexible catheters attached. The catheters were cut to varying lengths depending on the bird's size, and cut ends of the catheters were gently heated to round the sharp edge before first use. Initially, (Days 1-4), chicks were fed a 2:1 (formula: water) diluted mixture, and may also need to be given extra hydration with lactated Ringer's solution. Chicks were weighed first thing each morning, and total amounts to be fed were determined prior to the first feeding of the day based on weight gains. If >10% of body weight was gained over 24 hr, dietary amounts were not increased in order to slow the rate of growth; otherwise, amounts fed were gradually increased to maintain steadily increasing weight curves. At day 6, chicks were moved to a larger pen.

Days 7–12: A shallow pan of adult diet (commercial flamingo pellets; products varied by facility) and water was added to the pens and changed 3 times/day (0700, 1300, and 1900 hrs). By day 10, chicks were removed for exercise at least once daily for 30 minutes, and heat was dropped to 34–36 °C.

Days 14–20: The 1000 hr feeding was eliminated, and chicks were moved to a larger pen or exercised twice daily. Adult food pans were continued 3 times daily, and heat was dropped to 32–34 °C.

Days 21–27: Chicks were tube-fed 3 times daily (0700, 1200, 1600 hrs), and exercised outdoors, with access to a shallow pool.

Day 28–34: Tube feeding decreased to 2 times daily (0700 and 1600 hrs), as long as birds continued to gain weight, and chicks had access to the pool at all times.

Days 35–40: Tube feeding dropped to once per day (1300 hr). 180 ml can be fed for 8–12 days, then 120 ml for 6–10 days, then 60 ml for 4–8 days (wait until birds weigh 2000 g to decrease to 60 cc).

Results

Proximate and mineral composition of the formula used compared to crop milk obtained from free-ranging flamingos aged 6–10 weeks is found in Table 3. The amino acid content of the formula, compared with amino acid requirements of domestic poultry, is found in Figure 1.

Table 3: Nutrient composition of egg-based flamingo hand-rearing diet compared with crop milk composition in free-ranging 6–10 week old Caribbean flamingo (*Phoenicopterus ruber*) chicks (dry matter basis).

Nutrient	Egg-Based Formula	Crop "Milk"[1]
Protein, %	37.4	23–51
Fat, %	48.6	30–75
Ca, %	1.7	0.08–0.7
P, %	1.2	0.5–0.7
Mg, %	0.1	0.0–0.1
K, %	0.4	0.2–0.6
Na, %	0.4	1.5-2.7
Cu, mg/kg	0.4	na
Fe, mg/kg	134	103–611
Mn, mg/kg	10	na
Zn, mg/kg	77	8–27

[1]Ward et al. 2001; na = not analyzed

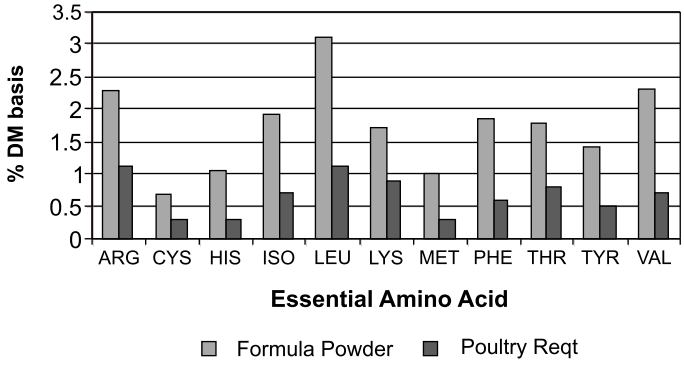

Figure 1: Amino acid composition of egg-based flamingo hand-rearing diet compared to dietary requirements of poultry chicks (National Research Council,1994).

An approximate guide to daily feeding amounts and weight of chicks is found in Table 4. Growth comparisons of Caribbean flamingo chicks from the 4 facilities are displayed in Figure 2; Chilean flamingo chick growth curves are seen in Figure 3.

Table 4: Intake amounts of Caribbean flamingo (*Phoenicopterus ruber*) chicks hand-raised on an egg-based diet, targeting a 10 % body weight gain per day.

Day	Intake ml/day	Meals/day
1	4–27	5
2–3	25–63	5
4–5	32–72	5
6–7	30–75	5
14	36–94	4
21	45–157	3
28	88–150	2
35–56	120–190	1
57+	drop to 60 at 2 kg body weight	1

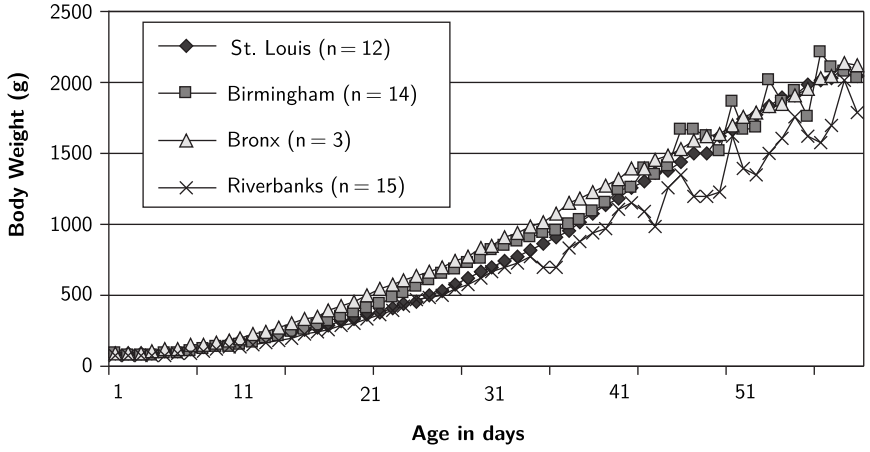

Figure 2: Growth curves of Caribbean flamingo (*Phoenicopterus ruber*) chicks from four US zoos raised on an egg-based diet.

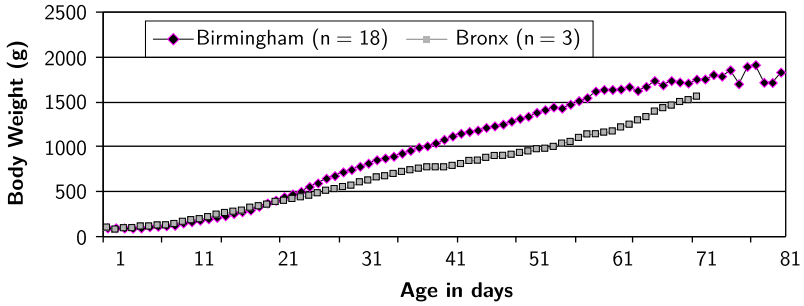

Figure 3: Growth curves of Chilean flamingo (*Phoenicopterus chilensis*) chicks raised on an egg-based diet.

Discussion

The early stage hand-rearing formulas (on a dry matter basis) reported in the literature contain roughly 40 % protein and 20 % fat, averaging between 25 and 35 % solids (Berry 1974; Kear 1974; Van Bocxstaele 1974; Hallager 1976; Kunneman and Perry 1992). This compares to the composition of flamingo crop milk (Studer-Thiersch 1975; Ward et al. 2001) containing 58 % fat and 35 % protein (dry matter basis), with a solids content of approximately 10 to 20 %. While chicks have been reared on these less-dense diets, they are substantially different from the secretions provided by the adults. Some include carbohydrates, usually as baby cereal, although young chicks probably do not have the enzymes required to process them (Sabat and Novoa 2001), and a wide range of supplements that may or may not provide optimal nutritional balance. To the authors' knowledge, no analyses of amino acids in flamingo crop milk has been reported; this egg-based formulation contains more than twice the minimal levels of essential amino acids recommended for poultry species, so may provide a better quality/balanced protein than previous formulations containing plant-based ingredients.

The current hand-rearing formula used better duplicates crop milk composition for other nutrients that have been analyzed to date (Table 3) including minerals and selected fat-soluble vitamins, and does not appear to be limiting in nutrient balance compared to poultry growth requirements. While water-soluble vitamin levels were not analyzed in the diet, calculated values suggest values currently well above minimal recommendations for poultry chicks such that additional vitamin supplements should not be necessary. Calculated energy content of the formula is substantially higher than earlier formulas due to the increased fat level, and appears to support normal growth and development

as long as growth does not exceed 10 % per day. Due to the fact that egg is the exclusive protein source, no limiting amino acids were detected, and this protein should be of highest quality and balance for growing chicks.

Fatty acids (FA) in flamingo crop secretions have not been quantified to date, but will likely depend upon the diet of the adults. A combination of egg yolk, as a primary animal-based fat source, combined with corn oil, was implemented in the hand-rearing diet to meet the as-yet unidentified FA balance for chick growth. Currently, the linoleic acid content of the formula is about five times higher than minimal requirements expected for this nutrient based on poultry chick dietary needs (National Research Council 1994). Theoretically, the oil could be eliminated from this formulation (and still maintain a fat content of approximately 55 % DM); Riverbanks Zoo removed oil and reported no problems with the diet. However, Birmingham Zoo noted a beak issue in Caribbean chicks when oil was deleted in the 2007 rearing season; the "nail" on the tip of the beak overgrew, requiring multiple trimming with a simple fingernail clipper. Possible links with dietary oil omission/inclusion will be examined in future studies.

Although Na content of crop milk from free-ranging flamingos measured was considerably higher than utilized in this formulation, it is possible that the estuarine environment from which wild chicks were sampled contributed to the elevated Na level and that excesses were simply excreted. We saw no indication of Na deficiency or imbalances in any of the chicks reared on the egg-based diet. Also, due to reported problems with iron storage disease in flamingos, although Fe content of this diet (65 mg/kg DM) is somewhat low compared to estimated requirements (90 mg/kg DM; National Research Council 1994), added mineral supplements are not recommended, and the use of pure grade (analytical) calcium carbonate supplements is necessary to minimize potential iron additions through contamination. Two possible imbalanced mineral nutrients detected are Mn and Cu, with the formula containing 10 vs. an estimated 60 mg/kg requirement for Mn (National Research Council 1994), and 0.4 vs. 5 mg/kg Cu (National Research Council 1994). Inclusion of adult diet mash at an early age should alleviate these potential problems. Weaning between 35–40 days seems to work best; at earlier ages more irregularities are seen with independent feeding of chicks, and weaning past 60 days results in difficulty giving up the hand feeding.

As with all bird hand-rearing protocols, it is essential to monitor fecal consistency and animal appetite, as well as daily weight gains to evaluate animal response to diets. The crop should not be overfilled, and the goal for weight gain was $\sim$10 % body weight per day. Growth rates for Caribbean flamingo chicks were comparable across institutions, ranging from 6.5 % (Riverbanks) to 6.8 % (both Birmingham and Bronx) of body weight per day, resulting from

controlled intake levels, and felt to be appropriate for the species. Average daily gains (Days 1–40) were 27.4, 30.2, 22.7, and 26.7 g for Birmingham, Bronx, Riverbanks, and Saint Louis chicks, respectively. Differences, however, were noted between Caribbean and Chilean flamingo chick growth patterns (Figure 2 compared to Figure 3); this was particularly obvious when identical hand-rearing protocols were followed at the same institutions. Average daily gains for the Chilean chicks were lower, 5.8 to 6.5 % of body weight per day for chicks at the Bronx Zoo and Birmingham, respectively. Species differences in metabolism may underlie these observations: Chilean chicks can tolerate cooler temperatures, and the slower growth rate may indicate a lower metabolism. Chileans have been found to have a longer gastrointestinal tract, with larger cecae, which may also indicate metabolic discrepancies between these two species (Wackernagel 1975).

Birmingham Zoo encountered a problem with hyperkeratosis on the feet of some Chilean chicks fed the egg-based diet that had not been previously seen using historical diet(s). Other husbandry practices, apart from diet, are also being examined to rule out variables that may have related to this condition at this institution. Foot problems were not reported for Chilean chicks at the Bronx Zoo.

Chick hydration must be monitored carefully when utilizing the egg-based diet. If a chick becomes even slightly dehydrated, moisture in the crop is quickly absorbed by the body and the egg-based diet in the crop can form into a hard rubbery mass that is difficult to break up. Thus it is critical to ensure that the diet contains adequate water, and to watch the brooder temperature(s) very closely; Caribbean chicks require higher temperatures than do Chilean chicks. Once chicks start playing with the water provided in their brooder boxes, hydration is no longer a problem.

Conclusions

An easily mixed, egg-based diet, supplemented minimally with oil, vitamin E, and calcium, has been shown to provide adequate nutritional balance to support growth of hand-reared Caribbean and Chilean flamingos at multiple zoological institutions. Few problems associated with diet preparation, administration, or animal responses were reported. Details of nutritional requirements for specific fatty acids, vitamins, and/or minerals of flamingos may further refine this formulation, and future research in these areas is encouraged.

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