Evolution of Diets for Herbivorous and Omnivorous Reptiles at the Philadelphia Zoo: From Mystery Toward Science

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At the Philadelphia Zoo the diets for herbivorous and omnivorous reptiles evolved over a period of years. Prior to 1992. the diets had been formulated solely by the former curator. Analysis of the general salad fed to smaller species of herbivorous and omnivorous reptiles (Animal Nutritionist – N-2) indicated unbalanced levels of fat-soluble vitamins. In addition. one of the salad's vitamin and mineral powder supplements contained a milk product that seemed inappropriate and potentially harmful. Two hours of observation were done on the animals in exhibits where the general salad was fed to determine time of arrival at the feeding site(s). feeding duration. items consumed. and group dynamics associated with feeding. Based on the information gathered. a new general salad that included the items that the animals most readily consumed was formulated. A nutritional supplement package from Nutrition Support Services. Inc. (Walkabout Farm. Rte I, Box 189. Pembroke. VA 24136) was added to the salad. The new general salad has a more appropriate fat-soluble vitamin ratio and increased levels of crude protein and fiber. The new general salad is fed to all the small herbivorous and omnivorous reptiles (omnivorous reptiles continue to receive some gelatin cake on their salads and live prey on non-salad days). Repeat observations showed acceptance of the new general salad The new salad requires fewer ingredients, is more nutritionally consistent. and is easier to prepare.

Key Words -herbivorous reptiles, omnivorous reptiles, reptile salad, fat-soluble vitamins, crude protein, crude fiber

Introduction

The changes among reptile diets at the Philadelphia Zoo within recent years reflect an increase in general knowledge of reptile nutrition. Prior to 1992, three different salads were fed to the herbivorous and omnivorous reptiles within the collection. The giant tortoises *(Geochelone nigra* and G. *gigantea)* were fed one produce-based diet. smaller herbivorous species received a different. produce-based salad Omnivorous reptiles received the same salad as small herbivorous reptiles modified by the addition of ground gelatin cake and tomatoes. Vitamin and mineral supplements were added to all three diets. From 1992 to 1996, all three salads were evaluated to determine the portion of salad actually consumed by the animals and the nutrient density of the portion consumed

In this study the Nutrition Department, working in conjunction with the Department of Herpetology and Nutrition Support Services, Inc., sought to improve the general salad as fed for small herbivorous and omnivorous reptiles within the collection. Several serious problems with the original general salad prompted the decision to completely reevaluate its formulation and presentation.

Preparation of the original general salad was complex due to the large number of ingredients. Variations in portions and additional ingredients complicated preparation further. Errors and inconsistencies arose in feedings since practicality limited both individual ingredient and total salad measurements.

Furthermore, the recipe required vitamin and mineral supplementation to achieve nutritional balance.

One supplement included dried milk. The inclusion of dairy products seemed inappropriate for reptiles and may have affected their health adversely. Nutritional analysis (Anima1 Nutritionist – N-2) revealed that the original general salad was high in vitamin A Finally, observations showed that several species consumed only specific ingredients, thereby invalidating the nutritional values of the complete diet. Evaluation of the overall practices of diet preparation, distribution, and consumption suggested that a new diet would be more efficient and nutritionally balanced

Materials and Methods

This study , conducted at the Reptile House of the Philadelphia Zoo from May 1996 through May 1997, evaluated the salad diets of several species (Table 1). The original general salad consisted of 1816 g of raw banana without the peel, 1924 g of raw apple with the skin, 1296 g of raw yams, 2268 g of raw escarole, 1135 g of raw carrots, 2542.4 g of raw kale, 660 g of hard-boiled eggs, 810.6 g of raw tomatoes, 153 g of Mineral Mix, which included dried milk (Ratcliffe, 1966],34 g of Promagic (American Nutritional Laboratories, Delmar, MD), 34 g of Vionate (Rich Health, Nutritional Research Laboratories, Irvine, CA), and 34 g of bone meal. The total original salad was divided into large (150 g), medium (79 g), small (36 g), or extra-small (8 g) portions. The complete diet was analyzed (Animal Nutritionist – N-2) on a dry matter basis to obtain values for energy, crude protein, crude fiber, fat, vitamin A, carotene, vitamin D3, vitamin E, thiamin, riboflavin, niacin, calcium, phosphorus, magnesium, potassium, sodium, arginine, tryptophan, lysine, methionine, cystine, phenylalanine, pyridoxine, folacin, vitamin B12, pantothenate, choline, biotin, vitamin C, iron, zinc, copper, manganese, selenium, iodine, cobalt, tyrosine, histidine, isoleucine, leucine, threonine, and valine.

Each of the original salad diets modified by additional ingredients was analyzed for the same values. The spiny bill turtle *(Heosemys spinosa)* received a large original salad plus 85 g of raw, diced tomatoes and 25 g of gelatin cake (Ratcliffe, 1966], which, like all of the additions to the original salad, were added on top rather than mixed in with the other ingredients. The South American red-footed tortoise *(Geochelone carbonaria)* received a large salad plus 85 g of raw, diced tomatoes and 19 g of gelatin cake. The Malayan box turtle *(Cuora amboinensis)* and Eastern box turtle *(Terrapene carolina carolina)* received small salads with 12 g of additional tomatoes and 5 g of gelatin cake. The African pancake tortoises *(Malacochersus tomieri)* received either large salads with 85 g of additional tomatoes, medium salads with 17 9 of additional tomatoes, or small salads with 12 9 of tomatoes depending on the age and size of the tortoise. The green crested basilisks *(Basiliscus plumifrons)* and brown basilisks *(Basiliscus basiliscus)* received small salads, each with 2 gf of gelatin cake. Inland bearded dragons *(Pogona vitticeps),* shingleback skinks *(Tiliqua rugosa),* and blue-tongued skinks *(Tiliqua scincoides)* received large salads with 25 gf of gelatin cake. Hosmer's skinks *(Egemia hosmeri)* and sungazers *(Cordylus giganteus)* received small salads with 5 g of gelatin cake, and ornate plated lizards *(Zonosaurus omatus)* received extra-small salads with 2.5 g of gelatin cake.

Analysis was also completed for the original salad excluding the 1135 g of raw carrots in order to assess their contribution of vitamin A to the total salad

Feedings were observed from the public side of the exhibits at the Reptile House. Each observation period was approximately one hour in duration and began when the salad was introduced to the exhibit. Repeat observations were made at many of the exhibits. The purpose of observing feedings was to ascertain the approximate percentage as well as items consumed Other details recorded included the location of feeding sites, the presentation of the salads, immediacy, duration, and frequency of feeding, and group dynamics. Table 2 provides a summary of exhibits observed.

Following the development of the new general salad, observations were repeated to assess initial acceptance of the new recipe.

Results

Analysis (DM basis) of the original general salad showed a vitamin A value of 151900 IU/kg, a vitamin D3 value of 610 IU/kg, and a vitamin E value of 13.75IUl/kg. The resulting ratio of vitamin A:D3:E was 10850:44:1. Crude fiber and crude protein were 4.4% DM and 13.52% DM respectively.The ratio of calcium to phosphorus was almost 4: 1. Table 3 provides a complete list of nutritional values.

Analyses of the ten variations of the general salad by the addition of tomatoes and gelatin cake showed trends. Though the majority of the values remained relatively unaffected by the additions, concentrations of crude protein, niacin. phenylalanine, isoleucine, leucine, threonine, and valine increased with the addition of gelatin cake to the salad. Crude protein was 13.52% DM in the original general salad and increased to values ranging from 17.4 to 29% DM with the addition of gelatin cake but remained closer to the original value when just tomatoes were added. The original salad's niacin value of 35 mg/kg increased to as much as 60 mg/kg with some added ingredients; recipes including additional gelatin cake showed the most significant increases. Phenylalanine was 0.65% DM in the

original general salad, isoleucine was 0.73%, leucine was 1.04%, threonine was 0.58%, valine was 0.77%, and arginine was0.7% DM in the original general salad The amino acid values (DM basis) increased with the addition of gelatin cake to as much as 1.1% phenylalanine, 1.5% isoleucine, 2.2% leucine, 1% threonine, 1.5% valine, and 2.1% arginine. Vitamin B12 also increased from 0.008 mg/kg to approximately 0.02 mg/kg wih the addition of gelatin cake. However, additions led to decreased energy values, most notable again in recipes with the highest percentage of additional gelatin cake; the original salad's value of3.83 kcal ME fell as low as 2.2 kcal ME.

The addition of gelatin cake and tomatoes to the original salad resulted in values comparable to those of the new salad for crude protein, niacin, phenylalanine, isoleucine, leucine, threonine, and valine. The ratio ofvitamin A:D3:E approached the ratio of the new salad, ranging from 1904:57:1 to 8022:32:1. Vitamin D3 values increased from 610 IU/kg to approximately 2000 IU/kg with additional gelatin cake, and vitamin E values increased from 13.75IUl/kg to approximately 40 IUY/kg with gelatin cake and 20 IU/kg with tomatoes. The addition of tomatoes also led to vitamin C levels of approximately 2000 mg/kg, increased from 1774 mg/kg. However, these values must be considered in conjunction with the fact that the additions also resulted in selective item consumption in sev'eral exhibits, indicating that the animals were not actually obtaining the nutrition of the complete diet.

There was limited variation in the number of additional ingredients to the original general salad but great variation in the percentage of the weight of the salads as fed that the additions comprised Additions comprised 5 to 42% of the total salad among the ten additions recipes. Gelatin cake, in particular, comprised 5 to 24%, and tomatoes comprised 18 to 36% of the salads.

The high vitamin A level in the original salad prompted analysis without carrots as an ingredient. The vitamin A level of the general salad was 110400 IUll/kg when carrots were excluded. Carrots, which contribute 12 mg of carotene per 100 grams as fed. accounted for about 48% of the salad's total vitamin A content. These data suggest that the high vitamin A level of the original salad may not be as detrimental as suspected because carrots contribute vitamin A activity in the form of carotene.

Observations showed a variety of feeding behaviors. One exhibit under observation included 2.2 black wood turtles *(*Rhinoclemmys *funerea*), 1.1 *B. p/umi frons,* and 0.0.6 tabasco sliders *(Trachemys scripta venusta). R. funerea* and *B. p/umifrons* were the intended salad-eaters within the exhibit. Keepers fed the animals one large (150 g) salad with gelatin cake on top, placing it on the floor of the exhibit, and one small (36 g) salad with gelatin cake on top, placing it on top of a high branch to which only *B. p/umifrons* had access. During the initial observation period, one *B. p/umifrons* ate gelatin cake from the small salad soon after it was placed in the exhibit but only for a short period of time. One *R. funerea* moved to the large plate soon after it was placed in the exhibit and ate gelatin cake preferentially, using its feet to move the other ingredients around After it ate for approximately ten minutes, no gelatin cake was visible, and no animals fed subsequently. Virtually all of the original salad remained except the tomatoes and the additional gelatin cake. The observation period highlighted sporadic and selective consumption. The second observation period spent at this exhibit showed similar beltaviors; one *R. funerea* came to the plate immediately and ate only gelatin cake. A second *R. funerea* fed on gelatin cake and tomatoes after the first one left. A third one fed on tomatoes after the second one had left. Feeding ceased twenty to twenty-five minutes into the observation period after which time *R. funerea* walked across and laid on the salad Neither *B. p/umifrons* fed during the second period

Another exhibit under observation included 1.2 prehensile-tailed skinks *(Corucia zebrata)* who received a large (150 g) salad with no additional ingredients. They ate steadily for the first 30 of the 60 minute observation period and sporadically for the remainder, displaying no specific ingredient preference while consuming 1/3 to 1/2 of the total salad. One spent the majority of the observation period on or around the salad plate, pushing away or blocking the other two C. *zebrata* from food. C. *zebrata* exhibited similar behaviors in the subsequent observation period, though consuming closer to 3/4 of the salad C. *zebrata* displayed consistent, balanced feeding.

The third observation exhibit included 2.6 *H. spinosa,* 1.0 emerald tree monitor *(Varanus prasinus kordensis),* and 1.1 Asian water dragons *(Physignathus concinnus).* One *P. concinnus* ate for the first ten minutes of the observation period *H. spinosa* ate approximately ten minutes after three large (150 g) salads, each with 85 g of tomatoes and 25 g of gelatin cake, were placed in the exhibit, despite being positioned directly at them by the keeper. They spent 20 to 30 minutes feeding before leaving the plates for the remainder of the hour. Approximately 3/4 of 2 of the salads were consumed while the third remained virtually untouched.

Observation of an exhibit including 1.1.1 *P. vitticeps* showed consistent eating and no selective item consumption. They ate for the full hour and a half observation period, though only one ate at a time. One *P. vitticeps*

descended on another and bit it before eating. Approximately 1/3 of the large (150 g) salad and 5 crickets were consumed

Most members of group exhibits ate, despite the behaviors of co-habitants. Though most groups consumed an observable if not significant portion of the salad within the observation period, the amount consumed varied among exhibit groups and among individual animals within the groups. No group consumed the entire portion fed within the observation period. Some animals consumed specific items exclusively or more readily than other animals.

The new salad recipe consisting of 5107.5 g of romaine, 3405 g of escarole, 1362 g of banana, 340.5 g of quartered apples, 9 hard-boiled eggs, and 1 bag of Walkabout Farm's reptile salad supplement was developed. A comparison of the nutritional contents of the new and old salads is presented in Table 3.

The only addition to the new salad is gelatin cake, comprising 5.26 to 23.8% of the weight of the salads fed to the animals. The addition of gelatin cake to the new salad had only a minor impact on nutritional values. The ratio of vitamin A:D3:E was disrupted since the additions increased all three fat soluble vitamin contents disproportionately. The ratios ranged from 166:66: I to 187:63: I. A decrease in vitamin C and increases in iron and zinc were also common; vitamin C decreased from 1330 mg/kg to as little as 1212 mg/kg, iron increased from 113 mg/kg to as much as 138 mg/kg, and zinc increased from 47 mg/kg to as much as 68 mg/kg.

Observations made following the implementation of changes in the salad recipe primarily show acceptance of the new general salad. One observation group including 0.0.2 T: *rugosa* received a large (150 g) salad with gelatin cake. They appeared to seek out the gelatin cake but ate other ingredients as they did so. Furthermore. after the gelatin cake had been consumed, they continued to feed on the remaining ingredients until 1/3 of the total salad had been consumed by the end of the one hour observation period. Both *T. rugosa* ate for the majority of the observation period, in cycles of pausing and resuming. They fed simultaneously for periods of time, but one maintained a position at the plate, nudging and blocking the other *T. rugosa.*

Within a group of 1.0.1 T: *scincoides,* one ate both gelatin cake and greens but only a small fraction of the large (150 g) salad during the initial observation period. Within the first fifteen minutes of the second observation period, both *T. scincoides* had consumed 114 of the total salad and all the gelatin cake. Their feeding ceased when one bit the other, and both retreated from the plate.

Observation of an exhibit including 1.1.1 *E. hosmeri* showed no feeding; only one *E. hosmeri* walked by the salad The addition of 0.0.1 *P. vitticeps* and the removal of 0.0.1 *E. hosmeri* changed feeding behaviors slightly. *P. vitticeps* fed from the small (36 g) salad with gelatin cake immediately. One *E. hosmeri* did not feed at all, one *E. hosmeri* fed within the first two minutes of the observation period, and neither *E. hosmeri* nor *P. vitticeps* consumed specific items exclusively. While *E. hosmeri* fed for only two minutes, *P. vitticeps* fed intermittently for the entire hour.

Within a group including 1.0 *Z. omatus,* 1.1 Standing's day geckos *(Phelsuma standingi},* and 1.2 Lichenose leaf-tailed geckos *(Uroplatus sikorae}, Z. omatus* was the intended salad-eater. During the first observation period, none of the animals ate salad, though *Z. omatus* ate some crickets and stood on the extra-small (8 g} salad for two minutes, putting his face to it. No animals fed during the second observation period.

The introduction of the new salad altered neither the amount of salad consumed nor previous behavior patterns, though fewer additions appeared to reduce selective item consumption. Observation of the exhibit including 1.2 C. *zebrata* and the exhibit including 2.6 *H spinosa,* 1.0 *V prasinus kordensis,* and 1.1 *P. concinnus* following the introduction of the new salad showed no observable changes from the first observation periods. Within the group of C. *zebrata,* one blocked the others from the salad by hovering around the plate. They ate almost immediately after the keeper placed the salad in the enclosure as they did prior to the salad change. Likewise, they ate steadily for the duration of the hour, finishing most of the salad. *H spinosa* waited approximately ten minutes before feeding, though the keeper placed them at the plates. They fed for twenty to thirty minutes before abandoning the plates for the remainder of the hour.

Discussion

Evaluation of the original general salad suggested the need for a replacement recipe, with an adjusted ratio of fat -soluble vitamins, reduced complexitiy and balanced vitamin and mineral supplementation. The vitamin A level of the original general salad (151900 IU/kg) exceeded the presumed upper safe levels for livestock and poultry

[NRC, 1987] .Elevated levels of vitamin A can cause metabolic bone disease due to competition with vitamin D3 [Bruce and Parkes, 1950]. Improper ratios of fat-soluble vitamins can have other effects, including potentially interfering with absorption and distribution of fatty acids [Bruce and Parkes, 1950]. Furthermore, our Curator of Reptiles and Amphibians susprctedI that hypercholesterolemia in bearded dragons, cholesterol deposits in the lenses of prehensile-tailed skinks, and other disorders may be related to the imbalance of fat soluble vitamins found in the original diet and/or is possibly related to the amino acid and fatty acid composition of the dried milk contained in the mineral mix or the horsemeat contained in the gelatin cake.

Initially, the elimination of additional ingredients was sought to simplify preparation. Analyses showed that the addition of tomatoes and especially gelatin cake altered many of the original salad's nutritional values including the ratio of f at-soluble vitamins. However, observations showed that the additions encouraged selective item consumption in some cases. Observations also provided a basis with which to compare feeding behaviors following the diet change.

The new salad recipe simplified the salad diets of the herbivorous and omnivorous salad-eaters by reducing the variations due to additions. It also reduced the multiple and potentially harmful vitamin and mineral supplements of the original salad Analysis of the new salad suggested that the animals would be consuming a more nutritionally adequate diet with a ratio of fat-soluble vitamins significantly closer to the desired 100: 10: 1 ratio [Donoghue and Langenberg, 1996], a ratio of calcium to phosphorus within the desired 1: 1 to 2: 1 range [Donoghue and Langenberg, 1996], a crude firer content within the accepted rangeof 10-40% DM for captive herbivores [Donoghue and Langenberg, 1996], and a crude protein content within the accepted range of 15-35% ME for captive herbivores and 15-40% ME for captive omnivores [Donoghue and Langenberg, 1996] .Observations following the salad switch suggest that while the animals still consumed only a fraction of the portion fed to them within the first one to two hours, they were receiving closer to the expected nutritional values with the new salad due to the apparently reduced selective item consumption.

Further observations and medical assessments of the herbivorous and omnivorous salad-eaters would be appropriate to determine the long term success of the new salad Season could also be examined more closely as a factor, and observations done several hours after feeding would more accurately assess total consumption.

Conclusions

1. While supplementing a base diet may improve its nutritional components, vitamin supplementation may affect animal health adversely, and ingredient supplementation encourages some species of herbivorous and omnivorous reptiles to consume selected items exclusively.
2. Reducing the availability of preferred items and adjusting remaining ingredients may reduce the incidence of consuming the preferred items exclusively and increase consumption of the intended balanced diet without altering other feeding behaviors significantly.
3. Further studies to assess the long-term success of the diet alterations are appropriate.

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Table 1. Animals Receiving the Origional General Salad (Both with and with out Additions)

Common Name	*Scientific Name*
Spiny hill turtle	*Heosemys spinosa*
Wood turtle	*Clemmys insculpta*
Black Wood turtle	*Rhinoclemmys funerea*
Malayan box turtle	*Cuora amboinensis*
Eastern box turtle	*Terrapene carolina carolina*
African pancake tortoise	*Malacochersus tornieri*
South American red-footed tortoise	*Geochelone carbonaria*
Green crested basilisk	*Basiliscus plumifrons*
Brown baslilisk	*Basiliscus basiliscus*
Inland beared dragons	*Pogona vitticeps*
Shingleback skink	*Tiliqua rugosa*
Blue-tounged skink	*Tiliqua scincoides*
Hosmer's skink	*Egernia hosmeri*
Prehensile-tailed skink	*Corucia zebrata*
Sungazer	*Cordylus giganteus*

Ornate plated lizard	*Zonosaurus ornatus*

Table 2. Summary of Exhibits Observed

Animals in Exhibit	Intended Salad Eaters within Exhibit
2.2 R. funerea, 1.1 B. plumifrons, 0.0.6 T. scripta venusta	R.. funerea and B. plumifrons
1.2 C. zebra	C. zebra
2.6.0 H. spinosa, 1.0 V. prasinus kordensis, 1.1 P. concinnus	H. spinosa and P. concinnus
1.1.1 P. vitticeps	P. vitticeps
0.0.2 T rugosa	T rugosa
1.0.1 T scincoides	T scincoides
a)1.1.1 E. hosmeri b) 1.1 E. hosmeri,0.0.1 P. Vitticeps	a) E. hosmeri b) E. hosmeri, P. Vitticeps
1.0 Z. ornatus, 1.1 Phelsuma standingi, 1.2 Uroplatus sikorae	Z. ornatus

Table 3. Comparative nutritional values for the origional and new general salad (Dry Matter Basis)

Nutritional Value	Origional General Salad	New General Salad
Energy (kcal ME)	3.83	3.2
Crude Portein (%)	13.52	21
Crude Fiber (%)	4.4	13
Fat (%)	5.1	6
Vitimin A (IU/kg)	151900	3300
Carotene (mg/kg)	158	69
Vitmin D3 (IU/kg)	610	1400
Vitimin E (mg/kg or IU/kg)	14	21
Thiamin (mg/kg)	5	9
Riboflavin (mg/kg)	6.5	14
Niacin (mg/kg)	35	61
Calcium (%)	1.9	1.0
Phrosphorus (%)	0.5	0.7
Magnesium (%)	0.2	0.2
Potassium (%)	2.0	2.1
Sodium (%)	0.3	0.2
Arginine (%)	0.7	1.05
Tryptophan (%)	0.2	0.2
Lysine (%)	0.8	1.0
Methionine (%)	0.3	0.4
Cystine (%)	0.2	0.54
Phenylalanine (%)	0.65	0.9
Pyridoxine (mg/kg)	11.5	10
Folacin (mg/kg)	2.5	6
Vitmin B12 (mg/kg)	0.008	0.029
Pantothenate (mg/kg)	24	58
Choline (mg/kg)	127	1345
Biotin (mg/kg)	0.06	0.87
Vitmin C (mg/kg)	1774	1330
Iron (mg/kg)	172	113
Zinc (mg/kg)	135	47
Copper (mg/kg)	7.7	8
Managanese (mg/kg)	17.7	40
Selenium (mg/kg)	0.02	0.2
Iodine (mg/kg)	0.56	0.3
Cobalt (mg/kg)	0.12	0.4
Tyrosine (%)	0.47	0.66
Histidine (%)	0.35	0.46
Isoleucine (%)	0.73	1.06
Leucine (%)	1.04	1.5
Threonine (%)	0.58	0.86
Valine (%)	0.77	1.2
Vitmin A:D3:E	10850:44:11	157:67:1

Calcium Phosphorus	3:8:1	1.4:1