Reptile Nutrition 101:
Veggies & Insectivores Delight

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I. Introduction

II. Nutrition guidelines
  a. National Research Council (NRC)
  b. Herptile nutrition extrapolated from other species
    i. Minimums for rats most commonly used
    ii. Nutritional Advisory Group

III. Nutritional strategies per taxonomic group
  a. Diet breakdown for chelonians
    i. Aquatic turtles
      1. Aquatic veggies
      2. Feeder fish
      3. Pellets
      4. Insects
    ii. Box turtles
      1. Weeds, garden veggies
      2. Slugs, earthworms
      3. Berries
      4. Flowers
    iii. Tortoises
      1. Most consume 100% plants only
      2. Weeds, fibrous roots
      3. Adapted to live in the desert
      4. Exceptions: South American spp., African forest tortoises
  b. Diet breakdown for lizards
    i. Herbivores
      1. Iguanas
      2. Uromastyx
      3. Chuckwallas

ii. Omnivores
    1. Bearded dragons
    2. Anoles
    3. Blue-tongue skink
    4. Veiled chameleons
    5. Tegus
iii. Insectivores
    1. Leopard geckos
    2. Monitors
    3. Some chameleons
    4. Frilled dragons
iv. Specialized
    1. Fruit/nectar feeders
    2. Crested geckos
    3. Columbian tegus

c. Almost all snakes are carnivores
    i. Temperate
        1. Examples: corn snake, milk snakes, rat snakes, kingsnakes
    ii. Tropical
        1. Examples: pythons & boas, snakes from Central & South America
    iii. Specialized diets
        1. Insects, amphibians, feeder fish
        2. Examples: garter snakes, rainbow boas, ring-neck snakes, hog nose, egg-eating snake

IV. Nutritional strategies
a. Herbivores
    i. Vegetable dinner wheel
        1. Dandelion greens
        2. Romaine lettuce
        3. Collard greens
        4. Mustard greens
        5. Red leaf lettuce
        6. Escarole
        7. Endive
        8. Swiss chard
        9. Bok choy

10. Kale
11. Spinach

ii. Hay science
1. Alfalfa
2. Botanical hay
3. Oat hay
4. Orchard grass
5. Organic meadow
6. Western timothy

iii. Grasses

b. Insectivore
i. Insect composition
ii. Domestic cricket (*Acheta domesticus*)
iii. Mealworm (*Tenebrio molitor*)
1. Mealworm-beetle life cycle
iv. Earthworm (*Lumbricus terrestris*)
v. Silkworm (*Bombyx mori*)
vi. Phoenix worm larvae (*Hermetia illucens*)
vii. Madagascar hissing cockroach (*Gromphadorhina portentosa*)
viii. Turkistan or red rusty cockroach (*Blatta lateralis*)
ix. Butterworm or tebo worm (*Chilecomadia moorei*)
x. Dubia cockroach (*Blaptica dubia*)
xi. Hornworm (*Maduca quinquemaculata*)
xii. Not readily on the market, but occasionally available
1. False katydid (*Microcentrum rhombifolium*)
2. Wood louse (*Procellio scaber*)

c. Carnivores
d. Omnivores
e. Super-specialized

V. Basic components of nutrition
a. Metabolizable energy (ME)
i. Definition: Net energy gained from food after digestion and absorption
ii. Standard metabolic rates for daily energy needs at optimal temps= 32 x BW kg $^{(0.75)}$
1. 500-gram reptile requires 9.5-57 kcal/day at 86°F (30°C)

iii. Measurement
    1. Inverts: 0.7-2.7 kcal ME/g
        a. Butterworms: 2.977 ME/g
        b. Cricket: 1.402
        c. Earthworm: 0.708
        d. House fly: 0.918
        e. Mealworm karvaeL 1.378
        f. Phoenix worms: 1.994
        g. Red Turkish roach: 0.244
        h. Superworm larvae: 2.423
        i. Wax worms: 2.747
iv. Factors that impact ME
    1. Species
    2. Age
    3. Activity
    4. Environmental temperature
    5. In reptiles, temperature is not maintained by ME
        a. Fewer calories needed than mammals
        b. Digestive efficiency is the same as mammals
    6. Reptiles – Metabolic rate based on metabolic body size

b. Protein
    i. Definition: Amino acid composition and availability
        1. Nitrogen availability
    ii. Measurement: g/kg or % DM
    iii. Insect protein sources
        1. Exoskeletons contain amino acids
        2. Bioavailability may be limited
            a. Phoenix worms and mountain chicken frogs (Dierenfeld 2008)
            b. Phoenix worms and leopard geckos (Boykin 2021)

c. Fat
    i. NRC min for rats
        1. 5% (50 g/kg) of diet fed (growing)
        2. Necessary for fat-soluble vitamins
    ii. Lipid content in feeder inverts: 3-6X higher than rodent diets
    iii. Is fat bad for herps?

1. Species dependent: strict herbivores rely on fat more than omnivores
2. Activity level

Invertebrates	**Crude fat (g/kg)**	**% fat**
Butterworms	294	
Crickets	68	As high as 22.8%
Earthworms	16	12.6%
False katydids		9%
Fruit flies	19	
Hissing cockroach		20.3%
Mealworm larvae	54	As high as 31.1%
Phoenix worms	140	
Red rusty cockroach		14.5%
Silkworms	14	
Superworm larvae	177	As high as 40.1%
Tenebrio beetles		17.7%
Waxworms	249	
Wood louse		11.3%
Zoophobas beetles		14.3%

d. Vitamins
    i. Vitamin A
        1. Definition: retinol, beta-carotene, retinyl esters
        2. Fat-soluble, light sensitive
        3. Measurement (IU/kg)
        4. Clinical relevance
            a. Poor levels in most insects
            b. Hypovitaminosis A
                i. A significant and common clinical problem in herptiles
                ii. Squamous metaplasia
                    1. Palpebral edema
                    2. Aural abscess
                    3. Respiratory epithelium compromise
                    4. Lingual squamous metaplasia ("short tongue syndrome" in amphibians)
                    5. Ulcerative chelitis
                    6. Vision loss

7. Growth deficits
8. Gastrointestinal bloat
9. Dermal ulcerations
10. Septicemia
11. Acute death

c. Supplementation with beta carotene is not as effective, must use retinol or retinyl esters

5. NRC min retinol for rats: 2300 IU/kg
6. Do we know min requirements for herps?
    a. Box turtles: 3-6 IU/g diet DM
    b. Aquatic turtles: 2-8 IU/g diet DM
    c. Chameleons: 5-9 IU/ cricket DM
    d. Foam nesting frogs: 230,000 IU vitamin A/kg of supplement

Invertebrates	**IU/kg**	**ug/kg**
Butterworms		<300
Crickets	<1000	
Earthworms	<1000	
False katydids	2953	
Hissing cockroach	182	
House flies		<300
Mealworm larvae	<1000	
Phoenix worms		<300
Red rusty cockroach	120	
Silkworms	1580	
Superworm larvae	<1000	
Tenebrio beetles	12	
Waxworms	<1000	
Wood louse	170	
Zoophobas beetles	41	

ii. Vitamin E
1. Definition: antioxidant vitamins, alpha-tocopherol
2. Measurement
    a. mg/kg
    b. % fat in diet
3. Clinical relevancy
    a. Invertebrates have adequate levels, ranging from 5-166 mg/kg

b. Steatitis in deficient patients
4. NRC rat min 18 mg/kg

iii. Vitamin D3
1. Definition
a. 25-hydroxycholecalciferol or calcidiol
b. Activated by photosynthetic mechanisms (UVB driven) in diurnal and crepuscular herps and people
i. Sun >
ii. UVB radiation >
iii. Vitamin D precursor in the skin >
iv. 25-hydroxycholecalciferol
v. 1, 25- hydroxycholecalciferol
c. Absorbed via intestine
d. Calcium absorption and homeostasis
e. Serum levels are dependent on MS, renal, integument and GI health
2. Measurement: ug/kg or IU/kg
3. Production and calcium homeostasis
4. Clinical relevance
a. Calcium deficiencies across many orders of herptile spp.
b. Well studied in diurnal herbivores
5. Insectivore supplementation?
a. Diurnal or crepuscular
i. House gecko (Carmen 2000)
ii. Jamaican anole (Ferguson 2005)
b. Nocturnal
i. Leopard geckos (Mitchell, ARAV 2013)
c. Homemade vs oral supplements
i. UVB first
1. Level comparable to natural history
2. Even nocturnal spp. can use UVB
ii. Supplementation
1. Caution: Inadvertent toxicity can occur
2. Insects “groom” powders off exoskeleton

3. If utilized, do so for 1 week or less

e. Minerals
    i. Calcium & phosphorus
        1. NRC min for calcium in rats: 3.5-5 g/kg
        2. NRC min for phosphorus in rats: 3 g/kg
        3. Insects
            a. Ca: 0.089-9.3 g/kg
            b. P: 1.5-3.7 g/kg
            c. Phoenix worms
                i. 9.3 g/kg
            d. Wood louse
                i. 14% calcium DM
                ii. 11.79 Ca:P ratio
            e. Digestibility?

VI. Food prep
a. Commercial diets
    i. Canned/dried prey items
    ii. Pellets
    iii. Powder/gel food
    iv. Advantages
        1. Shelf life of products
        2. Don't have to handle or care for live prey
        3. Consistent nutrition profile
    v. Challenges
        1. Acceptance by reptiles
        2. Variable quality/nutritional content
b. Care and feeding of prey
    i. General concepts
        1. Do not feed directly from pet store of post-shipment
        2. Need appropriate planning
    ii. Housing examples
        1. Containers and containment
        2. Stocking density/surface area
        3. Substrate/hides
        4. Crickets

a. The development and evaluation of a gut-loading diet for feeder crickets formulated to provide a balanced nutrient source for insectivorous amphibians and reptiles (Attard 2013)
    i. Ingredients
        1. Soybean flour
        2. Sweet potato flour
        3. Red lentil flour
        4. Spirulina
        5. Crushed rabbit alfalfa pellets
    ii. Gut load x 24h

5. Beetle larvae
    a. Similar setups for mealworms and superworms
    b. Hydration is important
    c. Breeding is easy
    d. Can be gut loaded
6. Roaches
    a. Popular
        i. Death head
        ii. Lobster
        iii. Dubias
        iv. Turkish
        v. Hissing
    b. Dubia blaptica
        i. Cannot climb glass
        ii. Adults live 1-2 years
        iii. Breed constantly
        iv. Quiet, no odor
    c. Madagascar hissing roaches (*Gromphadorhina portentosa*)
        i. Large, easy to care for
        ii. Tropical
        iii. Can climb glass
        iv. Adults: 2-3 years
        v. Juveniles take 3 months to mature
    d. Butterworms or trevoworms (*Chilecomadia moorei*)
        i. Chilean carpenter moth - invasive species

ii. Irradiated prior to import to prevent molting
iii. Store in fridge for weeks
iv. Gut load 24 hours prior?

e. Reptiworms, calciworms, and Phoenix worms
i. Phoenix worms are the larvae of the black solder fly (*Hermetia illucens*)
1. Well studied, used in aquaculture, poultry, vermiculite
2. Stored in cups at room temp

f. Hornworms
i. Grow rapidly and eat non-stop
ii. Feed to insectivores within 7-10 days depending on desired size
iii. Large specimens
iv. May require cuticle laceration

g. Silkworms
i. Picky eaters: mulberry leaves (vitamin A)
ii. Most vendors sell with a food substrate
iii. Store at room temperature and feed them within 7-10 days
iv. Moisture of feed can promote fungal growth

h. Earthworms
i. Dirt substrate
ii. Feed composting scraps
iii. Can gut load 24h prior

7. Moth and fly larvae
a. Drosophila melanogaster

iii. Prey health is important for insectivore health
1. Well hydrated
2. Well nourished, high-quality diets
3. Infectious disease

iv. Augmenting nutrition profile (vitamin/mineral)
1. Dusting
a. Shake invert in small particle dust prior to feeding
b. Imprecise way to guarantee supplementation
i. Insects can groom off dust or dust falls off

2. Gut loading
    a. Short-term feeding nutrient dense diet to prey
    b. Many studies confirm this method works for calcium
3. Do both!

VII. "Happy Meal"® menu
a. Larval insects
    i. High in fat
    ii. Deficient in vitamins and minerals
    iii. Variable protein bioavailability
b. Adult beetles, earthworms, roaches
    i. Lower fat
    ii. Good protein levels (especially earthworms)
c. Most insects have poor calcium levels
    i. Increase dietary calcium with supplementation
    ii. Exception: Phoenix worms have high calcium content
    iii. Macerate to increase bioavailability
d. Insect care
    i. Well hydrated
    ii. Well nourished
    iii. Feed calcium-rich diet at least 24h prior (not >9% total calcium)
    iv. Can be kept or bred at home

	Insect is known For	Human Food Comparison	Staple or Treat?
Domestic Cricket	Low protein, high fat (22.8%)	French Fries	Staple if gut loaded, otherwise a treat
Roaches	Lean protein with variable fat (14 - 50%)	Hamburger to Steaks	Staple
Silkworms	Some vitamin A, lean protein source	Turkey	Staple
Earthworms	Protein, good micronutrient content	Big Mac® + multi-vitamin	Staple
Phoenix Worms	Calcium content high	Tums® tablet	Staple, macerate prior to feeding
Butterworms	High ME and fat content (29% DM)	2 Hotcakes with sausage (25%)	Treat, recovery diet
Mealworm larvae	Fat (31%)	2 McDouble Hamburgers ®	Treats
Superworm Larvae	Fat (40.8%)	Two Sausage Egg & Cheese Biscuits (46%)	Treats
Waxworm larvae	More fat (51.4%)	Butter (53% fat)	Treat
Freeze-Dried or Canned	Variable moisture and high in fat	Doritos® Slim Jim®	Treat, use sparingly

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