

Nutrition of the Tortoise

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Tortoises are primarily terrestrial, diurnal reptiles originating from a wide variety of climes and terrains. Most are true herbivores. A few tortoises have been noted in reports concerning natural histories to consume animal matter such as slugs, snails and carrion. These high protein, high fat foods consumed by omnivorous tortoises are digested by hydrolysis in the small intestine. Tortoises are primarily hindgut fermenters, however, and thus require much fiber in their diets.

As for all herbivores, tortoises should be fed daily, with food offered in mornings so tortoises have access throughout the day. A variety of feeding schedules seem to work successfully. For example, tortoises may be offered complete and balanced diets every day, or, alternatively, tortoises may be fed complete and balanced diets every other day, with snacks and treats (which are incomplete and imbalanced nutritionally) offered on alternate days. Tortoises may graze pastures or live entirely indoors, or be managed successfully between these two extremes.

FOODS FOR TORTOISES

Tortoises should be offered vegetarian fare (box turtles and other omnivores are discussed later). Proportions of greens, fruits and vegetables to feed may vary by species. For example, tortoises from desert and arid environments tend to accept hays, cacti, and drier foods, while those from tropical habitats prefer moist, sweet foods.

Tortoises originate from different climates. This table is meant to serve as an approximation. Texts should be consulted for details on individual species.

ARID HERBIVORE

Geochelone sulcata
Geochelone pardalis
Geochelone elegans
Malocochersus tornieri

FOREST HERBIVORE

Geochelone denticulata
Geochelone carbonaria
Indotestudo elegans
Manouria emys

OMNIVORE

Terrepene carolinensis
Terrepene ornata
Kinixys belliana
Kinixys erosa

For large collections with many different species, a standard salad may be prepared with, for example, romaine lettuce as the primary ingredient and supplements to provide balance. Then judicious amounts of other foods may be offered to suit species' preferences.

Tortoises especially seem to be color-oriented toward food. Most enjoy diets containing bits of red, yellow and orange, and seem to relish strawberries and apples, squash and bananas, oranges, sweet potatoes, and mangoes.

Greens: Palatable greens include romaine and other leaf lettuces. These often serve as the main ingredient of salads, but other greens and high fiber items, such as fresh grasses or chopped hay, should be fed as well. To these staples are added sources of vitamins and minerals, and sometimes protein, while maintaining an adequate level of fiber.

Lettuce is commonly referred to as unsuitable for tortoises because of nutritional inadequacies. Nutritionally, lettuce is no worse or better than most greens, and better nutritionally than most fruits:

Calorie and nutrient contents of greens for tortoises. Information presented here are estimates only; actual contents vary. Note that fiber levels are no greater than 14%.

FOOD	WEIGHT	WATER	ENERGY		PRO ^a	FAT	CARB ^b	FIBER	Ca	P
ITEM	g	%	calories/gram		----- % DM -----					
			Af ^c	Dm ^d						
Lettuce, Romaine	100	94	0.18	3.0	36	7	50	11	1.1	0.4
Spinach, raw	100	91	0.26	2.9	36	3	48	7	1.0	0.6
Dandelion greens, raw	100	86	0.44	3.1	18	5	61	11	1.2	0.4
Beet greens, raw	100	91	0.24	2.7	24	3	51	14	1.3	0.4
Alfalfa sprouts, raw	100	88	0.39	3.2	37	4	39	12	0.3	0.8

Protein requirements of herbivorous tortoises are likely to range from about 14-35% dry matter, with the higher end of the range suited for growth and stress. Plants with protein contents likely to be adequate for growth include mostly greens such as romaine, spinach, alfalfa sprouts, clover, and dandelion; also bean sprouts, bamboo shoots, and mushrooms. These foods listed here vary in acceptance by different species; not all of these foods will be accepted equally well by all tortoises.

Fruits and vegetables: Many fruits and vegetables are quite low in protein. Additions of large amounts of these foods to greens risks excessive dilution of dietary protein:

Calorie and nutrient contents of vegetables and fruits for tortoises. Information presented here are estimates only; actual contents vary.

FOOD	<u>WEIGHT</u>	<u>WATER</u>	<u>ENERGY</u>		<u>PRO</u> ^a	<u>FAT</u>	<u>CARB</u> ^b	<u>FIBER</u>	<u>Ca</u>	<u>P</u>
ITEM	g	%	calories/gram		----- % DM -----					
			Af ^c	Dm ^d						
<u>Vegetables</u>										
Bamboo shoots, canned, 1 cup	133	94	0.18	3.0	28	1	51	13	0.2	0.2
Vegetables, mixed, frozen, 2/3 cup	100	83	0.47	2.8	16	2	68	7	0.1	0.3
Lima beans, baby, frozen, 1/2 cup	95	62	1.0	2.6	19	1	67	6	0.1	0.3
Mushrooms, raw, 10 small	100	90	0.27	2.7	30	6	49	9	0.1	1.3
Sweet potato, 1 large	180	64	0.82	2.8	5	1	84	2	0.1	0.2
<u>Fruits</u>										
Apple, no skin, 1 medium	128	84	0.51	3.2	1	2	86	4	tr ^e	tr
Banana, 1 medium	114	74	0.82	3.2	4	2	86	2	tr	tr
Cantaloupe, 1 cup	160	90	0.32	3.2	8	2	79	4	0.1	0.2
Strawberries, 1 cup	149	92	0.28	3.5	6	4	77	6	0.2	0.2

^a Pro = protein

^b Carb = carbohydrate

^c Af = as fed basis

^d DM = dry matter basis

^e tr = trace amounts

Plant vs animal protein: Generalizations about protein sources are risky with so little rigorous data published for reptiles. Plant proteins often lack sufficient essential amino acids (lysine, methionine, cystine, tryptophan, and threonine). Plant species vary in amino acid content; for example, cereals often lack lysine, and legumes (such as beans and alfalfa) often lack methionine. Animal proteins often contain more optimal proportions of amino acids, so are considered higher quality than many plant proteins. However, meats contain other substances, such as fat, phosphorus, and purines, that may cause problems and in effect negate advantages of higher quality protein. These issues are rarely clear-cut however. For example, many plants also contain high levels of purines (50-150 mg/100 g), such as asparagus, whole grain cereals, cauliflower, beans and peas, spinach, mushrooms, and wheat germ.

Controlled data for reptiles are scarce and anecdotal reports are rarely documented, but long-term feeding of commercial petfoods has appeared to be associated with problems such as shell deformities in growing tortoises. Anecdotal reports also suggest that box turtles (*Terrepenne carolinensis*) fed commercial petfoods for long periods (years) suffer soft tissue calcification from vitamin D intoxication. High fat and animal-source diets are inappropriate for herbivorous tortoises. Animal-source proteins which are free of fat may be appropriate in small amounts. For example, I've used dried, low-fat egg protein in small quantities, mixed with soybean meal and fresh produce, for my tortoises (twelve species, successful growth and reproduction).

Fiber: Fiber provides calories through hindgut fermentation, and aids gut motility. Excessive fiber, however, limits calorie intake and inhibits trace mineral absorption. Relatively wide ranges of fiber intakes, perhaps from 4-40% DM are found in tortoise diets. Both extremes may cause medical problems.

Adult tortoises probably need at least 12% DM as crude fiber; perhaps 20-30% is closer to optimal. Fermented fiber provides about 2 kcal ME/g DM.

Secondary plant compounds: While green plants provide needed essential nutrients and fuels, herbage contains non-nutritive substances too. Secondary plant compounds are stored by most plants and used as deterrents to bacteria, fungi, and herbivores. Many are toxic, such as saponins, phenols, and alkaloids. Most tortoises seem to be selective feeders, yet plants with potentially toxic substances may be consumed in variable quantities. Little work has been done on identifying secondary plant compounds in diets for reptiles, and the roles of these substances in clinical nutrition are unknown.

Oxalates occur in spinach, rhubarb, cabbage, peas, potatoes, and beet greens. Oxalates bind calcium and trace minerals, inhibiting their absorption. Conditioned trace mineral deficiencies may occur if diets contain mostly these foods and mineral intakes are marginal. Goitrogens occur in cabbage, kale, mustard and other cruciferous plants. Large intakes of these foods with marginal iodine intake may lead to hypothyroidism.

Care must be taken to restrict access of tortoises to poisonous plants, yet limited data on dose responses in reptiles precludes the presentation of lists of known plant offenders. Presumably safe plants include clover, dandelion and alfalfa for tortoises grazing outdoors. Outdoor plants that have caused illness in mammals or birds include cherry, rhododendron, oleander, lupine, foxglove, yew, and privet. Presumably safe houseplants for use in natural terraria include pothos (*Scindapsus* spp), snakeskin plant (*Sansevieria* spp), and umbrella tree (*Schefflera* spp). Pothos is especially tolerant of heat, wet and dry conditions. Houseplants that have caused illness in mammals or birds include dumb-cane (*Dieffenbachia* spp) and *Euphorbia* species. All plants in contact with tortoises should be free of pesticides and herbicides.

Grazing tortoises: For tortoises grazing and browsing in outside enclosures, accuracy in determining dry matter intake (DMI) is hard to obtain. If produce and pasture are both offered free-choice, the estimated pasture/browse intake may be proportioned according to length of time spent consuming each (expected DMI minus produce). Pasture- or browse-on-offer may be estimated and averaged over an exposure period of weeks or months (DMI, tons per acre or grams per square meter). However, tortoises are selective grazers and tend to waste feed, not consuming all available food and defecating on produce. Nutritional values vary greatly depending on the management practices of the enclosure. Pastures "improved" by liming or fertilization vary from unimproved areas.

Outside enclosures can be sampled for analysis by covering an X or Z pattern, cutting grass at regular predetermined intervals, for example, every 10 paces. A 6" x 6" square is cut with scissors and placed in a bucket. The cuttings are mixed and an aliquot removed for testing. Opinions vary on the accuracy of pasture sampling.

For pasture, laboratory analyses are recommended when appropriate. I use a DHIA (Dairy Herd Improvement Association) forage testing laboratory (Northeast DHIA, Ithaca, NY 14850; 607-257-1272); other states have similar labs. Feed samples may be submitted for proximate analysis (moisture, nitrogen, fiber, calcium, phosphorus, calculated protein, and digestible and net energies). Mineral (Mg, K, Na, Fe, Zn, Cu, Mn, Mo) analyses can be obtained if indicated. The labs provide pre-paid mailers. Since these labs provide services usually for livestock producers, call first if sending anything unusual, such as prey. Fees average about \$12 per sample for proximate analysis and \$20 for mineral assays. Vitamins are rarely assayed by commercial labs.

Commercial diets: Commercial forages include legumes, primarily alfalfa, marketed as a meal, pelleted, cubed, and chopped. Most show limited interest in processed forages, eating these items only when disguised with fresh produce or when no other foods are available.

Hay can be purchased from feed stores and farms. Alfalfa cubes sold in pet shops are readily available and consistent but expensive. The same cubes can be purchased from feed stores in 50 lb bags and stored in metal trash cans in a cool dry room. About half the vitamin A activity from beta-carotene is lost within a year.

Hay-based pellets are marketed for a variety of species and may be supplemented to be complete feeds. Most range from 12-28% crude protein and 14-19% crude fiber. Occasionally, nutritional problems are reported in mammalian species fed pellets, such as vitamin A deficiency or, in other cases, intoxication. Problems arise due to use of old hay or errors in mixing.

Some success has been noted in the use of hay-based pellets as bedding for juvenile herbivorous reptiles. While these products are safe if wholesome, in my experience pellets are very quick to mold. Risks of mold-related respiratory disease and digestive upset may be a high price to pay for the convenience of bedding with pellets.

When purchasing or recommending commercial herbivore diets, read labels with extreme care. Some may contain low-level antibiotics and other growth promotants that have unpredictable and potentially deleterious effects on reptiles.

Commercial diets marketed specifically for tortoises are variable in content. Look for products with adequate protein and fiber (at least 18% crude protein and 16% crude fiber, from label guaranteed analyses). Pellets may be soaked in water or fruit juice prior to feeding. Wet pellets may mold, however, so need to be offered fresh daily.

Supplements: Certain vitamins decompose in light or moisture, and shelf-life of most preparations is restricted to a few months after manufacture. Most commercial preparations have traveled from point of manufacture to a distributor, then to a retail outlet, prior to purchase. For this reason, use of products without expiration dates on labels is discouraged. Commercial supplements should be stored in a cool, dark place.

Trace minerals in contact with vitamins catalyze oxidation, especially in the presence of moisture. For homemade diets containing more than 12% moisture or exposed to air, supplements containing trace minerals should be added just before feeding, if possible. Because of the small amounts needed, supplements may be old and contain oxidized vitamins. Also, fat-soluble vitamins and many trace minerals are toxic in high quantities and supplementation in excessive quantities may lead to toxicities.

Although calcium is often included in commercial vitamin-mineral supplements, it is rarely present in quantities sufficient to meet requirements. Additional calcium may be provided as limestone (38% calcium), or as calcium salts – carbonate (40% calcium), lactate (18% calcium), and gluconate (9% calcium). Calcium and phosphorus are supplied in bone meal (24% calcium, 12% phosphorus) and dicalcium phosphate (18-24% calcium, 18% phosphorus). Bone meal tablets vary in size. A small (aspirin size) tablet weighs 0.75 g and provides about 180 mg calcium and 90 mg phosphorus. Products vary, so labels should be read carefully.

Clinical Nutrition

Feeding mismanagement of tortoises may lead to clinical disorders. For example, tortoises may not be able to access food offered in bowls and thus may show signs of under feeding. Tortoises should be fed from plates or other flat surfaces. Also, tortoises may show signs of chronic dehydration, including perhaps renal disease, due to inability to access fresh potable water. Tortoises should be provided with opportunities to soak in water, and, if fed pellets, offered high-moisture fruits as snacks.

Body condition: Morphometric analyses of tortoises may be used to assess body condition. Our goals have been to develop an equation that provides an optimal range of body weight (BW, g) for a given carapace length (L, cm). In a preliminary study in my collection, we looked for a correlation between BW and the L^3 (because weight is a function of the cube of length, given similar shapes and weight proportional to volume). Data on 42 tortoises representing nine species are described by a single equation:

$$BW = 0.15L^3 \quad r^2 = 0.99$$

Dr. Mader performed similar measures on 220 healthy California desert tortoises (*Gopherus agassizii*), including validation of weight/volume relationships, and found:

$$BW = 0.59(L \times W \times H) + 388 \quad r^2 = 0.89$$

If an individual has an actual BW lower than the predicted BW by, say, 10%, then it may be in need of nutritional intervention.

Energy deficiency. Underweight and cachectic body conditions develop for a variety of reasons. Too little food may have been offered, or inappropriate foods or feeding management (e.g. a too-cold environment) limited energy intake, or patients may have diseases that affect appetite (decreased) or metabolism (increased). Foods may be inappropriate because of:

- low energy density (kcal/g), such as found with diets of fruits and many vegetables;
- high fiber contents, such as found with diets including post-bloom hays, which limit dry matter intake;
- vitamin-mineral supplements, which have been fed at the expense of energy-containing foods.

Tortoises that lose weight lose lean tissue (protein) as well as adipose. Loss of protein from vital organs impairs function and threatens life.

To treat energy deficiency, first replace fluids and electrolytes, then provide initially small quantities of calories and nutrients, and increase amounts gradually. Starved patients that are re-fed gain water first, then replace some of the fat that was metabolized, followed by replacement of protein. So early increases in body weight, while encouraging, do not indicate complete restoration of vital tissue protein. Weeks are needed to restore tissue protein.

Iodine deficiency. Iodine plays a critical role in metabolism as a component of thyroxine and triiodothyronine and anything that affects the availability of iodine may induce goiter. Iodine deficient soils occur worldwide but other causes of goiter include the presence of dietary goitrogens. Goitrogens are found in bok choy, broccoli, cabbage, cauliflower, kale, mustard seed, rapeseed, and turnips. These plants do not have to be avoided entirely, but should be fed only intermittently or in small amounts. More work is needed to know specific amounts of these foods that can be tolerated safely in diets for reptiles.

Goiter occurs in tortoises and reportedly the disease is more prevalent in the giant species from Galapagos and Aldabra Islands. This has led to anecdotal reports that the giant tortoises require more than usual amounts of dietary iodine and/or sea salt. Little data exist to support or refute these claims. This is especially unfortunate because iodine is toxic in large doses and iodine intoxication has been reported for human populations treated for goiter by dietary modification. Iodine intoxication presents as goiter, identical in appearance to iodine deficiency, because of impaired utilization of iodine. In domestic mammals, there are clinical cases of goiter in offspring following over dosage of the dam.

Safe levels of iodine intake in reptiles are unknown. Safe levels in humans are estimated to be less than 300 mcg/day; the recommended daily allowance is about 1 mcg/kg body weight. Given the markedly lower metabolic rate of reptiles, an adequate daily level of dietary iodine might approximate one-quarter to one-third these levels, or about 0.3 mcg/kg body weight.

Iodine may be supplemented as iodized salt and as kelp in powder or tablet. Iodized salt contains 0.01% potassium iodide or 76 mcg iodine/g; one teaspoon of salt weighs about 4 g. About 13% of the salt sold in the US derives from the sea; other sources are mines and brine wells. Sea water that has been evaporated by the sun is often marketed as solar salt. Salt from the sea has minerals removed in order to be sold as table salt; these minerals are then added back again to market the product as sea salt, which increases product cost. Low sodium salts contain potassium chloride mixed with sodium chloride.

Kelp is one of a confusing list of names applied to seaweed. Used for centuries as a food item, kelp contains a wide variety of trace minerals, including iodine. Dried kelp for human or livestock consumption contains about 5% protein (low biological value), 7% fiber, 1.9% calcium, and 0.2% phosphorus. Average iodine content is 0.062% or 620 mcg/g, about 8-times the iodine content of iodized salt.

In some countries such as Norway and Japan, the kelp industry is well-organized, with product regulation. However, products sold in US, in health food stores for example, may have escaped such regulation and one cannot assume that quality control has been achieved. Product contamination may have occurred, as well as errors in labeling. Kelp products should be used with care, with specific intakes calculated, in order to avoid risk of toxicity.

A form of hypothyroidism has been associated with selenium deficiency. The de-iodinase that converts thyroxine to triiodothyronine contains selenium. This condition is characterized by changes in plasma concentrations – increased T_4 and decreased T_3 . It has been described only in mammals but needs to be kept in mind for reptiles raised on foods from selenium-deficient regions.

Fiber-related illness: Dietary fiber is a concern when feeding herbivorous reptiles because its role is critical for maintenance of gut motility and production of volatile fatty acids. Tortoises on low fiber diets (less than about 12% DM) have loose feces. Although not well documented, low fiber diets may also predispose herbivores to bloat and/or lactate-induced diarrhea from too-rapid fermentation of carbohydrate.

Fiber relates to diet digestibility and transit times. In tortoises, research on digestibilities and transit times produced varying results. Most seem to be in agreement, however, that transit times are slow relative to other species. In Galapagos and Aldabra tortoises, transit times ranged from 3-45 days, and, for the Greek tortoise, 55 days. This compares to about 1 day for rats, 2 for dogs, and 5 for ruminants.

For Galapagos tortoises free-ranging on Santa Cruz island, diet digestibilities averaged 52% for dry matter, 70% for protein, 41% for cellulose, 28% for acid-detergent fiber, and 22% for neutral-detergent fiber. These values suggest that tortoises are less efficient at digesting food than horses or sheep, and are similar to swine. Observations of scat on the island verified the laboratory data.

In my feeding trials, long-stem fiber sources, such as hay or grass, are readily apparent in feces. This should not be considered an abnormality, especially in larger species such as Galapagos or African spur (*Geochelone sulcata*) tortoises.

Fiber should be considered when making nutritional recommendations for tortoises. Fibers include cellulose, hemicellulose, gums, mucilages, pectins, lignins, and a variety of polysaccharides such as galactan. Cell-wall fibers include lignin, cellulose, and some hemicelluloses. These are measured by DHIA laboratories servicing the dairy industry. Less commonly quantitated are soluble fibers from the cell interior, such as other hemicelluloses, gums, mucilages, and pectins.

Each type of fiber varies in its action and beneficial properties. Because food ingredients contain different fibers in varying proportions, comparisons between studies are difficult. Generally, until more data are available for reptiles, fiber sources that are standard for mammalian herbivores are recommended.

Hays may be fed to large tortoises. Many prefer clover, timothy, and mixed hays to alfalfa. Hays may be chopped and added to diets of produce. Hays have been used as bedding and consumed along with a produce diet, but care must be taken to keep the hay clean and wholesome. Pellets and meals contain short-stem fibers, which may be less effective in regulating gut motility.

Hays generally provide about 25-40% (DM) crude fiber, whereas supermarket produce provides generally less than half that amount. Commercial fiber-containing products may be purchased from supermarkets and pharmacies; most contain cellulose, bran (which can irritate bowels), or psyllium. Purified cellulose is marketed (such as Solka Floc^R, James River Corp, Saddle Brook, NJ 07662). It is valuable in slurries for tube-feeding, especially when intestinal health is compromised. Enterocytes use volatile fatty acids that arise from fermentation of fiber in the lower bowel as energy sources. Fiber is therefore useful when promoting wound healing in the intestine and recovery from enteritis.

Omnivorous Tortoises

Box turtles and hinged tortoises consume variable amounts of animal matter in the wild. Slugs, snails, millipedes, earthworms and carrion have been consumed. Most likely, these tortoises are opportunistic feeders, consuming animal matter when it presents itself. It is unknown if animal matter is consumed daily.

These omnivores appear to do well in captivity when fed plant and animal matter, in proportions ranging from, say, 75:25-90:10. Plant ingredients should predominate in diets for these tortoises in captivity.

Commercial diets for omnivores should contain a mix of animal- and plant-source proteins, but adequate fiber, too. Estimates for label guaranteed analyses are about a minimum of 24% crude protein and 10% crude fiber.

SUGGESTED READING

Bjorndal, K.A. 1989. Flexibility of digestive responses in two generalist herbivores, the tortoises Geochelone carbonaria and Geochelone denticulata. *Oecologia* 78:317-321.

Donoghue, S. and Langenberg, J. 1996. Nutrition. In: *Reptile Medicine and Surgery*. WB Saunders, Philadelphia. pp 148-174.

Hamilton, J. and Coe, M. 1982. Feeding, digestion and assimilation of a population of giant tortoises (Geochelone gigantea (Schweigger)) on Aldabra atoll. *J Arid Environ* 5:127-144.

Harless, M. and Morlock, H. 1989. *Turtles: Perspectives and Research*. Krieger Publ Co., Malabar FL.

Meienberger, C., Wallis, I.R., and Nagy, K.A. 1993. Food intake rate and body mass influence transit time and digestibility in the desert tortoise (Xerobates agassizii). *Physiol Zool* 66:847-862.

Swingland, I.R. and Klemens, M.W. 1989. *The Conservation Biology of Tortoises*. IUCN. Kelvyn Press, Broadview, IL.