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Research article

# Exploring dietary practices and faecal consistency in zoo-housed cotton-top tamarins *Oedipomidas oedipus*

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**Abstract**

The cotton-top tamarin *Oedipomidas oedipus* is currently classified as critically endangered by the IUCN, prompting intensive conservation efforts, including the maintenance of healthy populations under human care. However, ensuring optimal welfare and health remains challenging, particularly in terms of nutritional management, due to inherent issues observed in callitrichid species in captivity. This study aimed to evaluate fecal consistency in cotton-top tamarins and investigate its association with different dietary regimes. A survey was conducted across 10 zoological institutions, encompassing 69 individuals, to collect data on dietary practices and faecal consistency. Faecal evaluation was assessed using a scale from 1 (solid) to 6 (watery), based on appearance and texture. A comparative analysis of institutional diets was performed based on the proportions of food groups offered, including cultivated fruits, vegetables, commercial foods, animal protein, supplements, and exudates. These proportions were then analysed in relation to faecal scores. In addition, individual body weights were evaluated in relation to the amount of food provided at each institution. A positive correlation was found between fruit inclusion levels and higher faecal score. Variations in body weight were observed among institutions, with lower average weights recorded in females where food quantities were reduced. A standardized faecal scoring system was developed to support health monitoring and animal management protocols.

## Introduction

The cotton-top tamarin *Oedipomidas oedipus*, a primate species of the Callitrichidae family, is currently classified as Critically Endangered by the International Union for Conservation of Nature (IUCN 2020). Significant threats to its survival include rapid habitat loss and illegal capture for the pet trade (Rodríguez et al. 2021). Although conservation actions are underway, maintaining cotton-top tamarins under human care remains challenging (Burrell and Altman 2006).

Species of the genus *Oedipomidas* are classified as opportunistic gummivores, with a frugivorous-insectivorous feeding preference (NRC 2003). Reports of the natural diet of cotton-top tamarins include wild (non-cultivated) fruits, invertebrates, nectar, and other plant exudates (particularly gums), varying seasonally depending on habitat availability (García-Castillo 2016). Gum consumption has been documented as a relevant dietary component in this species, as well as in other callitrichids (De La Ossa and De La Ossa-Lacayo 2014). These gums are rich in complex carbohydrates requiring microbial fermentation, calcium, potassium, sodium, and magnesium (García-Castillo 2016); some gums have been reported to possess medicinal properties, such as anthelmintic and anti-inflammatory effects (Ayoka et al. 2008).

Replicating an adequate diet in captivity poses a major challenge for institutions maintaining cotton-top colonies. Diets in human care are often characterized by high sugar content and limited access to key resources such as dietary fiber, insects, and gums (Richards-Rios et al. 2021). This type of nutritional management is often considered a contributing factor to gastrointestinal issues (Fitz et al. 2020). One of the main concerns is the predisposition to chronic digestive

disorders, such as wasting marmoset syndrome (WMS), a chronic enteric disease linked to the mortality of callitrichids (Richards-Rios et al. 2021). Other reported pathologies include colitis and colorectal adenocarcinoma, accounting for 10% to 40% of deaths in colonies under human care (Leong et al. 2004). Studies in zoological settings have documented a 50% incidence of idiopathic chronic colitis in captive marmosets, with 20% to 40% of these progressing to colorectal cancer (Shen et al. 2016). Additional health concerns linked to nutritional management include non-specific colitis (Yoshimoto et al. 2016; Malukiewicz et al. 2022), obesity (Strike and Felter 2017), insulin resistance, type II diabetes, bone diseases (Standaert et al. 2002), and periodontal disease (Acosta and Moreno 2007; Cabana and Nekaris 2015). Inadequate nutrition has also been implicated in the emergence of physiological and behavioural disorders (Schultz 2017).

Given the high susceptibility of cotton-top tamarins to gastrointestinal pathologies, the development of tools for the rapid, non-invasive assessment of intestinal health is essential. Faecal scoring is a widely used method for evaluating gut health in mammals (Whitehouse-Tedd et al. 2015). This technique involves visual and tactile assessment based on standardized descriptions of stool consistency (e.g. firm, normal, soft, liquid), providing a practical reference for animal care and veterinary teams (Fitz et al. 2020). Liquid stools are generally considered a sign of poor gut health, potentially indicating the presence of pathogens, immune disorders, dysbiosis, or gastrointestinal stress (Clark et al. 2016; De Cuyper et al. 2021).

This study aimed to determine the relationship between dietary practices and faecal quality as an indicator of digestive health in cotton-top tamarins housed under human care across zoological institutions worldwide.

## Materials and methods

### *Individuals and Institutions*

A total of 10 zoological institutions agreed to participate in this study, located in Colombia (n=3), Guatemala (n=1), Mexico (n=1), Australia (n=1), the United Arab Emirates (n=1), the United Kingdom (n=1), and the United States (n=2), encompassing 69 cotton-top tamarins. The research proposal was submitted for review to the professionals responsible at each participating institution. Only data from institutions that approved the methodology and consented to the publication of the information provided were included in the study.

Stool photographs were collected during routine husbandry activities over four randomly selected days. In four of the participating institutions, photographs were obtained individually or in pairs, depending on how the animals were housed. In the remaining institutions, photographs were collected from groups of three to six individuals, and it was not possible to attribute samples to specific animals. Additionally, detailed information regarding feeding schedules and dietary composition was requested from each institution.

To establish objective criteria for the classification of faecal consistency across all images, stool samples from 21 individuals housed in two institutions were subjected to visual and tactile evaluation.

Additionally, body weight data were obtained using the ZIMS 365 platform, with records available for 44 individuals from 9 of the 10 institutions surveyed. Weight data from Institution A were unavailable due to missing records (n=16). In the Species360 (ZIMS) database search for the remaining institutions, weight records were not found for five individuals. Furthermore, weight data from four animals were excluded from the adult mean weight analysis, as these individuals were identified as infants or juveniles and their lower weights were considered non-representative.

### *Diet Analysis*

Dietary components were categorized into the following groups: cultivated fruits, vegetables, insects, other protein sources, commercial primate foods, gums, seeds/grains, and vitamin or mineral supplements. The proportional inclusion of each food group was calculated based on the quantities reported by each institution on an as-fed basis.

### *Faecal Scoring System*

Faecal consistency was assessed using a scoring scale from 1 to 6, where 1 represented the driest and firmest consistency, and 6 indicated a liquid consistency classified as diarrhoea. This classification system was adapted from the Stool Scoring System for common marmosets *Callithrix jacchus* (Kramer et al. 2009), as well as from various primate-specific scales provided by the Fecal Condition Scoring Resource Centre of the Nutrition Advisory Group, Association of Zoos and Aquariums (AZA). For each institution, an average stool score was calculated based on all individual scores.

### *Statistical Analysis*

Body weight comparisons between males (n=26) and females (n=18) were conducted using the unpaired Student's t-test for parametric data. Body weight was also analysed in relation to the amount of food provided by each institution. Three standardized food supply levels were defined, and individuals were grouped accordingly. The mean weight of each group was calculated, and a Tukey post hoc test was applied to identify significant differences between groups. Simple Spearman correlation analyses were performed to assess associations between faecal scores and the proportional inclusion of each food group in the diet. A significance level of 5% ($P<0.05$) was adopted throughout.

## Results

The mean body weight of adult individuals was 526.0 g±70.9. A significant difference was observed between females (512.5 g±59.2; n=18) and males (536.0 g±77.6; n=26; P=0.012).

### *Ingredient analyses*

A total of 32 different dietary ingredients were used across the evaluated institutions, in varying proportions. The most commonly used items included apples, bananas, pears, carrots, and eggs (offered by more than 60% of institutions), while less frequently used ingredients (<30%) included grapes, figs, red berries, oranges, watermelon, green beans, broccoli, cauliflower, flies, canned marmoset food, Mazuri New World Primate Diet, chicken, rice, and sunflower seeds (Table 1).

The number of ingredients provided per institution ranged from a minimum of 4 to a maximum of 30. All institutions offered at least one type of cultivated fruit and some form of primate food (either commercial products or homemade mixes). Only one institution (Institution J) did not include any source of animal protein other than insects. Gums were offered by only three institutions (E, F, and J), while cereals and seeds were included in the diets of just two (E and J) (Table 2).

Cultivated fruits constituted the largest average as-fed proportion at 34.6% (±22.2), ranging from 7.8% to 71.4%. Vegetables were the second most prevalent food category with an average of 27.3% (±24.8), followed by primate pellets (24.2%±21.1) and insects (12.6%±6.2). Other components such as animal protein, gums, seeds/cereals, and supplements were offered in smaller proportions, averaging between 0.75% and 4% (Table 3).

On average, the amount of food provided per individual was 132 g±44.5 as fed, corresponding to approximately 25% of the

**Table 1.** Food reported in cotton-top tamarins *Oedipomidas oedipus* under human care diets (n=10)

| Caterory | Ingredient | Institutions (n=10) |
|---|---|---|
| Cultivated fruits | Apple | 8 |
| | Banana | 8 |
| | Mango | 6 |
| | Melon | 4 |
| | Papaya | 4 |
| | Pear | 4 |
| | Blueberries | 3 |
| | Fig | 3 |
| | Grape | 3 |
| | Orange | 3 |
| | Guava | 2 |
| | Watermelon | 2 |
| | Peach | 1 |
| Vegetables | Legumes | 7 |
| | Carrot | 6 |
| | Bean | 5 |
| | Sweet potato | 5 |
| | Avocado | 4 |
| | Cauliflower | 3 |
| | Brocoli | 2 |
| | Pea | 2 |
| Insects | Grasshoppers | 5 |
| | Giant mealworm | 4 |
| | Mealworm | 4 |
| | Fly | 1 |
| Primate food | Primate pellets | 4 |
| | Homemade mixture † | 3 |
| | Canned marmoset diet | 2 |
| | Primate cake | 2 |
| | Callitrichid Plus Gel | 1 |
| | Leafeater pellets | 1 |
| Animal protein | Boiled egg | 7 |
| | Cooked Chicken | 3 |
| Gum | Guar/Arabic gum | 3 |
| Seeds/cereal | Cooked rice | 2 |
| | Sunflower seeds | 2 |
| Supplement | Mineral and vitamin supplement | 4 |

† Each institution has its own combination of commercial foods, fruits, supplements and additives.

mean adult body weight (526 g±70.9). Regarding the relationship between body weight and the amount of food offered, a significant difference was found in the average weight of females between the lowest and highest food supply groups (P=0.016), as well as between the intermediate and lowest supply groups (P=0.001) (Table 4). For males, a significant difference was observed between individuals in the low and intermediate food supply groups (P=0.038).

***Faecal Score***

A stool scoring chart ranging from 1 to 6 was developed, with score 1 representing hard and dry stools and score 6 representing liquid or diarrheic stools (Table 5).

Score 6 stools were observed only at Institution B and were not associated with any pathologies or parasites, as the animals were considered healthy at the time of evaluation. Similarly, Institutions E and H reported occasional occurrences of this type

**Table 2.** Diet composition on a fresh matter basis, food offered, and faecal scores of ten groups of cotton-top tamarins *Oedipomidas oedipus* under human care

| Institution | Animals (n) | Fruits | Vegetables | Insects | Primate pellet | Animal protein | Gum | Seeds/ cereals | Supplements | Amount per animal (g) | Faecal score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Average (range) | 16 | 71.4 | 0 | 0 | 14.3 | 14.3 | 0 | 0 | 0 | 196 | 4 (3-4) |
| B | 14 | 53.5 | 18 | 5 | 6 | 17 | 0 | 0 | 0.5 | 96 | 5 (3-6) |
| C | 7 | 53.4 | 18.7 | 1.5 | 10.5 | 14.9 | 0 | 0 | 0.9 | 133 | 4 (3-5) |
| D | 4 | 53.6 | 0 | 0.9 | 26.8 | 17.9 | 0 | 0 | 0.9 | 224 | 3 (3-4) |
| E | 4 | 38.0 | 22.1 | 6.22 | 22.8 | 6 | 1.1 | 2.9 | 0.7 | 180 | 4 (3-4) |
| F | 5 | 22.3 | 22.3 | 1.8 | 26.8 | 17.9 | 8.9 | 0 | 0 | 112 | 2 (1-2) |
| G | 1 | 17.8 | 17.8 | 11.1 | 35.6 | 17.8 | 0 | 0 | 0 | 67 | 2 (2) |
| H | 10 | 16 | 64.2 | 0 | 15.1 | 4.7 | 0 | 0 | 0 | 106 | 3 (2-4) |
| I | 6 | 11.8 | 7.2 | 0.4 | 77.6 | 2.9 | 0 | 0 | 0 | 198 | 2 (1-3) |
| J | 2 | 7.8 | 75.7 | 7.1 | 6.3 | 0 | 2 | 1.2 | 0 | 122 | 3 (2-3) |

of stool; however, it was not possible to confirm whether these were associated with any medical conditions.

Stool types 5 and 4 were observed at institutions A, B, C, D, E, and H. Stool type 3 was recorded at eight institutions, with the exception of Institutions F and G. Stool type 2 was found at Institutions F, G, H, I, and J, while stool type 1 was observed only at Institutions F, H, and I.

Thanks to data provided by Fundación Proyecto Titi, it was possible to compare these findings with records of free-ranging cotton-top tamarins (Figure 1), which were classified as score 3 based on the researcher's evaluation.

A positive correlation was observed between the proportion of cultivated fruit in the diet and the average stool score, indicating that higher fruit inclusion is associated with softer stools ($r=0.8$; $z=3.6$; $P=0.005$). Conversely, negative correlations were found between stool score and the inclusion levels of primate food ($r=–0.6$; $z=–2.35$; $P=0.081$) and gum ($r=–0.9$; $z=–5.8$; $P=0.072$); however, these latter correlations only tended towards statistical significance.

## Discussion

This study revealed significant variation in nutritional management and faecal scores across the evaluated institutions. Although many institutions utilized similar dietary ingredients, the proportions in which these items were offered varied considerably. Four out of ten institutions relied primarily on cultivated fruit, which accounted for more than 50% as fed of their total diets. Two institutions emphasized vegetables, with inclusion levels exceeding 60%, while only one institution provided a diet predominantly composed of

**Table 3.** Average, minimum and maximum values of the composition of diets (as-fed basis) offered to individuals of cotton-top tamarins *Oedipomidas oedipus* in 10 zoological institutions

| Food Category | Average (%) | Minimum (%) | Maximum (%) |
|---|---|---|---|
| Cultivated fruits | 34.6±22.2 | 7.8 | 71.4 |
| Vegetables | 27.3±24.8 | 7.2 | 75.7 |
| Insects | 4.25±3.8 | 0.9 | 11.1 |
| Primate pellets | 24.2±21.1 | 6 | 77.6 |
| Animal Protein | 12.6±6.2 | 2.9 | 17.9 |
| Gums | 4±4.2 | 1.1 | 8.9 |
| Seeds/cereals | 2±1.2 | 1.2 | 2.9 |
| Supplements | 0.75±0.2 | 0.5 | 0.9 |

**Table 4.** Average body weight of adult individuals of cotton-top tamarins *Oedipomidas oedipus* under human care grouped according to the food supply per individual per day

| | Average weight | | | |
|---|---|---|---|---|
| Food offered per individual (g fresh weight, range) | Females | n | Males | n |
| 67-110 | 467.2 ±33.3a | 8 | 509.5 ±70a | 12 |
| 111-153 | 539.1 ± 42.5b | 7 | 569.7 ± 65.3b | 7 |
| 154-166 | 571 ± 68.4b | 3 | 548 ± 93.7ab | 7 |

Letters indicate significant difference between vertical values *P=0.05

commercial primate food, representing nearly 70% of the total fresh weight.

Other authors have highlighted that institutions offering diets composed of 45.4-55.7% commercial foods, 27.3-29% cultivated fruits, 12-21.8% vegetables, 3% insects, and 0.1-5% nutritional supplements on an as-fed bais have successfully maintained healthy captive cotton-top tamarin populations (Savage 1995). These values contrast with reports from wild populations of *Oedipomidas oedipus*, where the diet consists, on average, of 28–60% wild fruits (depending on the season), 14–45% exudates (gums), 2.1–16.9% nectar, 9.8% arthropods, 1.1% fungi, 0.7% flowers, and occasional consumption of frogs (García-Castillo

**Table 5.** Stool score in cotton-top tamarins *Oedipomidas oedipus*

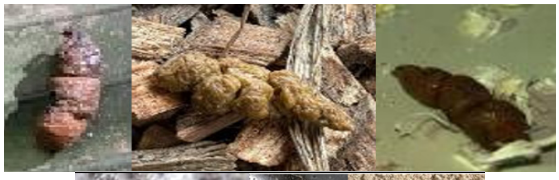
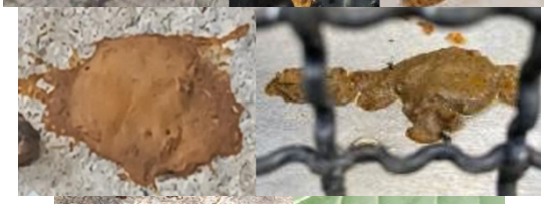
| Score | Description | Visual reference | Institution |
|---|---|---|---|
| 1 | Separate hard pellets, round or oval in shape. Primarily dry. No residue left after removal. |  | F, F, I |
| 2 | Firm but not hard. Pellets form one fecal unit that is moist with distinct segmentation. |  | F, G, J |
| 3 | Soft and log-like in shape, moist dough-like consistency, segmentation is not present. |  | A,D, H |
| 4 | Portions may be formed but inconsistent. A mushy stool that may occur in blobs |  | B, D, E |
| 5 | Has texture but cannot hold a vertical shape. Some splattering may occur. |  | B,C |
| 6 | Watery and presents as a flat puddle. Heavy splattering is likely to occur. |  | B |

**Figure 1.** Faeces from wild individual of cotton-top tamarins *Oedipomidas oedipus* under an anaesthetic procedure (Fundación Proyecto Titi, Colombia)

and Defler 2018). In particular, the absence of gum in diets under human care is striking.

Some of the least frequently used ingredients in the institutions evaluated, as well as in previous reports on diets under human care, were vegetable gums and nectar (Huber and Lewis 2011), both of which are often considered important components of the callitrichid diet (Garber and Porter 2010). A review of dietary data for *Saguinus* spp.indicated that gums from *Anacardium excelsum* and *Spondias mombin* are part of the natural diet of cotton-top tamarins in the wild, accounting for approximately 12% of their diet (García-Castillo and Defler 2018).

70% of the institutions included commercial primate-specific foods, while the remaining institutions used homemade mixes based on ingredients such as wheat flour, Nestum®, fruits, honey, dog food, and dietary supplements. These three institutions (B, C, and D) were among those with the highest level of cultivated fruit inclusion and where softer stools and lower average weights were more frequently observed compared to the other institutions. However, it was not possible to determine whether the absence of commercial primate food was directly related to the lower weights and increased incidence of soft stools.

The average amount of food provision observed in this study (132 g±44.5 as fed) aligns with the recommendations found in the Cotton-top Tamarin Management Manual (Savage 1995), which suggests daily dietary amounts ranging from 82.5 g to 137 g as fed per adult individual. Similarly, the EAZA Callitrichid Management Manual (2022) recommends offering food equivalent to 5% of body weight per day on a dry matter basis, corresponding approximately to 16–24% of body weight in fresh matter, closely matching the results obtained in this study (25% of average body weight).

Regarding stool quality, the six stool types identified in this study have also been reported by other authors using different classification systems. Yamazaki et al. (2017) describe four stool types in marmosets (Callithrix jacchus), where “normal” stool corresponded to scores 2 and 3 in the present study, the “soft” type was similar to our score 4, “diarrhoea” corresponded to score 5, and “liquid” to score 6. Fitz et al. (2020) proposed the categories: firm, normal, soft, and diarrhoea, which correspond to our scores 1, 2, 4, and 6, respectively. Additionally, these authors described a final category—“liquid diarrhoea”—which, based on its characteristics, did not have a direct equivalent in our findings.

Soft stools and diarrhoea were predominantly observed in institutions where cultivated fruit comprised a larger proportion of the diet compared to other ingredients. This pattern suggests a potential association between a high intake of sugars or easily digestible carbohydrates and gastrointestinal disturbances in primates (Viallard et al. 2023). Cultivated fruits, while palatable and frequently offered in captivity, generally contain higher levels of sugar and water and lower fiber compared to wild fruits, which may compromise gut function and stool consistency (Plowman, 2015). This observation aligns with the findings of Kirkwood (1983), who reported that reducing cultivated fruit content by 50% in the diet of cotton-top tamarins (and the simultaneous addition of eggs) led to a decrease in chronic diarrhoea, along with improvements in weight gain and hair regrowth in previously alopecic areas. Richards-Rios et al. (2021) also highlight that a lack of dietary fiber, commonly seen in diets with low inclusion of pellets, vegetables, or gums, may contribute to the development of Progressive Wasting Syndrome (PWS), a condition in tamarins that resembles inflammatory bowel disease (IBD) in humans; this was shown statistically in a survey of 65 EAZA zoos keeping callitrichids by Cabana et al. (2018).

Similar studies conducted on cebid species (*Ateles* spp., *Cercopithecus* spp., *Allochrocebus* spp., and *Sapajus* spp.) have demonstrated that the complete removal of fruit from the diet resulted in positive effects on stool quality, with significantly firmer stools observed following the dietary change (Viallard et al. 2023). Furthermore, Plowman (2013) reported improvements in dental health in colobus monkeys within one year of adopting a fruit-free diet, along with gradual weight loss in overweight individuals and improvements in stool consistency.

Some of the improvements observed have been attributed to the nutritional differences between cultivated and wild fruits, which can vary significantly (Bryson-Morrison et al. 2020; Goodroe et al. 2021). According to Schwitzer et al. (2009), cultivated fruits typically contain higher levels of sugar and lower fiber content compared to wild fruits. These characteristics have been linked to adverse effects associated with excessive carbohydrate intake in nonhuman primates, including obesity, gastrointestinal disorders, and dental disease. Consequently, despite the naturally frugivorous habits of many primate species, several zoos have initiated detailed evaluations and implemented fruit-free diet models (Plowman and Cabana 2019).

Other risk factors suggested for the development of digestive diseases in primates include diets containing gluten (Kuehnel et al. 2013; Fitz et al. 2020), habitat design, housing density, and overall stress levels (Cabana et al. 2018). These factors should be considered as part of a comprehensive health assessment aimed at improving welfare conditions and reducing the incidence of such disorders.

Finally, further research is needed to better understand the nutritional and physiological requirements of cotton-top tamarins, as well as to develop practical tools for assessing digestive health. Given that nutrition plays a fundamental role in the survival and long-term conservation of the species, such efforts are essential for improving management practices under human care.

Feeding regime is closely linked to gastrointestinal health and faecal condition in cotton-top tamarins. Although dietary ingredients varied substantially across institutions, faecal scores were generally comparable. This suggests that the overall nutritional balance—particularly the lack of fibre and high sugar content from cultivated fruits—may have a greater influence on gastrointestinal health than the specific dietary components themselves. Also, establishing a baseline for ideal fecal quality using tools such as the fecal stool chart, developed with information from various institutions and different dietary regimes under captivity, may provide guidelines for nutritional management decisions. However, further research in managed care settings is essential, incorporating welfare indicators and comparative data from wild populations.

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