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BIRDS OF PREY PELLET ANALYSIS: MORPHOMETRY AND CONSUMPTION INTERVAL OF CAPTIVE *ACCIPITRIDAE* SPECIES

(*Análise de pelotas de aves de rapina: Morfometria e Intervalo de consumo em espécies da família Accipitridae* em cativeiro)

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ABSTRACT

Pellet production is a typical characteristic of the digestive physiology of birds of prey. Alimentary pellets consist of non-digested parts of prey, such as fur, feathers, bones, and parts of insects, that are regurgitated. Obtained dietary samples, such as regurgitated pellets, can noninvasively contribute to the knowledge of the anatomical alimentary channel and the digestive efficiency of birds of prey. The aim of this study was to evaluate the pellet morphometry and meal-to-pellet interval (MPI) of the *Accipitridae* family subjected to two experimental diets. *Heterospizias meridionalis*, *Rupornis magnirostris*, and *Geranoaetus albicaudatus* were subjected to (1) mice and (2) quail pre-treating diets. Both diets were individually weighed and provided by removing excess feathers, skin, and some viscera. After consumption, the MPI was noted and, immediately after collection, the pellets were carefully weighed on a precision balance and morphometric measurements were taken using a caliper. Pellet weight, length, width, height, and volume were higher when raptors consumed mice. Differences in morphometric characteristics were found between species. *Heterospizias meridionalis* presented the highest values for the morphometric parameters evaluated. Consumption of mice increased the frequency of regurgitation and the number and weight of pellets egested, indicating that by providing this type of food, we can underestimate the consumption by birds if we do not consider nutritional losses by the pellets when calculating diets. Pellet assessment and MPI are important tools for monitoring the health and nutritional aspects of birds of prey.

Keywords: Birds of prey, retention time, egestion, health.

RESUMO

A produção de pelotas é uma característica típica da fisiologia digestiva de aves de rapina. As pelotas alimentares consistem em partes não digestíveis de presas como peles, penas, ossos e partes de insetos que são expelidos. A obtenção de amostras como as pelotas podem colaborar de forma não invasiva com o conhecimento da anatomia do canal alimentar e eficiência digestiva de rapinantes. O objetivo desse estudo foi avaliar a morfometria e o intervalo entre consumo e egestão de pelotas (ICP) em indivíduos da família *Accipitridae*. *Heterospizias meridionalis, Rupornis magnirostris* e *Geranoaetus albicaudatus* foram submetidos a dietas pré processadas com (1) camundongos e (2) codornas. Ambas as dietas foram individualmente pesadas e fornecidas após a remoção do excesso de penas, pele e algumas vísceras. Após o consumo, o ICP foi calculado e imediatamente após a coleta as pelotas foram pesadas e avaliadas quanto a medidas morfométricas com a ajuda de um paquímetro. O peso, comprimento, largura, altura e volume das pelotas foram maiores quando as aves consumiram ratos. Diferenças morfométricas foram encontradas entre as espécies. *Heterospizias meridionalis* apresentaram os valores mais altos para os parâmetros morfométricos avaliados. O consumo de camundongos aumentou a frequência de egestão, o número e o peso das pelotas, indicando que, ao fornecer este tipo de alimento, podemos subestimar o consumo pelas aves se não considerarmos as perdas nutricionais pelas pelotas ao calcular as dietas. A avaliação de pelotas e ICP são ferramentas importantes para monitorar os aspectos sanitários e nutricionais em rapinantes.

Palavras-chave: Aves de rapina, tempo de retenção, egestão, saúde.

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INTRODUCTION

Free-living raptors are frequently presented to wildlife rehabilitation centers, often owing to anthropogenic factors, such as accidental collisions with buildings during bird flight (MOLINA-LÓPEZ *et al*., 2011; MONTESDEOCA *et al*., 2016). Rehabilitating these birds and returning them to the wild represent great challenges. Furthermore, digestive anatomy, physiology, and nutritional knowledge are important tools for successful treatment during the raptor rehabilitation process (DANEEL, 2018), as adequate nutritional requirements are crucial for animal physical rehabilitation.

An interesting characteristic of raptors is the formation and egestion of pellets (REA, 1973; HOUSTON e DUKE, 2007). Pellets are formed by indigestible materials present in prey, such as bones, hair, and feathers (RHOADES e DUKE, 1997; HOUSTON e DUKE, 2007). The mechanism of gastric digestion and pellet egestion has been studied in great horned owls (KOSTUCH e DUKE, 1975; MURRAY, 2014) and is broken into four phases, initiated when a bird swallows food and it passes through the esophagus: (1) filling of the stomach, characterized by high amplitude and moderately-high-frequency contractions (1–1.5 per min); (2) chemical digestion, which is a long (4–8h) period of very-low-amplitude, low-frequency contractions (0–1 per min); (3) fluid evacuation, which occurs over a 1–2h period during which contractile activity slowly increases to approximately 1.5 contractions per min; and (4) pellet egestion, which involves very-high- amplitude and high-frequency contractions (2 per min) for 4–10min followed by pellet egestion, during which vigorous esophageal antiperistalsis moves the pellet from the stomach to the mouth in about 8–12s.

According to Cummings *et al*. (1976), the digestion of bones and their content in pellets are related to calcium intake, and there are differences between families of birds of prey. For example, Falconiformes and Accipitriformes digest prey bones more completely than Strigiformes. Thus, it is possible that an owl is more susceptible to a calcium deficiency in diets with few bones. Regarding the *Accipitridae* family, research on pellet motility in the digestive system (DUKE *et al*., 1976) has been carried out in *Accipiter gentilis*, *Buteo jamaicensis*, *Buteo lagopus*, *Buteo platypterus*, *and Haliaeetus leucocephalus.*

An important factor for understanding the characterization and mechanisms involved in pellet egestion is the frequency of this process. Pellet egestion does not occur immediately after its formation, and the pellet can be stored in the proventriculus for hours before being expelled (ELBROCK *et al*., 2001). It is known that the meal-to-pellet interval (MPI) is variable, and egestion usually occurs in the morning, unless food is ingested late the previous day (FORD, 2010). If a bird of prey does not regularly produce pellets, something may be wrong with the bird's digestive system. However, there are not enough studies to prove the influence of the frequency of pellet egestion on the health and nutritional conditions of the bird (COLES, 2007). The influence of the type and processing of food on pellet characteristics has also not been extensively studied.

Although they are rarely analyzed in rehabilitation centers and captivity, the pellets are a very useful material for studying the diet of the birds that produce them as their analysis is a simple and relatively reliable method without the need to manipulate or disturb the animals (TREJO e OJEDA, 2002); thus, this is a non-invasive method to monitor and evaluate frequency and abnormalities in the egestion process. Additionally, knowledge about pellet content and

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morphometric characteristics is essential, for example, for the correct determination of the metabolizable coefficient apparent in captive birds' nutritional trials (BIRD e HO, 1976; DANEEL, 2018).

Therefore, the aim of this study was to evaluate the quantity and the morphometry of pellets produced, and the MPI, in birds of prey of the *Accipitridae* family fed with different protein sources.

MATERIAL AND METHODS

The study was conducted at the Veterinary Hospital of the Wild Animals of the Faculty of Veterinary Medicine of the Federal University of Para, Castanhal, Para, Brazil (01°18′40.9″S, 47°56′50.5″W). The Ethics Committee on Animal Use (nº 067/2016 CEUA/UFRA) and the Brazilian System of Biodiversity Authorization and Information (SISBIO/ICMBio / MMA nº 56.848-1) approved all the experimental protocols used in the present study.

Animals and collection of samples

Five adult birds (n=5), three females and two males, representing the family *Accipitridae*, including two savanna hawks (*Heterospizias meridionalis*), two roadside hawks (*Rupornis magnirostris*), and one white-tailed hawk (*Geranoaetus albicaudatus*), were used in this experiment. Their mean body weights were 817.8g, 296.4g, and 954.2g, respectively. The hawks underwent a complete physical examination (including fecal flotation and urinalysis test) and demonstrated good body condition and health. The birds were maintained in five chambers made of medium density particleboard, specifically for this study, with dimensions 1.40m × 1.66m × 1.19m, constructed in a room designated for poultry rehabilitation, with artificial light. Two protein sources were provided: mice (MI) and quail (QUA). We chose these protein sources because they are commonly supplied to captive birds of prey (ZUCCA, 2002). The proportion of the food supplied was calculated based on the metabolic weight of the birds. The birds' maintenance requirements were calculated as proposed by Kirkwood and Thompson (1984): $EM = (110 \times P^{0.679} \times 4) / 18.8$, where P is the body weight of the bird. The weight of the food, calculated according to metabolic energy, was: 1) mouse: *H. meridionalis*: 43g; *R. magnirostris*: 28g; *G. albicaudatus*: 44g and 2) quail: *H. meridionalis*: 51g; *R. magnirostris*: 40g; *G. albicaudatus*: 60g. Food was cut into half-carcasses and distributed to the birds so that they all consumed equal portions This procedure is often carried out in captivity to verify the sanitary conditions of the food. Water was supplied *ad libitum*. To collect the egested material, the region close to the bird's perch was covered with plastic and all egested material was collected daily and identified (SAKOMURA e ROSTAGNO, 2016). The birds were monitored daily for feeding times and egestion. All pellet egestion times were noted and subtracted from the consumption times, to generate the MPI.

Pellet analysis

Immediately after collection, the pellets were carefully weighed on a precision balance and evaluated for length (cm), width (cm), and height (cm) with the aid of a caliper (Fig. 01) in

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accordance with the measurements made by Trejo e Ojeda (2002). The volume (cm³) of the pellet was calculated using the mathematical formula of the ellipsoid: $\frac{4}{3}\,\pi.a.b.c.$ where a = height, b = length, and c = width.

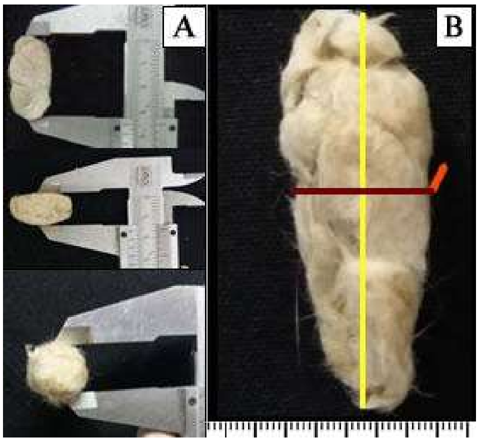

Fig. 01: Measurements with caliper (A) to obtain the length (yellow), width (red), and height (orange) of the pellets (B).

Statistical analysis

Statistical analysis was conducted using the SAS University Edition (Statistical Analysis System). The data obtained were tested for the assumptions of normality of errors and homogeneity of variance using the Shapiro-Wilk test. The data that presented normal distribution were subjected to the parametric analysis of variance, with the means compared, using the Tukey test at a 5% level of significance. Data not normally distributed were submitted to the Wilcoxon nonparametric test.

RESULTS AND DISCUSSION

During the experimental period, the mean room temperature was 28.7±1.9 °C and the relative humidity was 80.8±4.04 Thirty-six intact pellets were obtained, of which 29 were egested when birds consumed mice and 7 during quail consumption. The largest MPI was observed in the pellets from quail feeding. There was a statistical difference when comparing, among the species, MPI for mice diet (Tab. 01).

Table 01: Meal-to-pellet interval (MPI) for different species of *Accipitridae* raptors.

Diet	*H. meridionalis*	*R. magnirostris*	*G. albicaudatus*	*p-value*
Mice	32.89±12.53a	25.55±10.02ab	17.32b±1.34b	0.0189
Quail	164±00.0a	164±00.0a	80.75±00.0b	0.0000

Data are expressed as mean and standard deviation. Averages followed by different letters on the same line differ statistically (p<0.05).

The pellets in this study followed the same description reported by Coles (2007): they had a firm consistency, ovoid or ellipsoid shape, variable color depending on the diet offered,

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non-unpleasant odor, friable texture, and were almost dry. There was also no evidence of blood in the samples. When the birds consumed quail, the pellets disintegrated more easily, there were no intact bones, and the remains of the quail feathers were ground, giving the pellet a sand aspect. The coloration was dark brown with some black features, reminiscent of the quail plumage. The pellets formed during the consumption of mice were firm, had much hair, and the bones were centralized. The pellet was white, and translucent mucus was often observed covering the surface and bones of the jaw and femur.

The mean and standard deviation data of pellet morphometry, according to the treatments, are shown in Tab. 02. There were no significant differences in weight, width, and volume of the pellets among the different birds fed with quail. Differences were observed in all morphometric parameters evaluated for the diet of mice. When comparing the differences among species, *Heterospizias meridionalis* presented the highest values for the morphometric parameters evaluated.

Table 02: Pellet morphometry of three *Accipitridae* raptor species fed with different diets.

	Species			
Diets	***H. meridionalis***	***R. magnirostris***	***G. albicaudatus***	***p-value***
		Weight (g)		
Mice	3.79±1.51a	1.72±0.81b	2.38±0.89ab	0.0013
Quail	1.54±0.37a	0.11±0.00a	1.11±0.39a	0.1535
		Length (cm)		
Mice	3.79±0.78a	3.40±0.47ab	2.88±0.63b	0.0600
Quail	2.90±0.6a	0.90±0.00b	2.40±0.16ab	0.0538
		Width (cm)		
Mice	1.80±0.37a	1.21±0.13b	1.37±0.09b	0.0063
Quail	1.30±0.20a	0.60±0.00a	1.3±0.16a	0.090
		Height (cm)		
Mice	1.28±0.38a	0.83±0.36b	1.07±0.25ab	0.0273
Quail	1.00±0.10a	0.30±0.00a	1.00±0.53a	0.4173
		Volume (cm^3)		
Mice	22.39±13.01a	8.23±4.44b	10.44±3.88ab	0.0086
Quail	8.85±2.29a	0.38±0.00a	6.89±3.22a	0.2995

Data are expressed as mean and standard deviation. Averages followed by different letters on the same line differ statistically ($p < 0.05$).

In this study, it was observed that birds did not expel pellets daily even when consuming non-digestible parts such as hair, bones, and skin, and that the interval between consumption and egestion was greater with quail consumption than mice. Ford (2010) reported

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that birds of prey usually egest one pellet per animal ingested and that egestion occurs in the morning when ingestion occurs in the late afternoon of the previous day. The difference between these results and those described in the literature can be explained by the fact that the studies already carried out generally use whole prey as a diet for raptors with more non-digestible parts for pellet formation. However, the foods evaluated in this study were pre-processed, which reduced their particle size, which may be the reason for the long MPI. Therefore, it is speculated that the MPI varies according to the processing of the food supplied and the frequency of supply to captive birds of prey.

In a study with the eagle owl (*Bubo Bubo*), researchers observed that bone alterations found in the pellets reflect how the prey is ingested, as the bones show greater damage with increasing prey size (RUFÁ e LAROULANDIE, 2019). This may explain why the pellets resulting from quail consumption were better digested than those from mice. However, studies are needed on this topic, using species of daytime birds of prey, including those of the family *Accipitridae*.

The highest number, weight, and morphometric measurements (length and volume) of pellets were observed when the raptors consumed mice. It can be inferred that mice have more indigestible material for pellet production than quails and that, for this reason, the quantity and morphometric measurements were larger and different among the species. In this study, it is believed that the characteristics of the quail, such as the presence of hollow bones, feathers, volume, and higher mean retention time through the digestive system, complimented the efficiency of digestion, as there were fewer expelled pellets, with well-digested bones and feathers, which disintegrated to the touch.

We pointed out the centralized position of the bones so that they did not come into direct contact with the food channel in an attempt to protect the gastric mucosa and avoid the risk of injury. The presence of intact bones, mainly pellets, from the diet with mice, was identified. Similar results were described by Trejo e Ojeda (2002) and Backer (2013) in other raptors with daytime habits.

The difficulty of expelling pellets was related to increased internal body pressure owing to egg retention and gastric impaction, as a result of consuming food with disproportionate and indigestible sizes (COOPER, 2002; APPLEGATE *et al*., 2017), specifically, excess skin, hair, and dry feathers (COOPER, 2002). For this reason, routine evaluation of egestion frequency and food pellet characteristics are important for monitoring the health of birds of prey, including the family *Accipitridae*, which are frequently found in conservation centers and veterinary hospitals (SOUZA, 2016). The raptors of the *Accipitridae* family in this study can serve as an experimental model for other daytime raptors at risk or threatened with extinction. However, further studies on the importance of egestion and other aspects affecting the health of the birds are needed.

CONCLUSION

Pellets produced during the consumption of mice had the highest morphometric measurements and the shortest MPI. The type and form of food processing change the

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characteristics of the pellets. The MPI and the characteristics of the pellets can be an important non-invasive tool for monitoring the digestive efficiency of birds of prey.

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