Sloth Nutrition Guide

PAX TAG Sloth SSP

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Nutritional Requirements

Feeding and digestion in sloths

The two main genera of extant sloths consume diets of almost 100% leaves. *Bradypus* (three-fingered) sloths are highly specialized folivores (leaf-eaters), consuming nearly exclusively *Cecropia*, as well as occasionally *Clethraceae* and *Clusiaceae* leaves (Urbani and Bosque 2007). *Choloepus,* (two-fingered) sloths, consume leaves from a wide variety of species, as well as occasionally fruits, flowers and stems.

Both *Bradypus* and *Choloepus* sloths have a large (25% of a sloth's body weight, including contents), sacculated, multi-chambered stomach that resembles that of a small ruminant (Figure 1, Stevens and Hume 1995). Like ruminants, the sloth stomach is filled with microbes that ferment and digest food particles, and may help break down plant toxins. The stomach may also have a sieve-like function, retaining large particles, while allowing smaller ones to settle and be passed along (Stevens and Hume 1995; Clauss 2004).

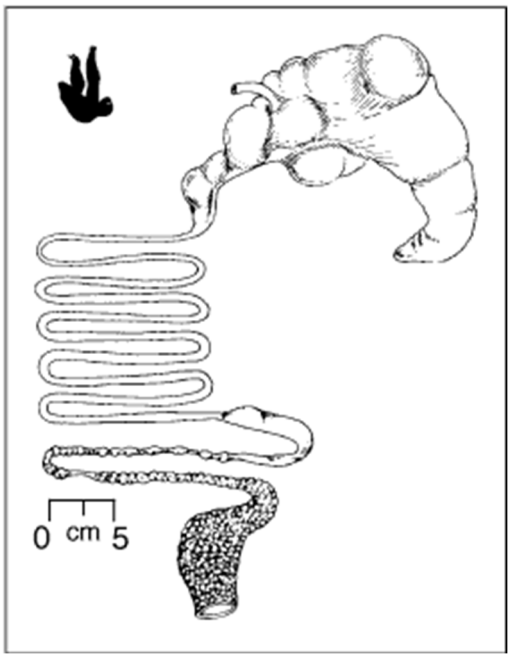

Figure 1. Sloth gastrointestinal system showing multichambered stomach, site of microbial fermentation.

Folivory

Given the abundance of leaves on the planet, the fact that so few mammals are folivores (leaf-eaters) suggests that there are distinct challenges with leaf eating (McNab 1978). Leaves are often well-defended with toxic plant secondary compounds such as alkaloids, phenols, terpenes, and condensed tannins. Folivores deal with this in several ways. Behaviorally, many folivores will rotate eating different plant species regularly to avoid prolonged consumption of any one toxin. Indeed, *Choloepus* in managed care will commonly refuse a browse species that was only recently enthusiastically consumed, presenting the appearance of "picky eaters". In fact, they are not picky, but merely following common browser trends of rotating among species regularly.

Physiologically, gut microbes can aid in detoxifying many plant compounds. The interplay between plant secondary compounds and the sloth microbiome has not been studied, but in ruminants, rumen microbes allow herbivores to eat many otherwise toxic compounds (Hammond *et al*. 1989; Hammond 1995) . *Bradypus* has a notably simple gut microbiome, likely due to its relatively monotonous diet, while *Choloepus* has a more diverse microbiome that may be able to deal with a more varied array of plant compounds (Dill-McFarland *et al*. 2016).

Leaves also have a very low caloric density. Folivores typically adopt one of two strategies: (1) consuming a large number of leaves, having a fast gastrointestinal passage rate, and digesting very little (i.e. the giant panda, which digests less than 40% of the material ingested) or (2) consuming a selective,

small number of leaves, having a slow passage rate, and digesting a large proportion of the food. Sloths follow the second path, defecating only every few days (sometimes only once a week), and reaching an extraordinarily high (~90%) food digestibility (Vendl *et al*. 2016), in the range usually seen in carnivores.

In order to achieve this high digestibility, food must remain in the stomach for sufficient time for the stomach microbes to attach to and ferment the food. The amount of time this takes is dependent on particle size, with smaller particles likely exiting the stomach faster than larger particles (Clauss 2004). Larger particles result from eating whole leaf material, including browse and leafy greens. Pulverized plant material, such as found in commercial or processed feeds, lacks the effective particle size to maintain stomach function. Therefore, sloth diets require a source of physically-intact fibers such as browse or leafy greens.

Sloths conserve energy in other ways. Although technically they are endotherms ("warm-blooded"), sloths share some characteristics with ectotherms, namely that they can raise and lower their body temperature using both physiological and behavioral mechanisms, such as sunning/basking. The ability to behaviorally control their body temperature is an important aspect of their husbandry and influences their energy requirements.

Although basal metabolic rate (BMR) and body size are very tightly correlated across nearly all groups of animals, sloths are exceptional, having the lowest BMR of any animal, meaning they require the lowest calories for their body size of any animal. They require only 38% (*Bradypus*) or 37-45% (*Choloepus*) of what would be expected for their body size. One way to achieve this is by having extremely low muscle mass – sloths have approximately half the muscle mass of terrestrial animals (McNab 1978), which dramatically lowers their metabolic rate.

Within their thermoneutral zone (above 18-35 °C / 65-95 °F in *Bradypus*; 24-35 °C / 76-95 °F in *Choloepus* (McNab 1978)), sloths maintain a relatively constant body temperature and metabolic rate. However, below their thermoneutral zone, body temperature decreases and eventually metabolic rate decreases, which can seriously endanger the animal. Cold stress is a common cause of sloth morbidity and mortality after cold spells in their native environments (APPC, personal communication).

It may be helpful to think of sloths as a conglomerate of different species requirements: They are like reptiles in terms of their climate needs (including the need for high humidity, warmth, and a location to bask), marsupials in terms of their low energy requirements, small ruminants in terms of their digestive physiology, and similar to folivorous primates in terms of nutrient recommendations (with several notable exceptions).

Energy requirements

Energy requirements are calculated on the basis of metabolic weight, defined as:

Metabolic body weight (MBW_{kg}) = (body weight in kilograms[1]) ^ 0.75.

For example, a 6-kg sloth would have a metabolic body weight (MBW) of 3.83 kg.

Captive sloth maintenance energy requirements can be calculated as:

[1] It is important to use kilograms.

Maintenance & Early Pregnancy	[2]45-60 kcal * MBW_{kg}
Late Pregnancy (last trimester)	60-70 kcal * MBW_{kg}
Growth/Gain/Lactation	75 kcal * MBW_{kg}

So, our hypothetical 6-kg sloth would require ~173 kcal/day for maintenance (3.83 * 45) at typical activity levels.

Establish a feeding program using these calculations, then adjust based on body weight and condition.

Nutrient requirements

Nutrient	Target (Dry Matter basis)	Notes
Protein	Common zoological sloth diets contain 15-25% protein, although levels as low as 10% are common for many folivores, and are likely adequate for sloths as well.	Protein requirements are minimized through the recycling of urea nitrogen through the stomach microbial community.
Fat		No known fat requirement. Sloths, like many ruminants, seem to avoid fatty foods, although eggs (including yolks) are well-liked by some sloths.
Fiber	Diets with a minimum of 10-30% NDF, and 5-15% ADF have been suggested for leaf eating primates (NRC 2003), and are likely good targets for sloths as well.	Most dietary fiber should be from **whole leaf sources,** such as browse or leafy greens, rather than pelleted feeds, to provide sufficient *effective fiber* for proper fermentation.
Sugar and Starch	Should make up less than 15% of the diet	Spread meals evenly throughout the day, avoid consuming large portions at one time
Calcium	0.5 – 1.0% (max)	Many sloth and non-sloth members of Xenarthra have developed hypercalcemia on zoological diets (Diniz et al.

[2] These values derived from (McNab 1992; Pauli et al. 2016; Vendl et al. 2016), and assume 90% digestibility of common zoo diet items by sloths (Vendl et al. 2016).

Phosphorus	0.5 – 1.0% (max)	1995; Crawshaw and Oyarzun 1996; Han and Garner 2016; PAX TAG communications). It appears this taxon is sensitive to levels of calcium, phosphorus, and vitamin D that are commonly recommended for and tolerated by other taxa. Note that minimum levels of these nutrients are still given here. Care must be taken that efforts to reduce calcium and vitamin D are not so extreme that they lead to deficiencies in these nutrients. Indoor-housed sloths are most at risk of deficiency, as sunshine (UV)-induced vitamin D synthesis may be limited. Because of the nuance involved in targeting the right range, we strongly encourage consulting a nutritionist who can calculate the exact proportion of these nutrients in the diet.
Ca:P Ratio	1.0 - 1.4 : 1	
Vitamin D	11 – 20 mcg (440 - 800 IU) /1000 kcal of diet 1320 – 2400 IU/kg diet dry matter	
Vitamin A	8,000-300,000 IU/kg	Adapted from primate recommendations (NRC 2003)
Vitamin E	100 IU/kg minimum	Adapted from primate recommendations (NRC 2003)
B vitamins and vitamin K	None (but see exception)	These nutrients are likely synthesized by a healthy microbial community and do not need to be provided in the diet. However, supplementation may be indicated if an antibiotic is used that disrupts the microbial flora.
Iron	100-300 ppm	Adapted from primate recommendations (NRC 2003)
Copper	20 mg/kg	Adapted from primate recommendations (NRC 2003)
Potassium	0.3%	Adapted from primate recommendations (NRC 2003)

Supplementation

In general, the diets recommended here should provide all essential nutrients. Fish oil supplements (without vitamin D3) have been shown to slow the rate of kidney decline in several other species, and may be appropriate in sloths exhibiting signs of kidney dysfunction. It has been used in at least one sloth with success.

Diets

Like ruminants, the microbial community in the stomach plays a vital role in processing and detoxifying leaves, as well as *producing needed nutrients*. Microbes and microbial products constitute a large portion of the nutrients available to the animal, and are likely the source of most required vitamins, amino acids, and fatty acids. Therefore, it is crucial to support the gut microbiome.

Maintaining a healthy microbial ecosystem in any foregut fermenting animal requires adherence to several key principles:

1) **Steady environment** – sloths use physiological and behavioral means to maintain the temperature, pH, and osmolality of their microbial fermentation chamber. In general, foregut fermenters eat small amounts throughout their waking hours, rather than consuming large discrete "meals". In sloths, body temperature is maintained through a combination of environmental temperature, behavioral modifications (posture, sunlight exposure), and physiological means. If sloths can't maintain appropriate body temperature, severe damage to the microbial community can result.

2) **Provision of adequate "effective fiber" or substrate of the right particle size** - food particles must remain within the fermentation chamber long enough to allow microbial fermentation, which can take several days. Smaller particles may be swept out sooner, escaping fermentation. Thus, **the diet must have adequate large form particles to maintain the fiber-fermenting microbes**, most commonly obtained through feeding whole leaves, including browse and leafy greens. Although pelleted feeds can contain high levels of fiber, the small particle size does not support effective fermentation.

3) **Limited sugar and starch** – Microbes readily and rapidly ferment sugar and starch, releasing gasses, acids, and more microbes. If a sufficiently large bolus of sugar arrives in the stomach, the rapid gas production can cause bloat, a painful and life-threatening condition, especially in sloths that lack the ability to belch. Although starch ferments more slowly than sugar, in ruminants, high starch intake can lead to acidification of the rumen contents and ruminal acidosis. When high levels of starch are fed regularly, the acidification alters the rumen microbiome and can permanently damage the lining of the stomach. In sloths, like ruminants, small amounts of sugars and starch spread throughout the day seem to be tolerated well, while large amounts provided all at once can be problematic.

4) **Browse -** Browse should always be firmly affixed to the enclosure. Loose browse makes it difficult for the animals to pluck leaves and increases the likelihood of an impaction from ingesting pieces of browse that are too long or big. Browse can be affixed by:
    - **a.** Threading through PVC pipes or holes in boards
    - **b.** Weaving through mesh or exhibit furniture
    - **c.** Placing in hay bags (designed to slow horse feeding)
    - **d.** Creating browse bundles using carabineers or clamps and attaching to the enclosure

5) **Diversity in browse –** Most folivores will not continue eating one species of browse for extended periods (varies greatly, but 3 days to two weeks is a typical rotation), and will "go off" browse species quickly. Providing a regular rotation of browse species is critical.

6) **Timing of feedings** – two-fingered sloths are typically nocturnal, and much of their feeding occurs at night. Unless kept on a reversed day-night cycle, animals should be provided a substantial portion of their diet overnight. Three-fingered sloths are more diurnal and their feeding schedule should reflect that.

7) **Location of feeding –** Activity can be encouraged by providing food in a variety of locations and heights throughout the exhibit.

8) **Positioning –** The ability for sloths to rest upright, in a "tree-hugging" position may be important for the passage of digesta through their systems (Clauss 2004). Enclosures should provide opportunities for them to sit comfortably in this position.

Selecting a diet

Two-fingered sloths are fed a variety of diets at zoological facilities. Most variants consist of a primate biscuit, greens, browse, and moderate amounts of fruits and vegetables.

Biscuits designed for primates, including those targeted to leaf-eating animals, are generally heavily fortified with vitamin D3. Diets formulated specifically for new world primates such as callitrichids are even higher in D3. Therefore, primate biscuits should be used carefully and in moderation in sloth diets. For sloths whose diets exceed the recommendations listed above for calcium and vitamin D, transitioning to a non-primate biscuit or lowering the amount of the biscuit might help get the values into the target ranges above.

An alternative to primate biscuits might be a product designed for hoofstock/browsers, which generally are less fortified with vitamin D, although experience with products like this is lacking, and pelleted products should not be used to provide the necessary levels effective fiber.

Sloths are often very fond of legumes, including varieties of beans and peas in their pods (i.e. green beans, snow peas, etc.). Much of the fiber in these lies in the pod, so feed the pods (not just the peas) where possible, and these can often be used as training/enrichment/interaction foods. Vegetables and fruits should be presented with peels/skins intact, in sizes/shapes (rectangular – 1 X 3-5 cm) that can be easily handled by the animal.

Diets that meet recommendations above:

Diet 1

25 g	High fiber biscuit	This diet contains: • 194 kcal • 18% protein • 5% fat • 30% NDF • 20% ADF • 0.8 % Ca • 0.5% P • 1.43 Ca:P ratio • 192 ppm Iron • 1,430 IU D/kg
200 g	Leafy greens (romaine, kale, collards, spring mix)	
85 g	Vegetables (bean pods, pea pods, peppers, squash, cucumbers, etc.)	
25 g	Fruit, used exclusively for husbandry/training/enrichment	
5 g	Hardboiled egg for husbandry/training/enrichment	
5-10	Browse branches (50 g total leaf material consumed)	

Diet 2

45 g	High fiber biscuit	This diet contains: • 325 kcal • 19% protein • 4% fat • 22% NDF • 14% ADF • 0.7 % Ca • 0.5% P • 1.31 Ca:P • 290 ppm Iron • 1,285 IU D/kg
460 g	Lettuces (romaine, green leaf, etc.)	
210 g	Vegetables (bean pods, pea pods, peppers, squash, cucumbers, etc.)	
25 g	Fruit	
5-10	Browse branches (50 g total leaf material consumed)	

Browse list

Sloths will consume a wide variety of browse species. Browse availability is extremely regional, but commonly fed species in the US include:

- Hibiscus (*Hibiscus spp.*) – often the most popular species – both leaves and flowers
- Bamboo (*Phyllostachys spp., Bambusa spp., Psuedosasa spp.*)
- *Cecropia* species (if available)
- Copperleaf (*Acalypha wilkesiana*)
- Elm (*Ulmus spp.*)
- Mulberry (*Morus spp.*)
- Plumbago, Cape leadwort (*Plumbago auriculata*)
- Willow (*Salix spp.*)

Browse should be offered through a coordinated browse program that ensures the identity and safety of the browse offered, including safety from contaminants such as pesticides, herbicides, mold, bird feces, and other hazards.

Nutritional Evaluations

Dietary Concerns

The primary nutritional concerns in sloths include issues related to urinary tract disease and soft tissue mineralization (Salas et al. 2014; Han and Garner 2016; Black et al. 2020). These disorders are related – renal disease can lead to calcium retention, and hypercalcemia can damage kidneys, so the exact cause and effect of these concerns are unknown at this time.

Evaluating nutritional status

Unlike many other species, xenarthrans rarely deposit visceral fat. As such, conventional body condition scoring measures that evaluate the prominence of various bones are challenging to apply. A muscle score may be more appropriate, as sloths who are ill will frequently lose muscle mass. Radiographs may also be helpful in assessing condition scores. This is an area that needs additional research for these species.

Body weights should be recorded regularly because body mass changes will be seen on the scale long before they can be (easily) detected from handling or observation. We recommend weighing at least every two months or more frequently where possible. It is important to weigh shortly after the animals have had a bowel movement. Because they defecate so infrequently, the weight of a bowel movement can be as large as 20% of their body mass. Weighing immediately after this allows better tracking of trends in body mass.

Feces should be firm and pelleted. Feces can be evaluated using the fecal condition scoring system in Appendix A. Feces with scores of 3 or higher may indicate a lack of effective fiber in the diet or other gut dysregulation.

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Appendix 1

Sloth Fecal Condition Scoring Guide	
Score 1 – deer pellets 	Score 2 – formed, but less pelleted 
Score 3 – Some parts not pelleted 	Score 4 – Formed, minimal pelleting 
Score 5 – Unformed, minimal pelleting 	Score 6 – Unformed, soft 
Score 7 – Diarrhea, no texture