Effect of slaughter weight on the bromatological composition and energy value of rats (*Rattus norvegicus*) and mice (*Mus musculus*)

Efeito do peso de abate na composição bromatológica e valor energético de mercol (*Rattus norvegicus*) e camundongos (*Mus musculus*)

Efecto del peso de sacrificio sobre la composición bromatológica y el valor energético de ratas (*Rattus norvegicus*) y ratones (*Mus musculus*)

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ABSTRACT
Carnivorous animals in captivity are commonly fed whole frozen prey carcasses, primarily rodents. However, there is a significant gap in the current scientific literature regarding the detailed characterization of the nutritional values of these prey, with most previous studies relying on single-size samples. Furthermore, variations in the dietary composition of rodents demonstrate a considerable impact on nutritional parameters, as evidenced by the increased protein levels in individuals fed specific diets. The objective of this study was to assess whether the nutritional values of whole frozen prey carcasses are influenced by size or age at slaughter, as well as the diet of the prey. To this end, we utilized mice (Mus musculus; n = 900) and rats (*Rattus norvegicus*; n = 1500), categorized by weight, ranging from neonatal stages to adulthood, resulting in 15 categories for rats and nine categories for mice. The body composition of rodents from both species varied significantly with age, enabling the development of a table containing values for moisture, protein, fat, mineral material, calcium, phosphorus, and energy content based on the body weight of the prey.

Keywords: carnivorous animal, nutritional value, whole prey.

RESUMO
Animais carnívoros em cativeiros são comumente alimentados com carcaças de presas inteiras congeladas, principalmente roedores. Entretanto há uma lacuna significativa na literatura científica atual, no que diz respeito à caracterização detalhada dos valores nutricionais dessas presas, sendo a maioria dos estudos anteriores baseada em amostras de tamanho único. Ademais, a variação na composição dietética dos roedores demonstra um impacto considerável nos parâmetros nutricionais, evidenciado pelo aumento dos níveis proteicos em indivíduos que foram alimentados com dietas específicas. O objetivo deste trabalho foi avaliar se os valores nutricionais de carcaças de presas inteiras congeladas são influenciados pelo tamanho ou idade ao abate e dieta das presas. Para tanto, foram utilizados camundongos (Mus musculus; n = 900) e mercol (*Rattus norvegicus*; n = 1500), categorizados por peso, desde recém-nascidos até a fase adulta, resultando em 15 categorias para os mercois e nove categorias para os camundongos. A composição corporal dos roedores das duas espécies diferiu significativamente com a idade e permitiu a elaboração de uma tabela com os valores de umidade, proteína, gordura, material mineral, cálcio e fósforo e valor energético em função do peso corporal das presas.

Palavras-chave: valor nutricional, presas inteiras, animal carnívoro.

RESUMEN
Los animales carnívoros mantenidos en cautiverio suelen ser alimentados con carcasas de presas enteras congeladas, principalmente roedores. Sin embargo, existe una brecha significativa en la literatura científica actual en lo que respecta a la caracterización detallada de los valores nutricionales de dichas presas, ya que la mayoría de los estudios previos se basan en muestras de un único tamaño. Además, la variación en la composición de la dieta de los roedores demuestra un impacto considerable en los parámetros nutricionales, evidenciado por el aumento de los niveles proteicos en individuos alimentados con dietas específicas. El objetivo de este estudio fue evaluar si los valores nutricionales de las carcasas de presas enteras congeladas se ven influenciados por el tamaño o la edad al sacrificio y por la dieta de las presas. Para ello, se utilizaron ratones (Mus musculus; n = 900) y ratas (*Rattus norvegicus*; n = 1500), categorizados por peso,

desde recién nacidos hasta la fase adulta, resultando en 15 categorías para las ratas y nueve para los ratones. La composición corporal de los roedores de ambas especies difirió significativamente con la edad, lo que permitió la elaboración de una tabla con los valores de humedad, proteína, grasa, material mineral, calcio, fósforo y valor energético en función del peso corporal de las presas.

Palabras clave: valor nutricional, presas enteras, animal carnívoro.

1 INTRODUCTION

It is estimated that approximately 7% of mammal, bird, reptile, and amphibian species kept in captivity are housed in zoos, rehabilitation centers, research facilities, breeding centers, and similar institutions (Carciofi et al., 2011). For the maintenance of these animals in captivity, there is a notable lack of studies and information regarding their nutritional requirements, leading professionals to rely on data from domestic animals that share similar physiological, anatomical, or behavioral characteristics with the wild species. Most available studies are related to the feeding habits of free-ranging animals (Queiroz et al., 2019; Couto et al., 2021; Silva & Couto, 2021).

Rodents and birds have long been widely used as the primary food source for carnivorous animals kept in captivity (Bird & Ho, 1976). Currently, as they are commonly employed as laboratory animals in experimental research, numerous studies address their reproduction, health, and welfare. Consequently, they are easy to handle, require little space, reproduce rapidly under controlled conditions, and benefit from extensive literature and breeding manuals that facilitate their production (Neves, 2013). Nevertheless, studies describing the nutritional composition of these prey species are scarce, with most being outdated and based on a single animal size (Bird & Ho, 1976; Dierenfeld et al., 2002). Therefore, the objective of the present study is to evaluate the body composition of two rodent species at different body sizes and to develop a nutritional value table for each.

2 METODOLOGY

The study was conducted at the Biotério Pantanal, a facility dedicated to providing whole frozen prey for feeding captive carnivorous animals, approved by CONCEA 01/2024.

Two prey species were used: mice (*Mus musculus*; n = 900) and rats (*Rattus norvegicus*; n = 1500). These were categorized by body weight, ranging from newborns to fully grown adults of each species (Table 1). This range of body weights allows the feeding of various predator species across different age classes. Each weight category was subdivided into four batches of 25 animals per batch.

Table 1. Diversity of whole frozen prey analyzed. BP = Biotério Pantanal.

Description	Weight Range	
	Mouse	Rat
BP1	up to 2.5g	-
BP2	2.6 to 4g	-
BP3	4.1 to 6g	4.1 - 6g
BP4	6.1 to 8g	6.1 to 8g
BP5	9 to 11g	9 to 11g
BP6	12 to 16g	12 to 16g
BP7	17 to 20g	17 to 20g
BP8	21 to 35g	21 to 35g
BP9	above 36g	36 to 50 g
BP10	-	51 to 65g
BP11	-	66 to 96g
BP12	-	97 to 150g
BP13	-	151 to 200g
BP14	-	201 to 250g
BP15	-	251 to 300g
BP16	-	301 to 350g
BP17	-	above 351g

Source: Authors.

The rodents used in this study belong to the BP® lineage, which consists of isogenic rodents. Isogenic rodents are genetically homogeneous populations, with 95% to 99% genetic similarity. They have been selectively bred to be early-maturing animals with high fertility, produced exclusively as food for carnivorous species.

All animals were maintained under controlled temperature conditions according to the requirements of each species. They were fed twice daily with species-specific feed, and water was provided ad libitum through automatic drinkers. For slaughter, the animals were subjected to electrical stunning (electronarcosis) prior to eutanásia (Couto et al, 2025), after which they were stored in an ultra-freezer for rapid freezing.

For each weight category, four batches were analyzed. The number of animals per batch was determined based on preliminary tests conducted before the study to assess the minimum quantity required after drying. Based on these results, 25 animals per batch were used.

Initially, all prey batches were cut into smaller pieces to improve drying efficiency. The material was weighed and then dried in forced-air circulation ovens at temperatures ranging from 65°C to 70°C, not exceeding 75°C. The weights of each batch were recorded before and after drying. Drying was performed for 72 hours, and after weighing, the material was ground using a stainless-steel ball mill (30 g per batch). The use of stainless steel prevented contamination of the samples with metals such as iron, zinc, and copper. Each batch was homogenized and stored in hermetically sealed ziplock bags, labeled with sample information, and sent to the bromatology laboratory.

At the bromatology laboratory, the samples were analyzed to determine total dry matter, crude protein, ether extract, and mineral content, following the procedures of Silva & Queiroz (2006). The calcium (Ca) and phosphorus (P) levels were also quantified.

Based on the bromatological composition, the gross energy (kcal/kg) values were estimated according to the following equation:

Gross Energy (kcal/g) Ether Extract (g) × 9 kcal + Protein (g) × 4 kcal + Carbohydrates (g) × 4 kcal. (1)

3 RODENT BIOLOGY

3.1 RAT (*Rattus norvegicus*)

The rat (*Rattus norvegicus*) is a rodent species that can exceed 500 g in body weight (BP17). Newborns weigh up to 6 g (BP3), begin consuming solid feed at around 14 days of age (BP6), and are weaned at approximately 21 days (BP8). Males exhibit prolonged reproductive capacity, while females enter estrus approximately three hours after parturition and remain receptive for about three days. Thereafter, females return to estrus every three days. On average, a female produces 12 pups per litter but may give birth to as many as 27 neonates, and they possess six pairs of mammary glands. Sexual maturity is reached between 8 and 10 weeks of age (BP13 and BP14).

3.2 MOUSE (*Mus musculus*)

The mouse (*Mus musculus*) is a rodent species that can reach up to 50 g in body weight (BP9). Newborns weigh up to 2.5 g (BP1), begin consuming solid feed at approximately 12 days of age (BP4), and are weaned at around 21 days (BP5). Males have prolonged reproductive capacity, while females enter estrus approximately three hours after giving birth and remain receptive for about three days. Subsequently, females return to estrus every three days. A female produces an average of 15 pups per litter, with a maximum of 34 neonates, and possesses five pairs of mammary glands. Sexual maturity occurs between 6 and 8 weeks of age (BP7 and BP8).

3.3 DATA ANALYSIS

To assess potential differences in the concentrations of nutritional parameters (calcium, phosphorus, protein, fat, energy, mineral matter, and moisture) among weight categories (BP3 to BP7), the data were tested for the statistical assumptions of normality and homoscedasticity using the Shapiro–Wilk and Levene tests, respectively. When these assumptions were met, a One-Way Analysis of Variance (ANOVA) was applied; when not met, the Kruskal–Wallis test was used. This analysis was performed separately for *Rattus norvegicus* and *Mus musculus*.

To verify possible differences in the concentration of each nutritional parameter between *Rattus norvegicus* and *Mus musculus*, data were again tested for normality and homoscedasticity using the Shapiro–Wilk and Levene tests, respectively. When the assumptions were satisfied, comparisons were made using the Student's t-test; otherwise, the Mann–Whitney U test was applied.

All analyses in the present study were conducted at a 5% significance level, using R software (R Core Team, version 4.4.1) with the packages car (Fox & Weisberg, 2019), vegan (Oksanen et al., 2022), and ggplot2 (Wickham, 2016).

4 RESULTS AND DISCUSSIONS

The bromatological percentages of rodents are presented below (Table 2).

Table 2. Nutritional and energy values of rodents at different weights and ages, from newborns to adult size.

		PERCENTAGE							Kcal/g
Rat	**Weights**	**Ca**	**P**	**PB**	**EE**	**MM**	**HUMIDITY**	**CARBOHYDRATE**	**ENERGY**
BP3	**4.1 to 6g**	0,3	0,3	11	4	2	83	0	82
BP4	**6.1 to 8g**	0,3	0,3	9	6	2	83	5	106
BP5	**9 to 11g**	0,3	0,3	11	6	2	80	6	124
BP6	**12 to 16g**	0,4	0,4	12	8	2	77	4	135
BP7	**17 to 20g**	0,4	0,4	13	8	2	75	7	152
BP8	**21 to 35g**	0,6	0,5	16	11	3	69	5	182
BP9	**36 to 50g**	0,6	0,4	15	10	3	72	0	153
BP10	**51 to 65g**	0,6	0,5	16	6	3	72	12	164
BP11	**66 to 95g**	0,6	0,5	15	7	3	74	5	139
BP12	**97 to 150g**	0,7	0,5	17	6	3	71	12	167
BP13	**151 to 200g**	0,7	0,5	18	7	3	70	6	161
BP14	**201 to 250g**	0,6	0,6	18	7	3	71	1	140
BP15	**251 to 300g**	0,8	0,6	18	7	4	70	4	151
BP16	**301 to 350**	0,8	0,5	20	6	4	68	9	166
BP17	**> 351g**	1,2	0,7	22	6	5	66	2	148
							PERCENTAGE		Kcal/g
Mouse	**Weights**	**Ca**	**P**	**PB**	**EE**	**MM**	**HUMIDITY**	**CARBOHYDRATE**	**ENERGY**
BP1	**up to 2.5g**	0,3	0,3	11	3	2	82	7	104
BP2	**2.6 to 4g**	0,3	0,3	11	5	2	81	7	114
BP3	**4.1 to 6g**	0,4	0,4	14	9	2	74	3	146
BP4	**6.1 to 8g**	0,5	0,4	14	10	2	70	14	198
BP5	**9 to 11g**	0,4	0,4	15	10	2	69	12	195
BP6	**12 to 16g**	0,6	0,5	16	9	3	71	4	159
BP7	**17 to 20g**	0,6	0,5	16	8	3	71	8	166
BP8	**21 to 35g**	0,7	0,5	17	10	3	71	0	140
BP9	**36 to 50g**	1	0,5	18	12	3	68	0	170

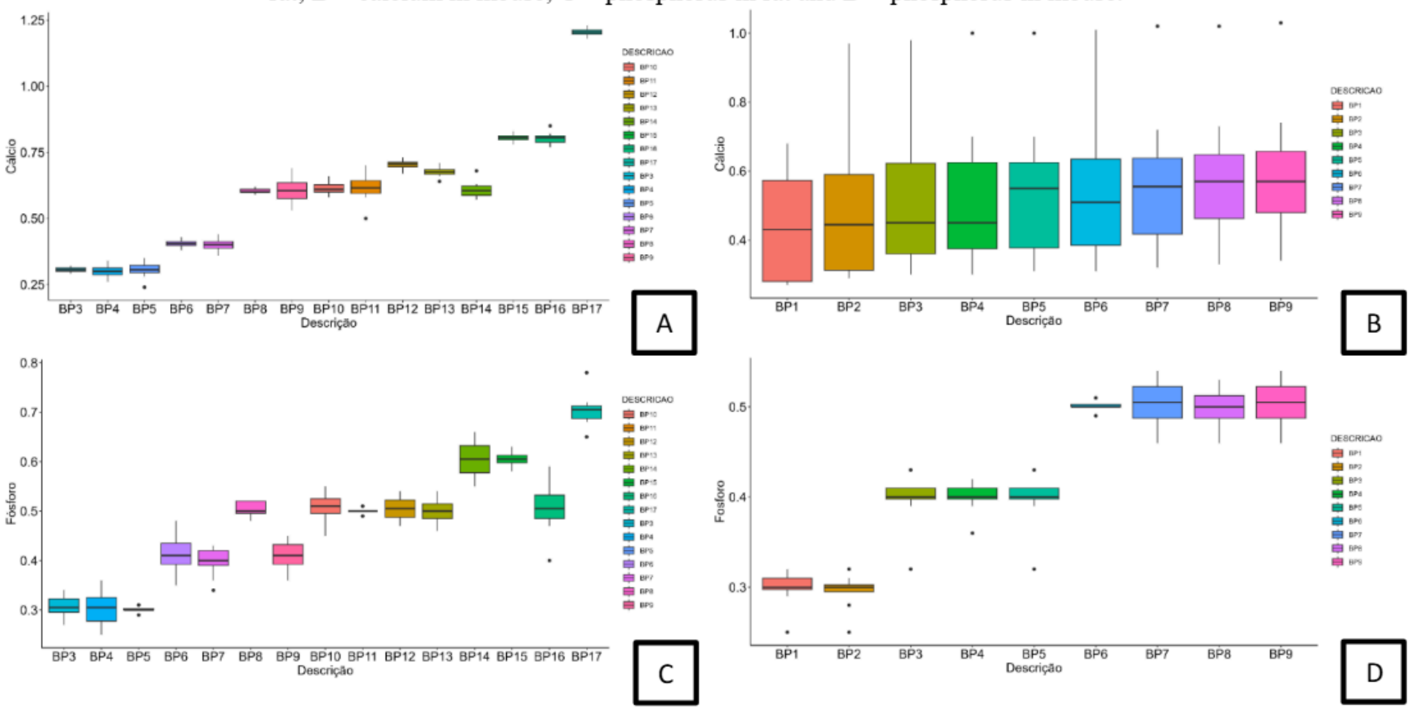
Source: Authors.

Calcium concentrations varied significantly among the body size categories of rats (*Rattus norvegicus*) ($H_{(14,\ 105)}$= 111.59; p<0.05). Lower calcium concentrations were observed in the smaller individuals (BP3–BP5) ($p < 0.05$), while higher concentrations were found in the larger animals (BP15–BP17) ($p < 0.05$) (Figure 1A). In mice (*Mus musculus*), however, calcium concentrations did not differ significantly among size categories ($F_{(8,\ 63)}$= 0.409; p<0.05) (Figure 1B).

Phosphorus concentrations varied significantly among the size categories in both *Rattus norvegicus* and *Mus musculus*, showing an overall increase with body growth. In *Rattus norvegicus*, phosphorus levels differed across size categories from juveniles to adults ($H_{(14,\ 105)}$= 107.93; p<0.05), with smaller animals (BP3–BP5) presenting lower phosphorus concentrations ($p < 0.05$) and larger individuals (BP14–BP17) showing higher concentrations ($p < 0.05$) (Figure 1C). Similarly, in *Mus musculus* ($H_{(8,\ 63)}$= 61.647; p<0.05), smaller animals (BP3 and BP4) had significantly lower phosphorus levels ($p < 0.05$), whereas larger animals (BP6–BP9) exhibited higher concentrations ($p < 0.05$) (Figure 1D).

Calcium and phosphorus play fundamental roles in the development and metabolism of living organisms. Calcium is essential for bone and dental structure formation and performs crucial functions in blood coagulation, muscle contraction, and nerve impulse transmission. These physiological roles highlight calcium's importance in maintaining homeostasis and the overall efficiency of biological systems in animals (Waldron, 2019; Rorive, 2021). Phosphorus, in turn, is involved in the regulation of biochemical processes such as phosphorylation, which activates and deactivates enzymes in complex metabolic pathways (Morris et al., 2021). Moreover, phosphorus homeostasis is vital for vertebrate skeletal health, as it contributes to the formation of mineralized tissues, being an integral component of bone structure alongside calcium (IOM, 2011).

Figure 1. Calcium and phosphorus concentrations in rodents of different ages and weights. A = calcium in rat; B = calcium in mouse; C = phosphorus in rat and D = phosphorus in mouse.



Source: Authors.

Protein concentrations varied significantly among the size categories of *Rattus norvegicus* (H(14, 105) = 102.52; $p < 0.05$). Smaller individuals (BP3–BP5) exhibited lower protein concentrations ($p < 0.05$), while larger animals (BP13–BP17) presented higher concentrations ($p < 0.05$) (Figure 2A). A similar pattern was observed in *Mus musculus* (H(8, 63) = 58.308; $p < 0.05$), where smaller animals (BP1 and BP2) showed lower protein concentrations ($p < 0.05$), and larger individuals (BP6–BP9) exhibited higher concentrations ($p < 0.05$) (Figure 2B).

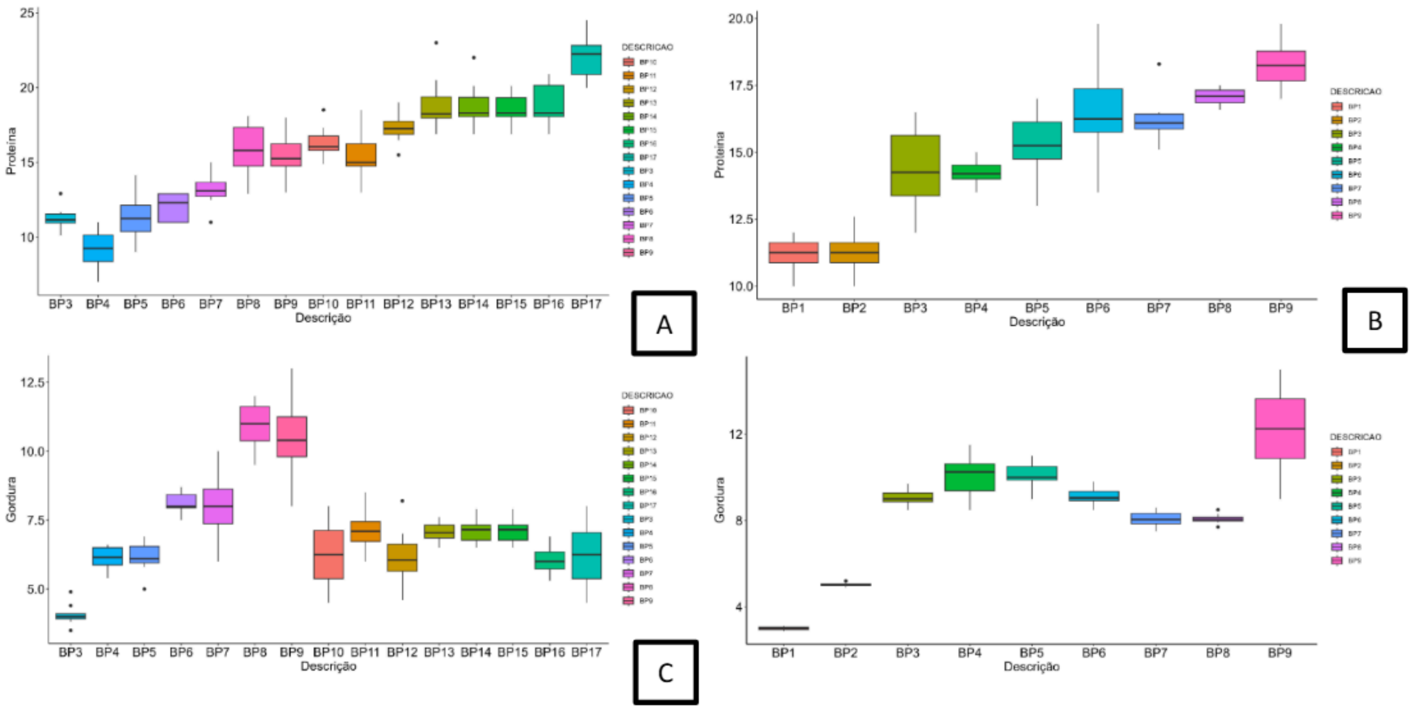
Fat content varied significantly among size categories of *Rattus norvegicus* ($H(14, 105) = 87.149$; $p < 0.05$). Intermediate-sized animals (BP8 and BP9) had the highest fat concentrations ($p < 0.05$), whereas smaller individuals showed lower values ($p < 0.05$). Larger animals also displayed reduced fat content ($p < 0.05$) (Figure 2C).

Similarly, fat concentrations varied significantly among *Mus musculus* size categories ($H(8, 63) = 63.561$; $p < 0.05$). Smaller animals (BP1 and BP2) had lower fat levels ($p < 0.05$), while larger individuals (BP9) exhibited higher fat concentrations ($p < 0.05$) (Figure 2D).

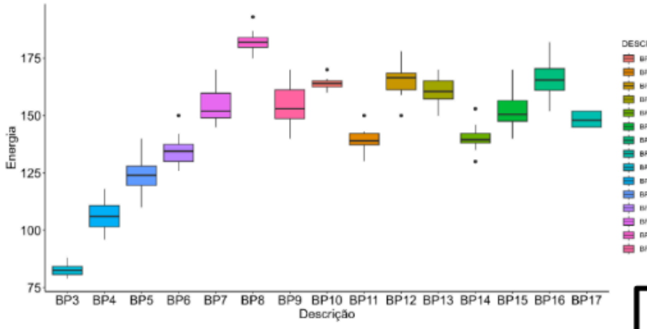
Energy content also varied significantly among *Rattus norvegicus* size categories ($H(14, 105) = 102.68$; $p < 0.05$). Smaller animals (BP3–BP6) presented lower energy values ($p < 0.05$), whereas larger individuals (BP7–BP17) showed higher energy contents ($p < 0.05$) (Figure 2E).

In *Mus musculus*, energy content also differed among size categories ($F(8, 63) = 131.3$; $p < 0.05$). Smaller animals displayed lower energy values ($p < 0.05$), while intermediate-sized individuals (BP4 and BP5) exhibited the highest energy contents ($p < 0.05$) (Figure 2F).

Figure 2. Protein, fat, and energy concentrations in rodents of different ages and weights. A = protein in rat; B = protein in mouse; C = fat in rat; D = fat in mouse; E = energy in rat; and F = energy in mouse.



D



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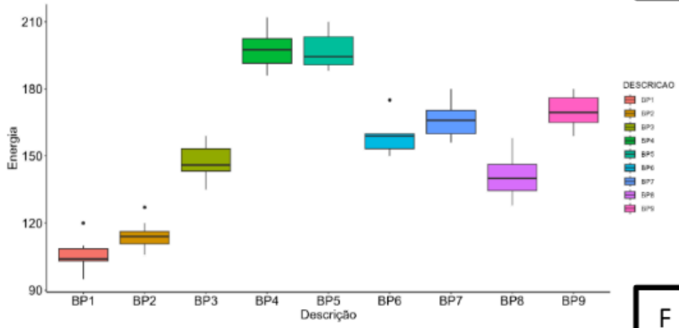


F

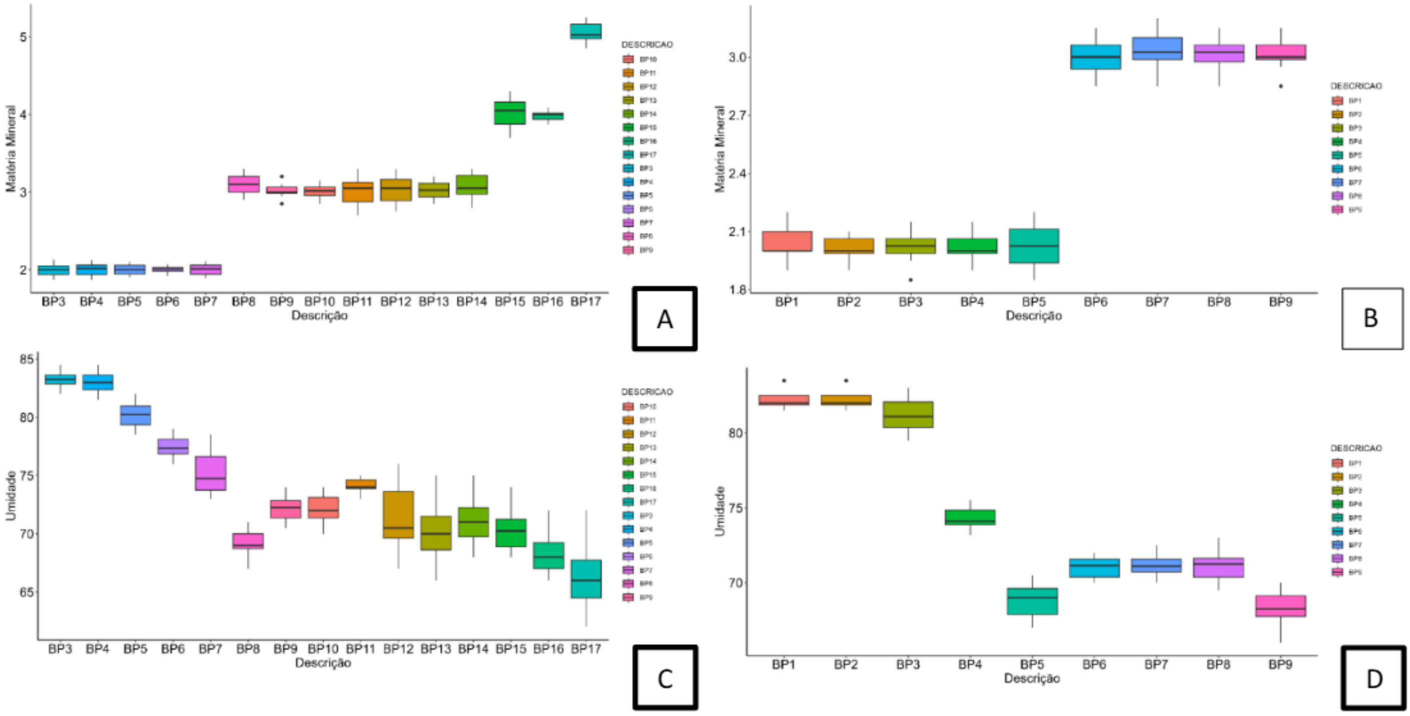
Source: Authors.

For *Rattus norvegicus*, the size groups BP8 (21–35 g) and BP9 (36–50 g) stood out, while for *Mus musculus*, the groups BP5 (9–11 g) and BP6 (12–16 g) corresponded to individuals suitable for weaning (after approximately 21 days of age). These groups exhibited a greater fat reserve compared to the other size categories (Table 2). The increase in fat storage is associated with the simultaneous availability of maternal milk and solid feed, as during this developmental stage the animals still consume maternal milk while beginning to ingest solid food. This diversity of nutritional sources contributes to the accumulation of higher fat reserves in these animals.

Mineral matter content varied according to age, with younger animals showing lower values compared to adults. In *Mus musculus*, mineral matter content varied significantly among size categories ($F(8, 63) = 237.8$; $p < 0.05$). Smaller animals (BP1–BP5) exhibited lower mineral matter levels ($p < 0.05$), whereas larger animals (BP6–BP9) showed higher concentrations ($p < 0.05$) (Figure 3A). Similarly, in *Rattus norvegicus*, mineral matter content also varied significantly among size categories ($H(14, 105) = 102.92$; $p < 0.05$), with smaller animals (BP3–BP7) presenting lower mineral matter levels ($p < 0.05$), and larger individuals (BP15–BP17) exhibiting higher concentrations ($p < 0.05$) (Figure 3B).

Moisture content, on the other hand, showed an inverse relationship with body size: younger animals exhibited higher moisture levels compared to adults. As the rodents grew, their body moisture proportion decreased. In *Rattus norvegicus*, moisture content varied significantly among size categories ($H(14, 105) = 98.692$; $p < 0.05$), with smaller individuals (BP3–BP5) showing higher moisture levels ($p < 0.05$) and larger animals (BP8–BP17) presenting lower moisture contents ($p < 0.05$) (Figure 3C). Similarly, in *Mus musculus* ($F(8, 63) = 268.89$; $p < 0.05$), smaller animals (BP1–BP3) exhibited higher moisture levels ($p < 0.05$), while larger individuals (BP5–BP9) showed lower moisture contents ($p < 0.05$) (Figure 3D).

Figure 3. Concentrations of mineral matter and moisture in rodents of different ages and weights. A = mineral matter in rat; B = mineral matter in mice; C = moisture in rat and D = moisture in mice.



Source: Authors.

There are several available protein sources with values equivalent to those of whole rodents used as food for captive carnivorous animals. The muscle tissues of birds, swine, and cattle, intended for human consumption, typically contain protein levels ranging from 16% to 18% (Torres et al., 2000; Lima et al., 2011). However, whole prey items used for feeding carnivores are generally more complete and nutritionally balanced compared to isolated meat tissues (Scott, 1968; Wallach, 1970). Weaned rodents, which correspond to intermediate age and weight classes (BP8 and BP9 for *Rattus norvegicus*; BP5 and BP6 for *Mus musculus*), present higher fat percentages; as development progresses, there is a concomitant increase in protein content (Douglas et al., 1994).

There is a clear scarcity of studies addressing the nutritional composition of whole prey intended for carnivore feeding. Among the available works, many are not published in scientific journals but are instead found in theses, dissertations, or conference abstracts (Barbosa, 2020). Most published studies focus mainly on adult or neonatal animals (Donoghue & McKeown, 1999) or use pooled samples comprising individuals of various weights, ages, and sexes (Barbosa, 2020). Moreover, there is a lack of data standardization among studies some report results on a dry matter basis, while others use wet matter (Kaufman & Kaufman, 1977; Bird & Ho, 1976; Litvaitis & Mautz, 1980), and some present values as percentages whereas others use mg/kg (Douglas et al., 1994; Barbosa, 2020).

This lack of standardization complicates cross-study comparisons. Furthermore, the management practices adopted during animal rearing an essential factor influencing nutritional composition are often poorly described in bromatological analyses. For instance, animals obtained as culls are often aged individuals that may exhibit high fat concentrations or signs of malnutrition, making them unsuitable for feeding (Donoghue, 1996). Bromatological analyses of such animals may record elevated fat percentages and high energy values; conversely, malnourished animals would show the opposite trend, including reduced protein levels (Donoghue, 1996). Despite the numerical data, such nutrients are of inferior quality and may cause health problems in predators consuming them, such as malnutrition or obesity.

Additional factors contributing to sample variability include physiological changes in females during gestation and lactation, such as increased fat reserves and milk production, which can affect bromatological results (Rappolee, 1995; Thorne, 2000; Gentry, 2012; Figueiredo, 2016).

Although small bromatological variations are reported among studies, consistent patterns can still be identified for captive-bred rodents (Donoghue & McKeown, 1999; Donoghue, 1996). These differences can be attributed to standard deviations, small sample sizes, methodological discrepancies, and, most importantly, husbandry and feeding conditions. Captive-bred rodents generally show lower mineral matter and protein levels compared to laboratory rodents, whereas laboratory rodents tend to have higher fat percentages (Davison et al., 1978, summarized by Litvaitis & Mautz, 1980). These results can guide the formulation of diets that meet predator nutritional requirements.

Carnivorous reptiles, for instance, are adapted to consume diets rich in fats and proteins. They possess short and simple digestive tracts, specialized for hydrolytic digestion in the small intestine. Their exogenous energy sources include fats, providing approximately 9 kcal/g, and proteins, providing 4 kcal/g (Donoghue, 1996; Secor et al., 1994). Healthy reptiles require a high intake of metabolizable energy, with macronutrient composition ranging from 25% to 60% between fats and proteins (Donoghue, 1996; Secor et al., 1994). This energy demand is associated with metabolic rate and body size (Bennett et al., 1976; Schmidt-Nielsen, 1990). Metabolic rates tend to increase during digestion and periods of activity (Secor & Phillips, 1997; Van et al., 1993). However, the metabolic demands associated with growth remain not fully understood (Nagy, 1997) and may be influenced by genetics, behavior, and environmental factors. In general, reptiles show higher metabolic rates during growth and reproduction (Donoghue, 1996).

Rodents may be offered either as whole prey or in parts, depending on the feeding behavior of the predator. Many carnivores such as raptors, mammals, fish, and lizards tear or fragment prey before ingestion (Couto et al., 2024a; Couto & Neto, 2024; Couto et al., 2024b), while snakes typically consume whole prey (Couto & Neto, 2024). In growing snakes, such as hatchlings and juveniles, prey with higher energy density is required. However, because of their small body size and the feeding strategy involving whole prey, their diet is restricted to neonate rodents (*Mus musculus* BP1 or BP2; *Rattus norvegicus* BP3 or BP4), which generally have lower energy values (Table 2).

Given the nutritional demands of young predators, it is essential that caretakers adjust feeding frequency accordingly juveniles are expected to feed more often than adults. Due to their body structure, neonates are digested more rapidly. As the predator grows, feeding frequency decreases while prey size increases. Thus, the technical expertise of professionals responsible for carnivore nutrition, combined with experience and accurate prey nutritional data, is crucial to ensure proper dietary management.

A widely known empirical guideline commonly followed by snake keepers and animal nutrition professionals suggests offering prey weighing approximately 20% of the snake's body weight. However, this practice, of unknown origin, can lead to malnutrition or obesity, conditions frequently observed in captive snakes (Frye, 1991; Scott, 1992). In the wild, snakes may consume prey weighing 75% or more of their own body mass (Couto & Neto, 2024).

It is therefore imperative to consider the snake's age and individual characteristics when defining its diet, recognizing that reptiles are ectothermic animals whose metabolism is influenced by environmental temperature. Snakes kept in enclosures with heat sources such as heating pads or lamps exhibit faster metabolism compared to those in unheated or cooler environments (Donoghue, 1996). Hence, it is essential for nutrition professionals to understand the environmental conditions under which each animal is maintained (Mattison, 1987; McKeown, 1996).

Additionally, individual variability must always be considered. Even littermates fed identical diets may exhibit different growth rates due to genetic and behavioral diferences some individuals are more active, while others are more sedentary resulting in distinct energy demands.

In general, calcium, phosphorus, mineral matter, fat, protein, and energy levels increase with rodent age and body weight (Table 2, Figures 1–3). Conversely, moisture content decreases as individuals grow and gain weight (Table 2, Figure 3). These variations are associated with postnatal development, since newborn rodents display distinct physiological characteristics compared to juveniles and adults (Neves, 2013).

Rat neonates are born after a 21-day gestation period, during which they are hairless, with closed eyes and partially formed skeletal structures. As they develop, ossification occurs, transforming cartilage into bone. Concurrently, fur growth begins, leading to the typical adult morphology. These developmental transformations result in changes in calcium, phosphorus, moisture, mineral matter, fat, protein, and energy levels throughout the rodents' lifespan, reflecting the influence of age on their nutritional composition.

5 CONCLUSION

The development of a table presenting the nutritional values of whole frozen prey animals, such as rodents, including protein, fat, energy, moisture, mineral matter, calcium, and phosphorus levels according to age and body weight, represents a significant advance in the formulation of diets for carnivorous animals. This initiative not only establishes a robust database for future research but also provides nutrition professionals with valuable information for developing diets tailored to the specific nutritional needs of captive carnivores, considering different prey sizes and nutritional diversity.

REFERENCES

Barbosa, LGB. 2020. Avaliação dos valores bromatológicos de camundongos (*Mus musculus*). Dissertação de Mestrado, UNESP de Botucatu-SP.

Bennett AF, Dawson WR. 1976. Metabolism. In Gans C (ed): Biology of the Reptilia, vol 5. New York, Academic Press, 1976,

Bird, DM., & Ho, SK., 1976. Nutritive values of whole-animal diets for captive birds of prey. *Raptor Res*, *10*(2), 45-49.

Carciofi, AC.; Oliveira, LDD. Doenças Nutricionais. 2011 .p.5. Disponível em: http://www.veterinariosnodiva.com.br/books/Doencas-NutricionaisSilvestres.pdf Acessado em 19 de janeiro 2025.

Couto, RM., Miguel, MC., Branco, AC., Lopes, DA., dos Santos, PS., Ferreira, VL., & Himmelstein, JA. 2024a. A risky meal: predation on the toads *Rhinella diptycha* (Cope, 1862) and *R. icterica* (Spix, 1824) by Crab-eating Foxes, *Cerdocyon thous* in Brazil. Herpetology Notes, 17, 453-457.

Couto, RMP.; Miguel, MC.; Branco, AC.; Santos, PS. *RHAEBO GUTTATUS* (Smooth-sided Toad). 2024.. PREDATION ATTEMPT. HERPETOLOGICAL REVIEW. v.55, p.80 – 80.

Couto, RMP.; Miguel, MC.; SANTOS, PS.; POLIZEL, DM.; FILARDI, RS.; LAURENTIZ, AC.; 2025. Slaughter and pre-slaughter protocols for rodents and birds used for animal feed. Revista fisio&terapia, v. 29, p. 29-30, 2025.

Couto, RMP.; Santos, VP. & Silva, FD. 2021. Consumption of *Melopsittacus undulatus* (Shaw, 1805) (Psittaciformes, Psittacidae) by *Sapajus cay* Illiger, 1815 (Primates, Cebidae) in Midwest region of Brazil. *Actual. Biol. 43(115): 1-6, DOI:10.17533/udea.acbi.v43n115a01.*

Davison RP.; Mautz WW.; Haves HH. and Holter JB. 1978 The efficiency of'food utilization and energy requirements of captive female fishers. J. Wildl. Manage. 42, 811-821.

Dierenfeld, ES., Alcorn, HL., & Jacobsen, KL. 2002. *Nutrient composition of whole vertebrate prey (excluding fish) fed in zoos* (p. 20). Beltsville (MD): US Department of Agriculture, Agricultural Research Service, National Agricultural Library, Animal Welfare Information Center

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

Donoghue, S., & McKeown, S. 1999. Nutrition of captive reptiles. *Veterinary Clinics of North America: Exotic Animal Practice*, *2*(1), 69-91.

Douglas, TC., Pennine, M., & Dierenfeld, ES. 1994. Vitamins E and A, and proximate composition of whole mice and rats used as feed. Comparative Biochemistry and Physiology Part A: Physiology, 107(2), 419-424.

Figueiredo, JR. 2016. Metabolic adaptations in female mammals during reproduction. Journal of Mammalogy, 97(2), 284-293. DOI: 10.1093/jmammal/gyv178.
Fox, J, Weisberg. S. 2019. An {R} Companion to Applied Regression, Third Edition. Thousand Oaks CA: Sage. URL: https://socialsciences.mcmaster.ca/jfox/Books/Companion

Frye, FL. 1991. Reptile care: an atlas of diseases and treatments. Neptune City, pp. 633.
Gentry, JR. 2012. Body composition and energy balance in pregnant and lactating mammals. Journal of Nutrition, 142(5), 886-890. DOI: 10.3945/jn.111.147793.

IOM (Institute of Medicine). 2011. Dietary Reference Intakes for Calcium and Vitamin D. Washington, DC: The National Academies Press.

Kaufman GA. and Kaufman DW. 1977 Body composition of the old-field mouse (Peromyscus polionoms). J. Mammal. 58, 429-434.

Lichtenbelt, WDVM., Wesselingh, RA., Vogel, JT., & Albers, KB. 1993. Energy budgets in free-living green iguanas in a seasonal environment. Ecology, 74(4), 1157-1172.

Lima, DM., Padovani, RM., Rodriguez-Amaya, DB., Farfán, JA., Nonato, CT. and De Lima, MT., 2011. Tabela brasileira de composição de alimentos. NEPA/UNICAMP.- 4. ed., Campinas: NEPA - UNICAMP, 161.

Litvaitis JA. and Mautz WW. 1980. Food and energy use by captive coyotes. J. Wildl. Manage. 44, 5661.

Mattison C. 1987. The Care of Reptiles and Amphibians in Captivity, ed 2. London, Blandford Press.

McKeown S. 1996. General husbandry and management. In Mader DR (ed): Reptile Medicine and Surgery. Philadelphia, WB Saunders, pp 9-19

Morris, MR., Norrie, A., & Sutherland, T. 2021. Metabolic Phosphorylation and Life: Insights from the Regulation of Phosphate in Human Health. Biochemical Society Transactions, 49(5), 2183-2193.

Nagy KA. 1997. Do high growth costs mean high resource needs by neonate reptiles. Abstracts of the Third World Congress of Herpetology. Prague, p 149

Neves, SM. 2013. Manual de Cuidados e Procedimentos com Animais de Laboratório do Biotério de Produção e Experimentação. *São Paulo: Universidade de São Paulo*.
Oksanen, J; Blanchet, FG; Friendly, M; Kindt, R; Legendre, P; Mc Glinn, D. et al., 2022. Vegan: Community Ecology Package. R package version 2.6-4. https://CRAN.Rproject.org/package=vegan

Queiroz, MS.; Couto, RMP. & Miguel, MC. 2019. *Leptodactylus chaquensis* - the voracious generalist frog as a predator of two different anuran species. Herpetology Notes, volume 12: 483-486.

Rappolee, DA. 1995. Reproduction and lipid metabolism: adaptations to the energetic demands of offspring. Biology of Reproduction, 52(3), 562-569. DOI: 10.1095/biolreprod52.3.562.

Rorive, G. 2021. Calcium: A Key Mineral in Animal Health. Veterinary Clinics of North America: Food Animal Practice, 37(2), 273-286. DOI: 10.1016/j.cvfa.2021.03.001.

Schmidt-Nielsen K: 1990. Animal Physiology: Adaptation and environment. Cambridge, UK, Cambridge University Press.

Scott PW: 1992. Nutritional diseases. In Beynon PH (ed): Manual of Reptiles. Gloucestershire, British Small Animal Veterinary Association, pp 138-152

Scott, PP. 1968. The special features of nutrition of cats, with observations on wild felidae nutrition in the London zoo. Symp. Zool. Sot. London 21, 21-36.

Secor SM, Phillips JA. 1997. Specific dynamic action of a large carnivorous lizard (*Varanus albigularis*). Comp Biochem Physiol 117:515-522.

Secor, SM., Stein, ED., & Diamond, JARED. 1994. Rapid upregulation of snake intestine in response to feeding: a new model of intestinal adaptation. American Journal of Physiology-Gastrointestinal and Liver Physiology, 266(4), G695-G705.

Silva, VC. & Couto, RMP. 2021. *Mussurana bicolor* (Mussurana). Diet. Herpetological Review 52(1).

Thorne, L. 2000. Energy balance during reproduction in mammals. Reproduction, 119(1), 1-9. DOI: 10.1530/rep.0.1190001.

Torres, EA., Campos, NC., Duarte, M., Garbelotti, ML., Philippi, ST., & Minazzi-Rodrigues, RS. 2000. Composição centesimal e valor calórico de alimentos de origem animal. *Food Science and Technology*, *20*(2), 145-150.

Waldron, MR. 2019. Calcium and Phosphorus Nutrition in Animals: Implications for the Animal and the Environment. Animal Feed Science and Technology, 248, 40-56. DOI: 10.1016/j.anifeedsci.2019.03.006.

Wallach, JD. 1970 Nutritional diseases of exotic animals. JAVMA 157, 583-599.

Wickham, H. 2016. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag, New York. https://ggplot2.tidyverse.org/