

Nutritional Physiology and Feeding of Companion Rodents



Jennifer L. Parsons, MS, PhD^{a,b,*}

KEYWORDS

• Rodent • Rat • Mouse • Hamster • Guinea pig • Chinchilla • Nutrition • Microbiome
• Digestive tract

KEY POINTS

- Feeding to each species' dietary niche is paramount, because not all rodents share the same evolutionary history; diets should be adjusted to species accordingly.
- Dietary health issues for many rodents stem from the historic tendency to model all rodent diets after those suited for domestic rats and mice, whose physiology and nutritional ecology differ significantly from most other rodent species.
- Historic rodent diets were also modeled for the needs of laboratory animal applications, which similarly differ significantly from the needs of companion animals.
- A focus on the health of the digestive tract microbiome is extremely important, including provision of proper substrates (foodstuffs as well as water), and support for species-appropriate cecotrophy.
- Unique nutritional health needs of rodents include management for near-continual foraging, constant incisor growth, and unique vitamin requirements for some species.

BACKGROUND

Nutritional Ecology

Members of order Rodentia share many similarities in appearance as well as feeding habits. To effectively manage their dietary husbandry, an understanding of the role of diet niche, evolutionary history, and free-ranging ecology is important. Almost all rodents worldwide are foragers on primarily plant matter, within a range of categories: specialist herbivores, generalist herbivores, granivores, omnivores, frugivores, and (represented by a small handful of species) insectivores. Companion rodents fall almost entirely into the first 4 of these categories. Specialist herbivores consume

^a Association of Zoos and Aquarium's Rodent-Insectivore-Lagomorph Taxon Advisory Group;

^b Mazuri Exotic Animal Nutrition, PMI Nutrition International, 4001 Lexington Avenue North, Arden Hills, MN 55126, USA

* Corresponding author.

E-mail address: jparsons@mazuri.com

mainly monocots (grasses), forbs, and shrubs; generalist herbivores consume similar items to specialist herbivores, with partial or seasonal reliance on additional feeds such as seeds, nuts, or fruiting bodies.¹ Omnivores expand the diet of a generalist herbivore to include animal matter such as insects, and granivores subsist on a majority seed diet.¹ It is important to note here that, with very few exceptions, wild-type fruits, seeds/nuts, and other categories of foodstuffs differ significantly in nutritional composition from analogs cultivated by humans (Tables 1 and 2).

Most rodents consume extremely high-fiber diets and derive a large amount of dietary energy from the digestion of either plant fiber (plant cell wall components), or cell solubles (enzymes and other molecules located inside the plant cell).² Plant fiber is made up of 3 types of molecules, which differ in proportion with plant type and part: (1) hemicellulose, which is partially digestible by mammalian enzymes, (2) cellulose, which no vertebrate enzymes can break down but which can be digested by microbial enzymes, and (3) lignin, which is completely indigestible.^{2,3} Herbivores that consume high-cellulose diets usually develop extensive anatomic and metabolic adaptations to host large populations of symbiotic microbes within their gastrointestinal tract and to utilize the metabolites synthesized by these microbes during cellulose digestion.^{2,3}

Digestive Anatomy and Physiology

Vertebrates adapted to utilize dietary cellulose diverge into 2 main groups: foregut fermenters and hindgut fermenters. Foregut or pregastric fermenters have developed specialized outpouchings of the esophagus, and ingested feed passes through sometimes extensive compartments before the true (glandular) stomach.^{2,4} These compartments host a diverse and complex ecosystem of cellulolytic protozoa, bacteria, fungi, and yeast.^{2,4} Hindgut fermenters host a similar microcosm within the intestinal tract instead, with extensive development and specialization of structures distal to the small intestine.^{2,4} Virtually all rodents are hindgut fermenters to some degree (Fig. 1).⁴ Although the colon is the primary site for cellulose digestion in many large-bodied

Table 1 Nutrient composition comparison among major categories of produce and forage, along with wild-type fruits							
Nutrient, % of Dry Matter	Wild Fruits	Commercial Produce				Grasses (Hay)	Alfalfa Hay
		Fruits	Starchy Vegetables ^a	Other Vegetables	Greens		
Protein	12.1	3.7	5.8	17.1	22.9	11.1	18.0
Acid-detergent fiber	37.2	6.6	6.9	12.1	12.4	33.4	29.6
Neutral-detergent fiber	48.2	12.1	14.9	28.6	17.3	65.4	
Sugars	7.6	17.1	12.4	30.5	10.2	9.3	
Starches	1.7	64.5	40.6	19.6	14.3	4.3	
Calcium	0.88	0.04	0.20	0.26	1.02	0.54	1.3
Phosphorus	0.23	0.08	0.21	0.45	0.40	0.20	0.23

^a Includes root vegetables, corn, winter squashes, and peas.
Mean data from Kendrick EL, Shipley LA, Hagerman AE, Kelley LM. Fruit and fiber: The nutritional value of figs for a small tropical ruminant, the blue duiker (*Cephalophus monticola*). Afr. J. Ecol. 2009; 47:556 to 566; U.S. Department of Agriculture, Agricultural Research Service. National Nutrient Database for Standard Reference. 2016; National Research Council. Nutrient Requirements of Horses. 6th rev ed. The National Academies Press; 2007.

Table 2
Nutrient composition comparison among wild-type and cultivated nuts and seeds

Nutrient, %	Baobab	Wild-type	Sunflower		Almonds	Walnuts	Macadamia	Millet
	Seed	Nuts	Peanuts	Seeds				
Protein	36.3	8.0	25.7	22.8	20.0	24.4	8.3	11.0
Crude fiber	14.1		8.5	8.6	12.5	6.8	8.6	8.5
Fat	29.3	5.3	49.2	49.6	52.2	56.6	73.7	4.2
Calcium		1.0	0.06	0.12	0.27	0.06	0.07	0.01
Phosphorus		0.9	0.38	0.70	0.52	0.46	0.14	0.29

Mean data from Murray SS, Schoeninger MJ, Bunn HT, Pickering TR, Marlett JA. Nutritional composition of some wild plant foods and honey used by Hadza foragers of Tanzania. *J Food Compos Anal* 2001; 14(1):3 to 13; Agrahar-Murugkar D, Subbulakshmi G. Nutritive values of wild edible fruits, berries, nuts, roots and spices consumed by the Khasi tribes of India. *Ecol Food Nutr* 2005; 44:207 to 223; U.S. Department of Agriculture, Agricultural Research Service. National Nutrient Database for Standard Reference. 2016

hindgut fermenters (eg, equids), rodents in particular show significant specialization of the cecum, where the majority of microbial activity occurs in these species.⁴ A handful of exceptions exist, because some rodents (eg, hamsters) have developed a combination of foregut and hindgut fermentation, with a pregastric region in the stomach, which houses a microbial population, lower pH than the glandular portion of the

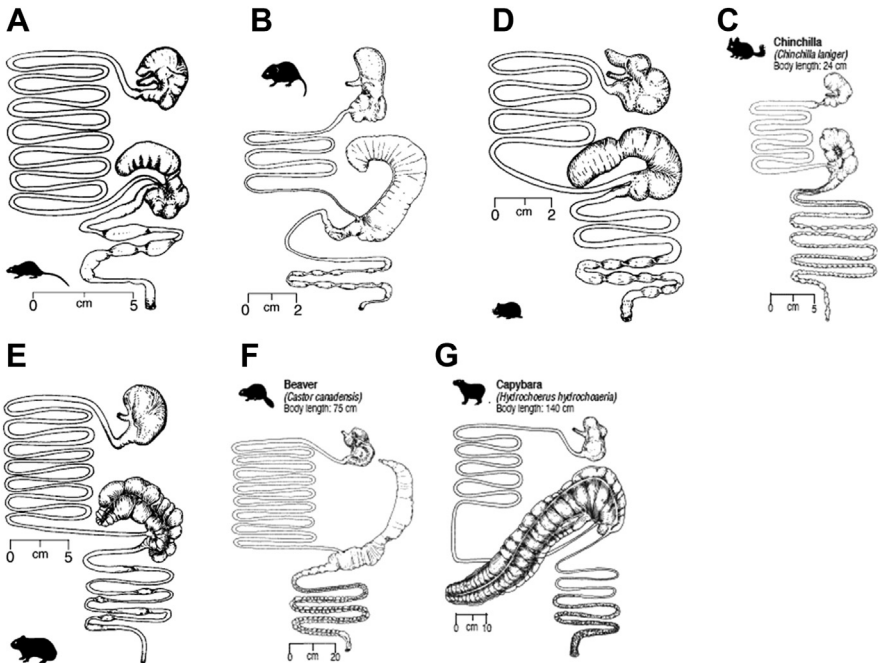


Fig. 1. Digestive tract anatomy of representative companion and wild rodent species, in order of increasing anatomical and physiological complexity from left to right and top to bottom. (A) Domestic rat, (B) hamster, (C) vole, (D) chinchilla, (E) guinea pig, (F) beaver, and (G) capybara. Adapted from Stevens CE, Hume ID. *Comparative Physiology of the Vertebrate Digestive System*. 2nd ed. Cambridge University Press; 1995, with permission.

stomach, and similar function to the rumen in both fermentation and dietary urea utilization (Fig. 2).^{2,4,5}

Due to the ability of gut microbes to convert cellulose into useful metabolites, microbial cells themselves represent an important source of nutrition. As microbes live out their normal life cycle and die, they pass out of the principal fermentation chamber to mingle with ingesta. Foregut fermenters digest these cells in the glandular stomach, whereas cecal fermenters can form discrete masses of microbial cells within the cecum, packaged within a layer of mucus to avoid comingling with colon contents as they travel distally: these “packets” are called cecotropes.⁶ Through neural signaling from the hind end, cecal fermenters are alerted to cecotropes about to pass, and will consume them directly from the anus, thus recovering a significant amount of nutrients that would otherwise be lost in feces.⁶ This process is called cecotrophy (differentiated from coprophagy, which describes consumption of feces or undigested feed, rather than cecotropes⁶), and is quite well documented in rabbits as well; lagomorphs and many rodents that are prevented from practicing cecotrophy will develop nutritional deficiencies.⁷

Proper maintenance of the microbial environment is crucial to any animal that depends on energy from cellulolysis. Microbes require a consistent source of fuel (in this case, cellulose), consistency regarding pH, temperature, and fluid volume, and time for gradual adaptation to any change in environment.² Microbial communities respond to change through microevolution: altering proportions of microbe species during the course of several generations. Thus, a sudden change in dietary substrates will lead to either inefficient feed breakdown or a suboptimal environment for the microbial species present at that moment.²

Microbial fermentation produces 3 main byproducts: volatile fatty acids (VFAs), acidic compounds (eg, lactic acid), and gas (CO₂ and CH₄).² Foregut and hindgut fermenters use VFAs as an energy source, and the structural properties of their digestive tract allow passage of these short-chain molecules into the bloodstream and on to the liver for further metabolism.^{2,3} Under ideal conditions, production of gas and

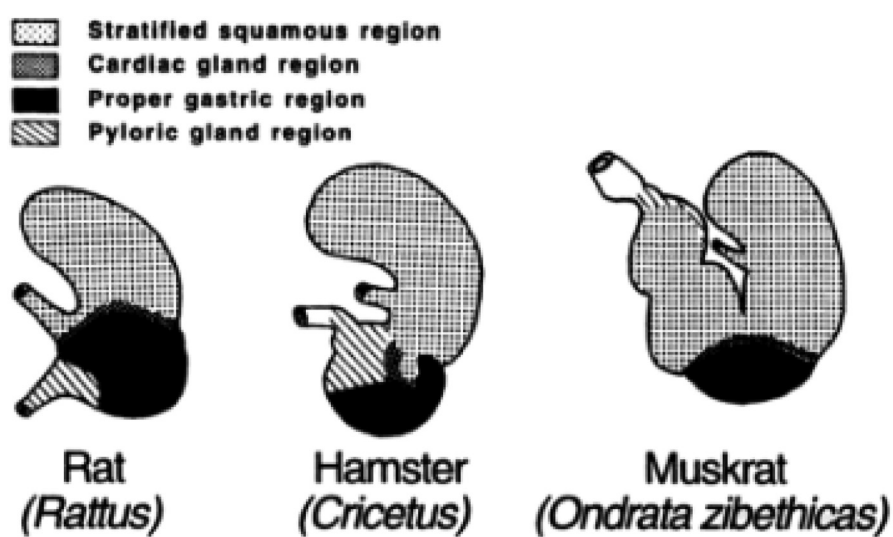


Fig. 2. Distribution of gastric epithelium in 3 species of rodents. From Stevens CE, Hume ID Comparative Physiology of the Vertebrate Digestive System. 2nd ed. Cambridge University Press; 1995.,with permission.

acids is minimal; however, when overexposed to easily-digested and rapidly-fermented substrates, runaway fermentation can occur, causing digestive-tract acidosis and gas build-up. This condition is described as rumenoacidosis or bloat in foregut fermenters, and colitis or colic in hindgut fermenters.² Colic poses structural hazards (distention and intestinal perforation), as well as the risk of acidosis extending to the bloodstream and setting off further metabolic derangements.² Low hindgut pH begins to kill resident microbes, which can release toxins as they die off. These toxins can also enter the bloodstream, where they often lodge in regions of poor vascularization and cause tissue necrosis, a condition called laminitis in equids and similar species.² Hindgut fermenters are somewhat shielded from the effects of rapidly-fermentable dietary substrates, compared with foregut fermenters, by the placement of their microbial community at the end of the tract, after much has been digested and absorbed in the glandular stomach and small intestine. However, heavy loads of easily-fermentable compounds, especially those to which the animal is not accustomed, can still reach the hindgut.

Rodents and lagomorphs are known for their continuously-growing incisors, ostensibly an adaptation to constantly chewing on tough plant material, or forages with a high-silica content.⁸ Under human care, animals without hard materials to chew on can quickly develop dental overgrowth and malocclusions, which impair normal dietary intake. Hard substrates can be provided, either in the diet or in the form of non-toxic wood blocks or similar commercially-sold products, with a preference toward the latter, because most hard pellets are rarely formulated for the species under discussion (as will be explained in depth later in this article).

Rodents have several unique needs related to their typically diminutive nature as well, especially when coupled with their aforementioned gastrointestinal anatomy and nutritional ecology. Small body size results in a large surface area to volume ratio, creating substantial mass-specific energetic demands.⁹ Free-ranging rodents therefore evolved high metabolic rates, and spend the majority of their waking hours foraging, with near-constant ingestion of often fibrous plant matter. Thus, much of their nutritional physiology is adapted to continual throughput of ingesta, and even in domesticity, these taxa require frequent feed intake for proper digestive function and metabolism, as well as to maintain the gut microbial community.⁷

Key Nutritional Factors

Energy

Energy requirements have not been quantified for most rodent species. For the laboratory rat, maintenance energy intake of 112 kcal/BW_{kg}^{0.75} seems sufficient, with the gestation requirement between 10% and 30% greater than those for maintenance (depending on litter size and phase of gestation), and the lactation requirement at least 311 kcal/BW_{kg}^{0.75}, again depending on litter size.⁷ For the laboratory mouse, sufficient energy intake for maintenance was estimated at 161 kcal ME/BW_{kg}^{0.75}, for gestation at up to 360 kcal ME/BW_{kg}^{0.75}, and for peak lactation at 310 to 430 kcal ME/BW_{kg}^{0.75} for large litters.⁷ For both species, energy needs for growth were not possible to estimate completely without sufficient information about the animal, its activity level, and environment.⁷ However, one could expect that energy needs would lie between those for maintenance and reproduction.

For other rodent species, energy needs of rats and mice could be used as a starting place to estimate total feed intake; however, for all rodents (including rats and mice), it is essential to adjust feed intake based on body condition, especially considering differences in efficiency of feed digestion among species, life stages, and individual animals.

Water

Appropriate water intake is not only essential to an animal’s basic physiologic and cellular functions but in the presence of significant gut microbial communities, the maintenance of proper fluid volume in the gastrointestinal lumen also ensures a healthy microbiome.² Therefore, ensuring free access to clean, fresh water that is ideally near room temperature is paramount. Many rodents may be acclimated to use an inverted drinkers fitted with ball valves, diaphragm-style valves, or similar attachments, and this provides the most effective way to ensure continual access to clean water—provided the reservoir is cleaned and refilled ideally daily.

Protein

For species that rely on microbial fermentation for adequate digestion, microbial cells represent an important pool of high-quality protein, with optimal amino-acid balance. For rodent species that routinely practice cecotrophy, ensuring a balanced diet requires free access to this important nutrient source. Once species-appropriate access to microbial protein is ensured, dietary protein needs fall along diet niche lines (Tables 3 and 4). Excess protein can represent a significant substrate for excessively-rapid microbial fermentation, leading to the suite of gut health issues mentioned above and below. Therefore, for best digestive tract health, it is generally recommended to feed toward the lower end of recommended protein ranges (see Table 4) for animals at maintenance, and toward the higher end of these ranges for animals undergoing reproduction or juvenile growth.

Fat

Few studies exist to quantify total lipid requirements for rodents, apart from quantities that ensure rapid growth and/or reproduction in high-producing laboratory colonies. Given the need to manage body condition to ensure long-term health, more moderate dietary fat levels are recommended, again varying slightly by diet niche (see Table 4).

Carbohydrates

Plant cellulose in the form of dietary fiber is an essential substrate for gastrointestinal microbiota, and an important source of energy in the form of VFAs; proper provision of dietary fiber (see Table 4) is extremely important to rodent health. Equally as important is the control of sugars and starches, which represent extremely readily-fermentable substrates and can lead to significant dysbiosis. Sugar intake must be minimized as much as possible, and an appropriate balance must be struck between

Table 3 Published nutrient requirements for laboratory rodents					
Nutrient, % of As-fed Diet	Granivores: Domestic Rat/Mouse		Specialist Herbivore: Guinea Pig (Growth)	Specialist Herbivore: Vole (Growth)	Omnivore: Hamster (Growth and Reproduction)
	Growth	Maintenance			
Protein	15–18	5	18	11–13	16–18
Fat	5	5			3–5
Fiber		<7	13–15	25	
Calcium	0.5		0.8		0.6–1.0
Phosphorus	0.3		0.4		0.4–0.7
Vit C (mg/kg)	N/A	N/A	200	N/A	N/A

Data from National Research Council. Nutrient Requirements of Laboratory Animals. 4th rev ed. The National Academies Press; 1995

Table 4
Appropriate total-diet nutrient concentrations for representative rodents, by diet niche

	Domestic Mice/Rats	Generalist/Omnivorous Rodents (Chinchilla, Hamster, Gerbil)	Herbivorous Rodents (Guinea Pig, Vole)
Protein (%)	15–20	14–20	10–18
Crude fiber (%)	<7	10–15	>20
Lipid (%)	5–7	3–5	2–3
Starch (%)	10–20	< 10	<10
Calcium (%)	0.5–1.0	0.5–1.0	0.5–1.0
Phosphorus (%)	0.3–0.5	0.3–0.5	0.3–0.5
Vit D (IU/kg)	1000–1500	1000–1500	1000–1500
Vit C (mg/kg)	N/A	N/A	200–300 ^a

^a For caviés (growth requirement).

dietary starch and fiber, based on the evolutionary history of the species in question (see [Table 4](#)). For strictly herbivorous rodents in particular (such as guinea pigs), dietary starches should be minimized and dietary fiber emphasized as much as possible.

Vitamins

Yet another benefit of microbial fermentation is the production of all known B vitamins as well as vitamin K in the regions of the digestive tract where it occurs.² However, the hindgut does not absorb vitamins well, thereby making cecotrophy especially important to the satisfaction of micronutrient requirements.

Fat-soluble vitamins A and E are dietary essentials for all rodents. For vitamin A, most species seem to have similar requirements at 2400 IU/kg diet.⁷ Vitamin E requirements depend on the form of tocopherol used: Research with rats and mice has found that RRR- α -tocopherol works best with these species, with a similar requirement for both species of 18 to 22 mg/kg diet, or 27 to 32 IU/kg diet.⁷ Other forms of tocopherol may be used but dose must be scaled to biological activity. Of note is the possibility for selenium status to influence dietary vitamin E needs because these 2 nutrients may interact with each other. Thus, a selenium-deficient animal may need higher amounts of vitamin E; conversely, an excess of either nutrient may reduce needs for the other or could even induce toxicity.

Vitamin D₃ requirements also seem similar across rodent species and are currently estimated at 1000 IU/kg of diet.⁷ It is particularly important to note here that most free-ranging rodents are crepuscular or spend a significant amount of time in burrows or under heavy forest canopy. These species have naturally low requirements for vitamin D and can develop hypervitaminosis quite quickly when exposed to large amounts of exogenous synthetic vitamin D₃. High-quality rodent feeds are formulated with this lower requirement in mind, and generalized herbivore feeds typically contain reasonably moderate amounts of D₃. However, care must be taken to avoid inadvertent consumption of feeds made for other species—especially those intended for primates, whose vitamin D₃ requirements are considerably higher. Similar to the other fat-soluble vitamins mentioned above, vitamin D₃ in excess can become toxic quite quickly, and historically (and at times still today), hypervitaminosis D in rodents was and is common and often dramatic¹⁰ and can result in metastatic calcification of soft tissues across a range of presentations, with the location and severity of lesions depending on both species and dose.

Unlike most mammals, members of the family Caviidae (cavies and maras) cannot synthesize ascorbic acid (vitamin C) quickly enough to meet nutritional requirements,⁷ a trait shared by a sporadic group including primates, dolphins, vampire bats, and some fish. Domestic guinea pigs must therefore be provided with a source of vitamin C, either via fortified feeds or via a variety of water-soluble products in their drinking water.

Finally, it should be noted that vitamins, particularly those in the fat-soluble category, may interact with each other. Oftentimes, an excess of one vitamin may express as a deficiency in another—for example, hypervitaminosis E can present as hypovitaminosis K, or hypervitaminosis A may express as hypovitaminosis D or E. In cases where an excess or deficiency of a given vitamin is suspected, analysis of other vitamins that may potentially interact is highly recommended.

Another important note with vitamins regards the choice of analytical method, and practitioners should never be afraid to discuss laboratory methods and sensitivities with contract laboratories. In general, chromatographic techniques (gas chromatography or liquid chromatography) work best for vitamins, and radioimmunoassay or enzyme-linked immunosorbent assay-based methods tend to lack accuracy and/or repeatability.

Minerals

Rodents also seem to share similar mineral requirements across taxa, and those published for the laboratory rat and mouse may suffice for other species. Calcium and phosphorus are of particular interest, with animals at maintenance requiring lower dietary concentrations than those undergoing growth or reproduction (see [Tables 3 and 4](#)). Because these nutrients interact with each other, total-diet calcium intake must be greater than that for phosphorus, in a generally-recommended ratio of 1.5 to 2:1 Ca:P.⁷ Calcium and phosphorus also depend on vitamin D₃ for regulation of absorption and metabolism, and deficiency or toxicity signs can be very similar; therefore, analysis of all 3 nutrients is highly recommended when investigating a suspected deficiency or excess in 1 of the 3.

Less is known about other mineral requirements in rodent species, but again domestic rat and mouse literature may be consulted as a starting point.⁷ As in all mammals, magnesium and potassium may interact with each other and also with calcium and/or phosphorus; therefore, care must be taken to choose well-balanced feeds, and again a full mineral panel may be useful when diagnosing suspected mineral issues. Similarly, copper, iron, and zinc may inhibit each other, and as mentioned previously, selenium and vitamin E may interact. Fortunately, laboratory methodology is much more standardized with regard to minerals than for vitamins, and most reputable contract laboratories return reliable, affordable results.

Other Nutritional Health Concerns

Great care should be taken regarding management and maintenance of a healthy digestive tract, especially given the complex interactions among the gut microbial community and the host animal's own digestive anatomy and physiology. As mentioned previously, improper proportions of dietary fiber and easily-fermentable carbohydrates can lead to chronic colitis (and associated follow-on pathology) or acute colic. Interruptions in feed intake can cause a simple energy deficiency or, when combined with insufficient hydration, can cause gastrointestinal stasis, a dysfunction in the normal mechanisms for peristalsis, and a slow-down in passage rate.¹¹ Animals that either are fasted too long or undergo voluntary hyporexia or anorexia could experience a shutdown of cecal function as microbes are depleted

of fuel and die off en masse.¹¹ In clinical cases where gastrointestinal microbiome has been severely disrupted, normal function may in some cases be restored through fecal microbial transplantation from a healthy conspecific that has been screened for internal parasites and other infectious disease.

Because rodents are very efficient with digestion and nutrient assimilation, obesity is a problem in individuals under human care that do not experience the temperature demands and activity levels of wild counterparts. Obesity poses the same health risks as with all mammalian species but additionally restricts animals from effectively practicing cecotrophy. Until the obesity is resolved, it is important to ensure that the base of the animal's enclosure is solid (not wire mesh), to allow it to find and consume cecotropes. Obesity is challenging to manage in these species because the solutions common to other animals (limit-feeding or meal-feeding) risk complications from inconsistent passage of ingesta.

RECOMMENDATIONS

To prevent nutritional issues, consideration of each species' dietary niche and the needs of their microbial population is important. Diet item choices must be tailored accordingly: high-fiber, low-sugar, low-starch diets for specialist herbivores, with somewhat higher starches and lower fiber permissible for granivores and omnivores. **Table 4** summarizes total-diet nutrient recommendations for representative species by diet niche.

For virtually all species, produce is not an ideal diet foundation: on a dry-matter basis, commercial produce is low in fiber, high in protein, and in the case of fruit, extremely high in sugars (see **Table 1**). Fruit is almost never an appropriate diet item for rodent species, and for the most specialized herbivores such as guinea pigs, it is recommended to avoid fruit completely. Small amounts of low-starch produce such as dark greens or nonstarchy vegetables may be allowed in rodent diets for husbandry reasons (eg, training, medication vehicles), but for all rodent species it is recommended to feed produce in controlled, measured quantities, in smaller proportions relative to forages and/or fortified feeds that provide fiber.

For specialist and generalist herbivores (eg, guinea pig and chinchilla), consistent intake of forage (grasses) is important. These species do best when fed a diet similar to large-bodied grazing herbivores: freely available grass hay and a quality high-fiber pellet—although generalist herbivores also may do well on reduced quantities of hay if provided with sufficient fiber in the fortified portion of the diet. Alfalfa hay is not appropriate for animals at maintenance, and although it may be used with breeding, growing, or senior animals, it should be given only in very limited and measured quantities, because it is generally too high in protein, calcium, and easily-fermented nutrients (see **Table 1**). Pellets should ideally contain more than 20% crude fiber and less than 10% starch; this was once difficult to find in commercial feeds but with recent advances in manufacturing technology, low-starch commercial pellets are now available.

The temptation often arises with many companion rodent owners to feed a seed-based or nut-based diet; however, for reasons similar to the previous discussion of commercial produce, providing significant quantities of seeds or nuts should be avoided. As with human-cultivated produce, commercially-available seeds and nuts share little resemblance to wild-type seeds, and are much lower in fiber, higher in fat, and depleted of essential nutrients (see **Table 2**). Such products contribute to obesity and can cause nutritional deficiencies, especially in calcium: they naturally lack calcium, and excessive fats may bind calcium in the gastrointestinal tract,

creating calcium soaps that evade digestion and absorption.¹² Seeds or nuts may again be offered as occasional tools to encourage foraging behavior or for other husbandry needs but should be restricted to lower-fat options and fed in very limited quantities.

Because the field of rodent nutrition was initially orientated heavily toward laboratory animal care, caution should be exercised when selecting feeds for rodents in particular. The first (and still many) commercial feed labeled for rodents was developed to meet nutritional profiles suited for laboratory mice and rats, 2 extreme granivores bred from wild counterparts that evolved in close association with human habitation and human granaries. Domestic rats and mice are therefore adapted to higher-starch, higher-protein, and lower-fiber diets than the majority of rodent species. Laboratory rodent feeds can also be heavily fortified with vitamin D₃ to meet the needs of indoor colonies intended for reproduction. Therefore, “rodent pellets” are not recommended for specialist or generalist herbivores, and one should instead search for species-appropriate options—especially in the case of guinea pigs, which not only require a very high-fiber and low-starch diet but also require feeds fortified with vitamin C. However, when feeding truly granivorous species under indoor conditions, quality fortified feed intended for domestic rats and mice may form the basis of a healthy diet.

Management of obesity while ensuring consistent feed intake requires a number of approaches. Rodents can efficiently utilize poor-quality feed sources, so simply switching an animal to a “low-calorie” (high-fiber) diet as one would with a dog or human will not suffice. Slow feeders or puzzle feeders may be used to slow intake and draw out the time it takes to consume a given amount of calories; they may also provide mental stimulation, which is important for any animal under human care. When further limitation of dietary calories becomes difficult, energy expenditure can be increased by providing ample opportunity for physical activity. Some animals may be trained to walk in a harness, and several products exist that encourage rodents to move and explore. However, when selecting a form of exercise such as a wheel or ball, great care should be taken to ensure that animal welfare best practices are met, with regard to the size and shape of the device relative to the animal’s form, the safe functioning of the device, and avoidance of mental stress—for example, by exposing an unacclimated prey species to situations that simulate predation.

SUMMARY

Rodents represent a diverse group of species across a range of evolutionary backgrounds, which nonetheless share commonalities in approaches to dietary management. Nutritional management of companion rodents must diverge from laboratory animal management and must consider the importance of a healthy gastrointestinal microbiome to successful animal health outcomes. Where published nutrient requirements exist, they must be applied appropriately to species, life stage, and body-condition management, and extrapolation of requirements from similar species should be done with care. Common nutritional health concerns include digestive tract dysbiosis, gastrointestinal stasis, dental malocclusion, obesity, and hypervitaminosis D. These and other concerns may be avoided or alleviated through proactive management of appropriate feedstuffs in correct proportion, avoidance of most feeds made specifically for laboratory rodents, and emphasis on promoting healthy physical activity levels and mental stimulation through environmental enrichment.

CLINICS CARE POINTS

- Proper diet management consists of diet-niche-appropriate balance of macronutrients, provision of vitamin-fortified and mineral-fortified feeds, species-appropriate freedom to exercise cecotrophy, and free access to clean water.
- Digestive-tract dysbiosis may be avoided and/or potentially corrected by establishing the right dietary balance of fiber, sugars/starches, and protein. Fecal microbial transplant may be a powerful tool to recover significantly disturbed microbiome.
- Unique considerations for the management of rodent nutritional health include their small body size (and therefore high metabolic rate and need to eat continuously), ever-growing incisors, and specific nutrient needs such as vitamin C for caviés.
- Obesity can be challenging to manage and can present add-on health issues; body condition is more easily managed proactively, through careful selection of diet items and encouragement of activity via environmental enrichment.
- In cases of suspected micronutrient excess or deficiency, multinutrient analyses are highly recommended. In the case of vitamins, choice of laboratory and analytical method are extremely important.

DISCLOSURE

Dr J.L. Parsons is a nutritionist with Mazuri Exotic Animal Nutrition, which markets rodent products.

REFERENCES

1. Parsons JL. Nitrogen requirements of Southern Plains small mammals: dietary niche, life history, and environmental implications, . Thesis. Stillwater, OK: Oklahoma State University; 2001.
2. Pond WG, Church DC, Pond KR, et al. Basic animal nutrition and feeding. 5th edition. Hoboken, NJ: Wiley; 2005.
3. Robbins CT. Wildlife feeding and nutrition. 2nd edition. San Diego, CA: Academic Press; 2001.
4. Stevens CE, Hume ID. Comparative physiology of the vertebrate digestive system. 2nd edition. New York, NY: Cambridge University Press; 1995.
5. Reznik G, Reznik-Schuller H, Mohr U. Clinical anatomy of the European hamster *Cricetus cricetus* L. U.S. Government Printing Office; 1978. Available at: <https://digital.library.unt.edu/ark:/67531/metadc28308/m1/163/?q=proventriculus>. Accessed March 10, 2023.
6. Guerra Aldrigui L, Gama Nogueira-Filho SL, Mendes A, et al. Effect of different feeding regimes on cecotrophy behavior and retention of solute and particle markers in the digestive tract of paca (*Cuniculus paca*). Comp Biochem Physiol A 2018;226:57–65.
7. National Research Council. Nutrient requirements of laboratory animals. 4th rev edition. Washington, DC: The National Academies Press; 1995.
8. Martin LF, Ackermans NL, Tollefson TN, et al. Tooth wear, growth and height in rabbits (*Oryctolagus cuniculus*) fed pelleted or extruded diets with or without added abrasives. J Anim Physiol Anim Nutr (Berl) 2022;106(3):630–41.
9. McNab BK. The physiological ecology of vertebrates: a view from energetics. Ithaca, NY: Comstock Publishing Associates; 2002.

10. Kenny D, Cambre RC, Lewandowski A, et al. Suspected vitamin D3 toxicity in pacas (*Cuniculus paca*) and agoutis (*Dasyprocta aguti*). J Zoo Wildl Med 1993;24(2):129–39.
11. Harkness JE, Wagner JE. Biology and medicine of rabbits and rodents. 4th edition. York, PA: Williams & Wilkins; 1995.
12. Frommelt L, Bielohuby M, Stoehr BJM, et al. Effects of low-carbohydrate, high-fat diets on apparent digestibility of minerals and trace elements in rats. Nutrition 2014;30(7–8):869–75.