

# Voluntary intake of captive psittacines fed mixed diets of seeds and extruded feed

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**Abstract:** This study aimed to determine the feed, nutrient, and energy intake of three different small/medium psittacine species fed four different feeds based on three different types of seeds (canary seeds - *Phalaris canariensis*, millet seeds - *Panicum miliaceum*, and sunflower seeds - *Helianthus annuus*) and extruded feed. For this study, 21 individuals of each species (21 rose-ringed parakeets - *Psittacula krameri*; 21 lovebirds - *Agapornis* spp.; 21 cockatiels - *Nymphicus hollandicus*) were individually housed in cages for the evaluation of voluntary feed, nutrient, and energy intake. Rose-ringed parakeets preferentially ( $P < 0.001$ ) consumed sunflower seeds, while lovebirds, selected millet seeds over extruded feed without sunflower seeds ( $P < 0.013$ ). When sunflower seed was not provided, all bird species selected millet seeds over extruded feed (rose-ringed  $P = 0.003$ ; cockatiels  $P = 0.004$ ; lovebirds  $P = 0.013$ ). Selective feeding on sunflower seeds resulted in a higher intake of fat, protein, and gross energy. Low calcium intake (lower than 0.3%) and an imbalanced calcium-to-phosphorus ratio were observed in diets where extruded feed was not consistently consumed. The energy intake for the rose-ringed birds was 28.8 kcal/day, and 17.4 kcal/day for cockatiels, and lovebirds. These values exceeded the recommended maintenance energy requirement when experimental diets containing sunflower seeds and exclusively extruded feed were offered. Psittacine feed intake varies according to the type of feed and among species, and this selective feeding behavior can result in nutritional imbalances, causing chronic disorders.

**Keywords:** birds, formulate diet, nutrition, parrot, requirements.

## 1. Introduction

Among birds, psittacines are popularly kept as pets due to their sociable nature, intelligence, colorful appearance, longevity, and ability to imitate human sounds (Péron and Grosset, 2014; Cubas et al., 2014). The family Psittacidae includes parrots, parakeets, parrotlets, macaws, lovebirds, lorries, and lorikeets. Feeding an appropriate diet is one of the major considerations in keeping captive birds (Beaufrere et al., 2019; Phalen, 2020). Free-ranging wild psittacines consume a varied balanced diet, including seeds, nuts, flowers, and invertebrates. They spend a lot of energy on behaviors such as foraging, flight, and reproduction (Koutsos et al., 2001a). Nevertheless, the energy requirements of these birds in captivity can be extremely diverse, and the type, quality, and availability of feed are dictated by their guardians. Diet is a key factor in preventing and reducing health and psychogenic disorders, but many pet guardians does not know how to feed their birds healthy feed. Imbalance can lead to physical, physiological, and behavioral modifications that can cause discomfort and sometimes threaten the bird's survival (Péron and Grosset, 2014).

Avian feed for the pet market includes seed mixes, extruded feed, and mixtures of both. In Brazil, commercial seed mixes for psittacines commonly contain corn, sunflower, safflower, pumpkin and squash seeds, wheat, peanuts, millet, oat groats, and buckwheat, although other seeds may be present. Although seed mixes seem to be favored by bird guardians, psittacids do not select any food to promote health but only to experience pleasure when consuming it and following habits (Kalman, 2011). Selective feeding behavior or any type of selectivity rarely results in a nutritionally balanced diet (Brightsmith, 2012; Cojean et al., 2020; Freitas et al., 2020). Feeding birds exclusively seed-based diets can be deficient in minerals, vitamins, essential amino acids, and excessive fat (Heatley and Cornejo, 2015). Manifestation of resulting nutritional deficiencies remains subclinical for prolonged periods, and when clinical symptoms do emerge, they are often unspecific and remain undiagnosed (Wolf et al., 1998). The nutritional status of birds influences not only their physical status but also their immunity and reproductive success (Koutsos et al., 2001a).

Nutritional imbalances can lead to conditions including obesity, reproductive problems, kidney and liver diseases, nutritional deficiency, and reduced life expectancy (Carciofi et al., 2003; Brightsmith, 2012; Phalen, 2020). Additionally, pet birds are kept in small cages, which limits physical activity and energy expenditure (Hess et al., 2002). This study aimed to determine the feed, nutrient, and energy intake in three different small/medium psittacine species fed three different types of seeds (canary seeds - *Phalaris canariensis*, millet seeds - *Panicum miliaceum*, and sunflower seeds - *Helianthus annuus*) and extruded feed.

## 2. Materials e Methods

### 2.1. Animals and accommodation

Sixty-three birds were enrolled in the study. The birds were divided into three experimental groups, according to the species, including 21 cockatiels (*Nymphicus hollandicus*), 21 lovebirds (*Agapornis* sp.), and 21 rose-ringed parakeets (*Psittacula krameri*). All birds were adult and considered healthy based on routine physical and fecal examination. The average weight of the birds at the beginning of the experiment was 98 g for cockatiels (81 – 112 g minimum and maximum, respectively), 49 g for

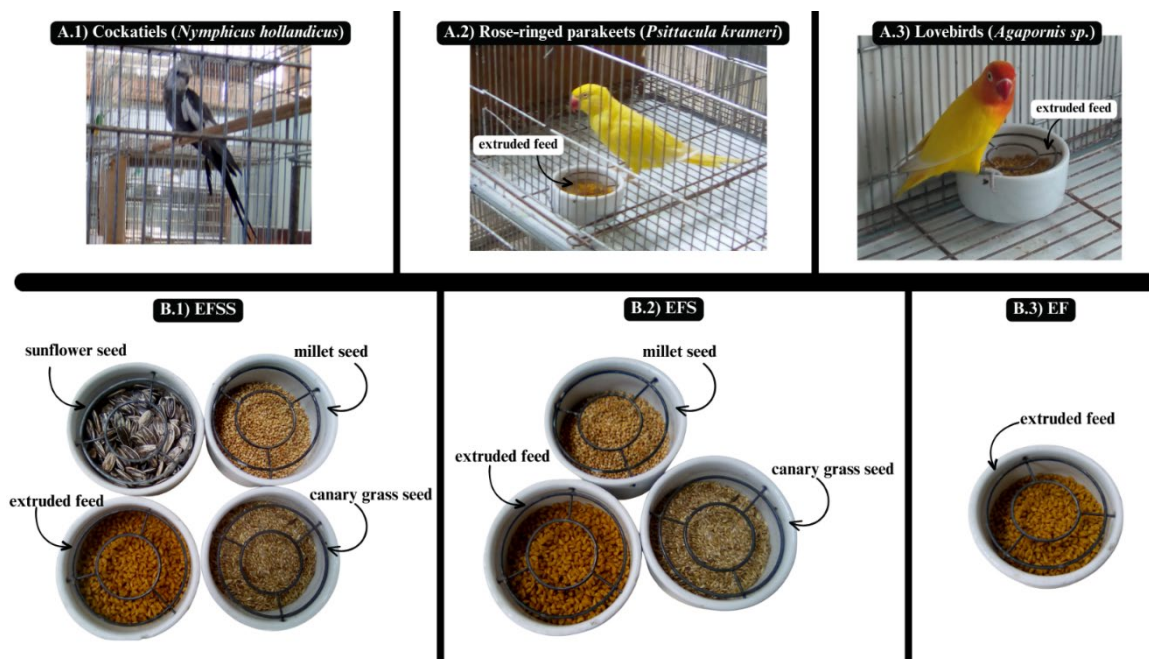
lovebirds (43 – 53 g minimum and maximum, respectively), and 131 g for rose-ringed parakeets (117 – 146 g minimum and maximum, respectively).

The birds were individually housed in wire-mesh cages (60 cm x 50 cm x 50 cm) located in a room with common environmental conditions, within a masonry shed. Each cage was provided with two wooden perches, a ceramic drinker, ceramic feeders, and wire-mesh bottom trays to prevent direct contact with the other birds' excreta (Figure 1. A.1; A.2 and A.3). Light schedules were kept constant during this study (12L:12D). Feed and water were provided *ad libitum*.

## 2.2. Experimental treatments and diets

Each species was distributed in a randomized experimental design into three experimental groups of seven individuals per diet. The experimental diets were composed of commercial “complete maintenance extruded” feed for small/medium psittacines Bambito (Biotron Zootecnica, Rio Claro, Brazil), canary grass seeds (*Phalaris canariensis*), millet seeds (*Panicum miliaceum*) and/or sunflower seeds (*Helianthus annuus*). The birds were divided into three treatments: EFSS group (extruded feed + canary grass seed + millet seed + sunflower seed; Figure 1B.1); EFS group (extruded feed + canary grass seed + millet seed; Figure 1B.2); and EF group (extruded feed; Figure 1B.3) (Table 1). Rose-ringed parakeets received a large-sized sunflower seed ( $1.47 \pm 0.11$  cm), while the other species received a smaller variety ( $0.93 \pm 0.05$  cm). Each bird was provided 25% of its initial body weight of each feed in a separate ceramic feeder on the cage floor, daily. The 25% value of each feed in relation to body weight was based prior experience of monitoring and observation of the birds' intake, leftovers, and waste. This was done to ensure that the birds had the opportunity to choose without missing any type of food that could influence their food selection process. Although the birds were familiar with this food, as it had been included in their normal diet mixture for several years, a three-day adaptation period was provided.

The leftovers in the feeders and trays were collected and weighed daily. Feed intake was calculated for seven consecutive days by recording the weight of feed offered minus the weight of the leftovers in the feeder and the waste in the trays. Feed intake calculations have been adjusted for husked seed. To establish the husk: kernels ratio, 100 g of each seed was manually decorticated to separate husks and seed kernels. The whole seeds and seed kernels were weighed on a precision Kn Waagen 3000/1 scale (KN Waagen Balanças Ltda., São Paulo, Brazil) with a precision of 0.01g. Husk weight was determined by the difference between the total seed weight and the endosperm weight.



**Figure 1** – Individually housed in wire-mesh cages by bird species (A.1; A.2 and A.3) and treatments diets, extruded feed + canary grass seed + millet seed + sunflower seed (EFSS) group (B.1), extruded feed + canary grass seed + millet seed (EFS) group (B.2) and extruded feed (EF) group (B.3).

## 2.3. Laboratory analyses and nutrient intake

Before consumption, the seed kernel (portion edible by birds) was analyzed to assess its nutrient composition, regarding the amount of dry matter (DM) at 105°C drying stove apparatus (Quimis), crude protein (CP, method 954.01) Kjeldahl apparatus (Vapodest 200, Gerhardt, Koenigswinter, Germany), acid-hydrolyzed ether extract (AHEE, method 954.02) hydrolysis system apparatus (Ankom HCI and Ankom<sup>XT10</sup> Extractor), total ash (method 942.05) muffle furnace at 550°C apparatus, calcium (Ca,

method 984.27) titration burette apparatus (Titronic basic) and phosphorus (P, method 984.27) spectrophotometer apparatus (Femto 600 Plus), according to the Association of Official Analytical Chemists (AOAC, 2002). Gross energy (GE) was determined in a calorimeter bomb Parr Instrument Co., (Model 1261; Moline, IL, USA). All analyses were conducted in duplicate and repeated when the variation was greater than 5%. Seeds and extruded feed metabolizable energy (ME) was not determined but was estimated considering 90% of the gross energy (kcal) content of each seed based on Earle and Clark, (1991). For extruded feed, ME values were estimated using the Atwater equation:

$$(ME \text{ (kcal/kg)}) = [4 \times CP (\%) + 4 \times NFE (\%) + 9 \times \text{crude fat} (\%)] \times 10.$$

Daily nutrient intake (DNI) was calculated on a DM basis from the formula:

$$DNI = \text{ingested DM} \times \text{nutrient feed composition} / 100.$$

The maintenance energy requirement (MER; kcal/bird/day) was estimated using the equation of MER ( $154.6 \times BW^{0.73}$ ) which applies to adult birds kept in an indoor cage within a thermoneutral zone with minimal flying activity and the average weight of each species (Earle and Clark, 1991; Koutsos et al., 2001b). MER was estimated considering the average body weight for rose-ringed parakeets (131 g), cockatiels (98 g), and lovebirds (49 g), and compared to the estimated ME consumed for each species and diet.

## 2.4. Statistical analysis

All data were tested for normality using the Shapiro-Wilk method and homogeneity of variance, using Levene's. When these assumptions were accepted, data were analyzed as a completely randomized design. Parametric data were submitted for analysis of variance ANOVA and means were compared by the Tukey test. Non-parametric data were analyzed by the Kruskal-Wallis or Mann-Whitney test according to the number of treatments. Data were considered significantly different when  $P < 0.05$ . Software Past version 4.11 (city, country) was used in all statistical analyses (Hammer et al., 2001).

## 3. Results

### Feed composition

The proportion of husks and kernels, along with the nutritional composition of each feed (on a DM basis) is summarized in Table 1. The husk proportion varied between 21 and 66% for the different seed types, while seed kernels comprised 34 and 79% of the seed. Sunflower seeds, both large and small, exhibited a high concentration of fat, whereas canary grass and millet seeds showed a low concentration of fat content. Extruded feed, canary grass, and millet seeds demonstrated carbohydrate levels exceeding 60% (primarily starch). Compared to extruded feed, all seeds had low calcium levels and Ca:P ratios less than 1:1. The GE of seed kernels ranged from 4778 to 7685 kcal/kg.

|                        | Husks (%) | Kernels (%) | DM (%) | CP (%) | AHEE (%) | NFE (%) * | Ca (%) | P (%) | Ca:P | GE (kcal/kg) |
|------------------------|-----------|-------------|--------|--------|----------|-----------|--------|-------|------|--------------|
| Sunflower seed (large) | 51        | 49          | 95.3   | 23.3   | 41.2     | 19.2      | 0.7    | 0.9   | 0.8  | 7685         |
| Sunflower seed (small) | 35        | 65          | 95.6   | 18.9   | 37.7     | 28.0      | 0.2    | 0.6   | 0.3  | 7541         |
| Millet seed            | 21        | 79          | 87.9   | 14.8   | 3.1      | 74.6      | 0.1    | 0.3   | 0.4  | 4820         |
| Canary grass seed      | 66        | 34          | 88.1   | 17.4   | 2.7      | 70.7      | 0.1    | 0.3   | 0.5  | 4778         |
| Extruded feed          | NA        | NA          | 90.5   | 16.2   | 12.8     | 62.7      | 1.2    | 0.5   | 2.2  | 4850         |

<sup>1</sup>Commercial complete maintenance extruded feed for small/medium psittacines; DM= dry matter CP = crude protein, GE = gross energy, AHEE = acid-hydrolysed ether extract, Ca = calcium, P= phosphorus: \*NFE = nitrogen-free extract was calculated by difference. NA = not applied.

**Table 1** – Proportion of husks and kernels, nutritional composition (% in dry matter, DM), and gross energy (dry matter) of seed kernels and extruded feed<sup>1</sup>.

### Feed intake

Voluntary feed intake, categorized by species and treatments is presented in Table 2. Among rose-ringed parakeets, a preference for sunflower seeds was evident in the EFSS diet ( $P < 0.001$ ). There was no significant difference in extruded feed intake, millet seed, and canary grass seed in EFSS treatment. However, in the absence of sunflower seeds (treatment EFS), millet seed intake was notably higher ( $P = 0.003$ ) compared to extruded feed.

For cockatiels and lovebirds, no differences were detected in the intake of feed items within the EFSS. In the EFS (no sunflower seed), cockatiels presented a higher ( $P = 0.004$ ) intake of millet seeds when compared to extruded feed and canary grass seed. In the absence of sunflower seeds (treatment EFS), lovebirds presented a higher ( $P = 0.013$ ) intake of millet seeds when compared to extruded feed.

| Treatments <sup>1</sup> | Extruded feed*            | Millet seed*            | Canary grass seed*       | Sunflower seed*          | P value |
|-------------------------|---------------------------|-------------------------|--------------------------|--------------------------|---------|
| Rose-ringed parakeets   |                           |                         |                          |                          |         |
| EFSS                    | 0.34 ± 0.6 <sup>b</sup>   | 1.51 ± 1.5 <sup>b</sup> | 0.84 ± 0.5 <sup>b</sup>  | 8.83 ± 1.66 <sup>a</sup> | <0.001  |
| EFS                     | 1.16 ± 1.0 <sup>b</sup>   | 4.72 ± 2.6 <sup>a</sup> | 2.48 ± 0.9 <sup>ab</sup> | NA                       | 0.003   |
| EF                      | 10.26 ± 0.71 <sup>a</sup> | NA                      | NA                       | NA                       | NA      |
| Cockatiels              |                           |                         |                          |                          |         |
| EFSS                    | 1.17 ± 1.5                | 3.24 ± 2.3              | 0.91 ± 0.6               | 1.92 ± 2.0               | 0.078   |
| EFS                     | 1.81 ± 2.4 <sup>b</sup>   | 4.56 ± 1.9 <sup>a</sup> | 0.85 ± 0.7 <sup>b</sup>  | NA                       | 0.004   |
| EF                      | 8.81 ± 1.2                | NA                      | NA                       | NA                       | NA      |
| Lovebirds               |                           |                         |                          |                          |         |
| EFSS                    | 0.14 ± 0.3                | 1.96 ± 1.6              | 1.20 ± 0.3               | 2.11 ± 2.1               | 0.076   |
| EFS                     | 0.71 ± 1.0 <sup>b</sup>   | 2.99 ± 1.9 <sup>a</sup> | 1.26 ± 0.8 <sup>ab</sup> | NA                       | 0.013   |
| EF                      | 6.86 ± 1.6                | NA                      | NA                       | NA                       | NA      |

<sup>1</sup>Extruded feed (EF). Extruded feed+canary grass+millet seeds (EFS). Extruded feed+canary grass+millet+sunflower seeds (EFSS).

\*Data is statistically compared between feeds within treatments. Values followed by different letters in the line differ statistically. NA= Not applied.

**Table 2** – Voluntary feed intake (g/bird/day - as fed) according to species and treatments.

### Nutrient intake and maintenance energy requirement vs. metabolizable energy intake (MEI)

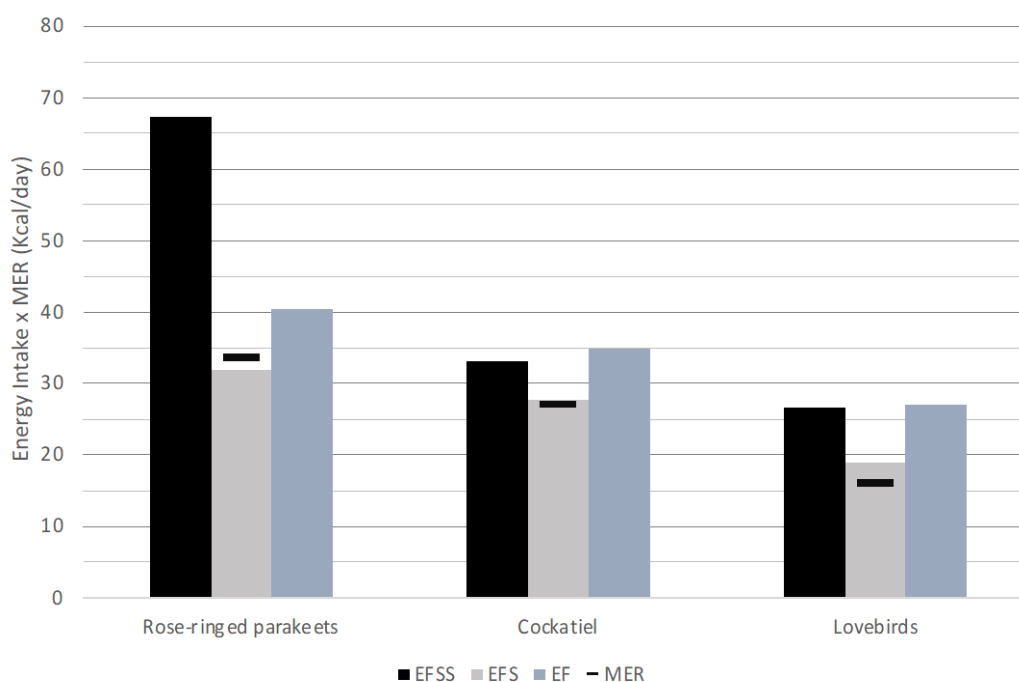
Nutrient intake for each species and feed is summarized in Table 3. Among rose-ringed parakeets, a lower DM intake was observed in the EFS compared to EFSS treatment ( $P = 0.001$ ). Intakes of CP, EE, and GE were the highest in the EFSS groups. Calcium intake was highest in the EF group and phosphorus intake was higher in EFSS treatment ( $P < 0.001$ ). Cockatiels exhibited a lower intake of EE in the EFS group. Calcium intake was highest in the EF group. In the case of lovebirds, a lower intake of EE was seen in the EFS diet group. The intake of calcium and phosphorus was highest in the EF group. Across all species, the Ca:P ratio remained less than 1:1 in both the EFSS and EFS diets.

| Treatments <sup>1</sup> | DM*                     | CP*                    | EE*                     | Ca*                      | P*                       | Ca:P   | GE*                  |
|-------------------------|-------------------------|------------------------|-------------------------|--------------------------|--------------------------|--------|----------------------|
| Rose-ringed parakeets   |                         |                        |                         |                          |                          |        |                      |
| EFSS                    | 10.8 ± 1.7 <sup>a</sup> | 2.3 ± 0.4 <sup>a</sup> | 3.6 ± 0.6 <sup>a</sup>  | 0.07 ± 0.01 <sup>b</sup> | 0.09 ± 0.01 <sup>a</sup> | 0.78:1 | 75 ± 12 <sup>a</sup> |
| EFS                     | 7.4 ± 1.5 <sup>b</sup>  | 1.2 ± 0.2 <sup>b</sup> | 0.3 ± 0.1 <sup>c</sup>  | 0.02 ± 0.01 <sup>c</sup> | 0.03 ± 0.01 <sup>c</sup> | 0.87:1 | 36 ± 8 <sup>b</sup>  |
| EF                      | 9.3 ± 0.6 <sup>ab</sup> | 1.5 ± 0.1 <sup>b</sup> | 1.2 ± 0.1 <sup>b</sup>  | 0.11 ± 0.01 <sup>a</sup> | 0.05 ± 0.02 <sup>b</sup> | NA     | 45 ± 3 <sup>b</sup>  |
| <i>P</i> value          | 0.001                   | <0.001                 | <0.001                  | <0.001                   | <0.001                   | -      | <0.001               |
| Cockatiels              |                         |                        |                         |                          |                          |        |                      |
| EFSS                    | 6.6 ± 1.6               | 1.1 ± 0.3              | 0.9 ± 0.8 <sup>ab</sup> | 0.02 ± 0.02 <sup>b</sup> | 0.03 ± 0.01              | 0.61:1 | 37 ± 12              |
| EFS                     | 6.4 ± 1.1               | 1.0 ± 0.2              | 0.3 ± 0.2 <sup>b</sup>  | 0.03 ± 0.03 <sup>b</sup> | 0.03 ± 0.01              | 0.80:1 | 31 ± 6               |
| EF                      | 8.0 ± 1.1               | 1.3 ± 1.0              | 1.0 ± 0.1 <sup>a</sup>  | 0.10 ± 0.01 <sup>a</sup> | 0.04 ± 0.01              | NA     | 39 ± 5               |
| <i>P</i> value          | 0.075                   | 0.073                  | 0.043                   | <0.001                   | 0.250                    | -      | 0.220                |
| Lovebirds               |                         |                        |                         |                          |                          |        |                      |
| EFSS                    | 4.9 ± 1.0               | 0.8 ± 0.6              | 0.9 ± 1.1 <sup>a</sup>  | 0.01 ± 0.01 <sup>b</sup> | 0.02 ± 0.01 <sup>b</sup> | 0.42:1 | 30 ± 11              |
| EFS                     | 4.4 ± 1.6               | 0.7 ± 0.2              | 0.2 ± 0.1 <sup>b</sup>  | 0.01 ± 0.01 <sup>b</sup> | 0.02 ± 0.01 <sup>b</sup> | 0.70:1 | 21 ± 8               |
| EF                      | 6.2 ± 1.4               | 1.0 ± 0.2              | 0.8 ± 0.2 <sup>a</sup>  | 0.07 ± 0.02 <sup>a</sup> | 0.03 ± 0.01 <sup>a</sup> | NA     | 30 ± 7               |
| <i>P</i> value          | 0.246                   | 0.186                  | 0.034                   | <0.001                   | 0.118                    | -      | 0.137                |

<sup>1</sup>Treatments: Extruded feed (EF). Extruded feed, canary grass, and millet seeds (EFS). Extruded feed, canary grass, millet and sunflower seeds (EFSS). \*Data are statistically compared between treatments within species. Values followed by different letters in the column differ statistically. DM= dry matter, CP = crude protein, EE = ether extract, Ca = calcium, P= phosphorus, Ca:P = calcium: phosphorus ratio, GE = gross energy

**Table 3** – Nutrient (g/bird/day on dry matter) and gross energy intake (kcal/bird/day on the dry matter) according to the species of birds and their treatments.

The comparison of birds' energy intake (EI) to their estimated maintenance energy requirements (MER) is presented in Figure 2. Among rose-ringed parakeets, a superior EI was observed in relation to MER when consuming both EFSS and EF diets, whereas EI was below MER in the EFS treatment. Cockatiels and lovebirds presented superior EI over MER in all treatments. The MERs were estimated at 34.9 kcal/day for rose-ringed parakeets (130g), 28.8 kcal/day for cockatiels (100g), and 17.4 kcal/day for lovebirds (50g). These values were then compared to the estimated AME consumed for each species and treatment. The ingested AME was 67.36, 32, and 40.52 kcal/day for rose-ringed parakeets; 33.23, 27.78, and 34.81 kcal/day for cockatiels; 33.48, 19.04, and 27.11 kcal/day for lovebirds in EFSS, EFS, and EF treatments, respectively.



Treatments: Extruded feed (EF). Extruded feed, canary grass, and millet seeds (EFS). Extruded feed, canary grass, millet, and sunflower seeds (EFSS). AME was estimated considering 90% of gross energy (Earle and Clark 1991). MER was calculated by the formula  $154.6 \cdot (BW)^{0.73}$  (Koutsos, 2001b) for the average body weight of each species, rose-ringed parakeets (131g), cockatiels (98g), and lovebirds (49g).

**Figure 2** – Birds energy intake by species and treatments compared to estimated maintenance energy requirements (MER).

#### 4. Discussion

It was possible to determine the macronutrients of decorticated (husked) seeds commonly fed to pet birds. There was a wide variation in the fat and nitrogen-free extract content of the evaluated seeds. Fat levels were at least 12 times higher in sunflower kernels than in millet or canary grass kernels, while the nitrogen-free extract content was at least three times higher in canary grass and millet seeds. The gross energy of millet seed, canary grass seed, and extruded feed was similar. The choice of consumed feed (seeds x extruded feed) varied among the studied bird species. Rose-ringed parakeets ingested preferentially sunflower seed. When presented with the four feed options, cockatiels consumed similar quantities of each feed. In the EFS group, all three species were more inclined to select millet seeds. The extruded feed was consistently consumed by all three species only when the exclusive diet offered.

Protein requirements were achieved by birds in all groups. Protein intake in rose-ringed parakeets ranged from 16 to 21% (EFSS and EFS, respectively), while in cockatiels and lovebirds, the intake was very close to 16% (minimum 15.6 to 16.7%). Fat intake was notably high in rose-ringed parakeets fed the EFSS group (54.5%) compared to EFS (4%) and EF (12.9%), due to the high intake of sunflower seeds. Cockatiels and lovebirds exhibited fat intake ranging from 13.6 to 18.4% in EFSS groups, close to 12.5% in EF groups, and remained at 4% in EFS groups for both species. The birds in the EF groups were the only ones able to meet the minimum calcium requirements, approaching 1.2%, and thereby meeting the nutritional recommendations. Rose-ringed parakeets in the EFSS group ingested more calcium (0.65%) than the other two species (0.28%), since the large sunflower seed had considerably higher calcium concentrations than the small variety, and DM intake in this group was the highest. Cockatiels and lovebirds fed the EFSS group could not ingest sufficient calcium due to the low concentration in the seed kernels. Minimum recommendations for phosphorus intake were achieved by the birds in all groups (ranging from 0.4-1%). Because of the birds' selective intake and the calcium and phosphorus profiles of the seeds, the Ca:P ratio was only adequate (1:1 to 2:1) in the EF group for all species.

Energy intake in the EFSS groups was significantly higher than the estimated maintenance energy requirement (MER) for all species. Rose-ringed parakeets fed with EFS did not reach the estimated MER. Birds exclusively fed with extruded feed consumed a higher amount of energy compared to the estimated MER. In the present study, no fluctuation in body weight was observed in the birds, however, the analysis period was relatively short. Selective feeding behavior is expected in psittacines when different feeds are available in large amounts, and it does not necessarily result in the consumption of a balanced diet, with different factors regulating intake (taste, habits, food placement, texture, size, shape, and color) (McKenzie and Whittingham, 2010). Carciofi et al. (2003) evaluate the feed intake of six parrots from five different species when fed a diet based on fruits and

seeds. The authors observed substantial variation among individuals in terms of selectivity of alimentary items but a general trend to prefer seed over other feed items (such as papaya), leading the diets to be nutritionally heterogeneous and non-balanced.

Seeds are generally the first choice of birds, because they are quite palatable and, in the case of granivorous birds, they resemble the food of natural habitats (Koutsos et al., 2001a). The formulation of seed mixtures specific to each species is primarily determined by the size of the seeds relative to the bird's beak size, the optimal cost-benefit ratio, and availability. This approach prioritizes the individual dietary preferences of birds rather than considering their specific nutrient requirements; As a result, nutrient intake is influenced by each bird's personal preference for the available feed options (Kalmar, 2011; Péron and Grosset, 2013). Although the total protein requirements were in this trial, literature reports highlight concerns about seed-based diets, including deficiency in essential amino acids (Werquin et al., 2005; Heatley and Cornejo, 2015). Harper and Skinner (1998) report that the required amount of protein in the diet for small psittaciformes is from 10 to 14%, containing the appropriate amino acid profile (essential amino acids). Koutsos et al. (2001b) observed that the protein requirement for cockatiels and parakeets was likely 11% of the diet or less. During the growth period, a diet containing 20% protein (1% methionine + cysteine, 1.5% lysine) is recommended to achieve optimal growth (Koutsos et al., 2001b).

Regarding minerals, the general requirement during the maintenance phase is low. For cockatiels and parakeets, the calcium requirement becomes 0.35-0.85% (Koutsos et al., 2001a). Most seeds commonly fed to captive parrots have <0.1% Ca, and grains such as millet and corn, are especially low with <0.03% Ca. Birds in the EFS groups exhibited a calcium intake lower than 0.3%, rendering them susceptible to metabolic disorders. Experimental and clinical evidence indicates that a diet exclusively based on seeds can result in calcium deficiency and that the need for this mineral is above 0.05% (Wolf et al., 1998). Additionally, seeds can contain high levels of phosphorus (P), which can form phytate complexes that bind calcium (Stanford, 2006). Suboptimal Ca supply and Ca:P ratio in seed-based diets are well-known causes of impaired skeletal mineralization, leading to nutritional secondary hyperparathyroidism, rickets, or osteomalacia (Wolf et al., 1998; Kalmar, 2011). Seeds decrease reproductive performance because they lack calcium, lysine, and vitamins A and E (Péron and Grosset, 2013). In a study involving eight psittacin species, it was demonstrated that fledging success was higher (90% success vs. 66%) when a pelleted diet was provided instead (Ullrey et al., 1991).

The regulation of feed intake is not always perfect, and obesity can result from feeding diets with high energy density (Péron and Grosset, 2013). The high-fat content associated with the physical act of husking sunflower seeds enhances their palatability and could explain a higher feed intake in rose-ringed parakeets in EFSS groups. Free-ranging parrots spend at least half of their time foraging, being more active, and concomitantly having a high overall energy expenditure (Graham et al., 2006; Lightfoot and Naciewicz, 2006; Rozek et al., 2010). In captivity, parrots housed in cages are inactive for up to 90% of their waking time, resulting in reduced energy expenditure (Harper, 2000; Rozek et al., 2010). Consumption of more energy than the daily energy expenditure can lead to weight gain, obesity, and contribute to lipid-related issues in psittacines (Beaufreire et al., 2019). The development of lipid-related lesions in captive parrots, especially pet birds, is associated, not only with high energy and fat intake but also with reduced physical activity (Scott and Evans, 1992; Werquin et al., 2005; Di Santo et al., 2019).

In sedentary pet birds, being overweight may be associated with pododermatitis, and higher oxidative damage while performing an escape flight (Larcombe et al., 2010). Apart from the physical concerns, keeping psittacines in captivity can result in boredom due to a lack of stimulation and the inability to explore and forage (Péron and Grosset, 2014). Although it is possible to enrich the captive environment and stimulate physical activity, only birds that practice flight routinely achieve adequate energy expenditure and improve their serum lipid profile (Lierz, 2003; Di Santo et al., 2019). It is essential to be cautious when exclusively feeding birds a seed mixture, as this type of diet can lead to selective eating, resulting in an imbalance and inadequate intake of essential nutrients. This can result in malnutrition and associated issues, including poor overall nutrition, compromised body condition, reproductive failure, and even death (Perpiñán, 2015; Cummings et al., 2022).

To address the selective eating behavior of psittacines and prevent imbalanced nutrient intake, formulated diets should ideally constitute approximately 75% of their total dry matter intake (Ullrey et al., 1991; Hess et al., 2002; Brightsmith, 2012). Mixed diets, including seeds, fruits, and vegetables, are strongly recommended to provide a well-rounded diet for psittacines, promoting natural behaviors (Meehan et al., 2003; Brightsmith, 2012). Additionally, implementing solid feeding protocols that consider the frequencies and volumes of each feed, along with strategic supplementation of macronutrients, vitamins, and minerals, can help maintain their nutritional balance.

## 5. Conclusion

Rose-ringed parakeets showed a preference for sunflower seeds, while cockatiels and lovebirds consumed similar quantities of each feed option. This demonstrates that birds are prone to selective eating with no nutritional wisdom, leading to nutritional imbalances. When sunflower was not available (EFS group), the three species were more prone to select millet seeds. Because of the birds' selective intake and the Ca and P profiles of the seeds, the Ca:P ratio was inadequate in EFSS and EFS groups for all bird species. In fat diets (EFSS group) birds presented superior energy intake over maintenance energy requirements in all treatments.

**Briefing notes:** This study was approved by the Committee on Ethics in the Use of Animals of the Agriculture Sciences Sector of the Federal University of Paraná under protocol number 066/2017.

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