

## environment

# Water and mineral composition of the exudate resulting from scarification of pau-pombo trees by black-tufted marmosets

Água e composição mineral do exsudato resultante da escarificação de árvores pau-pombo por micos-estrela

Juliane Martins Lamoglia<sup>I</sup> , Vanner Boere<sup>III</sup> ,  
Edgard Augusto de Toledo Picoli<sup>I</sup> , Juraci Alves Oliveira<sup>I</sup> ,  
Carlos de Melo e Silva Neto<sup>II</sup> , Ita de Oliveira e Silva<sup>IV</sup> 

<sup>I</sup>Federal University of Viçosa, MG, Brazil

<sup>II</sup>Federal Institute of Goiás, GO, Brazil

<sup>III</sup>Federal University of Southern Bahia, Itabuna, BA, Brazil

<sup>IV</sup>Federal University of Southern Bahia, Arts and Sciences at Campus Jorge Amado, Itauna, BA, Brazil

## ABSTRACT

Black-tufted marmosets to obtain tree exudates for food often use *Tapirira guianensis* trees. Tree exudates are sources of calories, nutrients and water. In seasonal droughts, the high concentration of water in the exudates can be an immediate source for marmosets. One of the most important elements for the metabolism of marmosets is calcium, but it remains to be proven whether *T. guianensis* gum is rich in calcium. This study characterizes the water and mineral composition of the exudate that is consumed by black-tufted marmosets in urban forests in the Cerrado domain. Orifice and stem exudate samples were collected from eight scarified *T. guianensis* trees. The composition of the exudate was characterized using bromatological methods. The exudate was shown to have high levels of water and calcium, which are essential for the metabolism of marmosets. Due to its characteristics, *T. guianensis* may be an important tree species for the feeding ecology of marmosets and should be taken into consideration when making wildlife management plans in the Cerrado domain.

**Keywords:** *Callithrix penicillata*; Exudate composition; Feeding ecology; *Tapirira guianensis*

## RESUMO

Os micos-estrela costumam usar árvores *Tapirira guianensis* para obter exsudatos para alimentação. Os exsudatos das árvores são fontes de calorias, nutrientes e água. Em secas sazonais, a alta concentração de água nos exsudatos pode ser uma fonte imediata de água para os saguis. Um dos elementos mais

importantes para o metabolismo dos saguis é o cálcio, mas ainda não foi comprovado se a goma de *T. guianensis* é rica em cálcio. Este estudo caracteriza a composição hídrica e mineral do exsudato que é consumido por micos-estrela em florestas urbanas no domínio do Cerrado. Amostras do orifício e exsudato do caule foram coletadas de oito árvores escarificadas de *T. guianensis*. A composição do exsudato foi caracterizada por métodos bromatológicos. O exsudato demonstrou conter elevados teores de água e cálcio, essenciais para o metabolismo dos saguis. Pelas suas características, *T. guianensis* pode ser uma espécie arbórea importante para a ecologia alimentar de saguis e deve ser levada em consideração na elaboração de planos de manejo da fauna silvestre no Cerrado.

**Palavras-chave:** *Callithrix penicillata*; Composição do exsudato; Ecologia alimentar; *Tapirira guianensis*

## 1 INTRODUCTION

Black-tufted marmosets (*Callithrix penicillata*) are small Neotropical primates that inhabit forests, savannas, and urban areas in the Cerrado domain (Bicca-Marques *et al.*, 2018). Their diet is diverse, but fruits, arthropods, and tree exudates predominate (Souza-Alves *et al.*, 2021). Tree exudate is a fundamental part of the diet and ecology of marmosets, as it provides essential nutrients for metabolism (Power, 2010; Smith, 2010) and influences social behavior (Harrison; Tardif, 1994). Marmosets therefore actively exploit some tree species, scarifying the bark to obtain exudates (Francisco *et al.*, 2016). The consumption of exudates is possible because marmosets have morphological and functional specializations for scarifying the bark, and are able to reach secretory ducts and stimulate the production of exudates (Power, 2010).

Tree exudates are complex substances containing water, proteins, complex carbohydrates, and minerals, which are ingested by marmosets (Power, 2010; Francisco *et al.*, 2016). The ingestion of exudates has nutritional benefits for marmosets. Small bodied mammal species such as marmosets, generally have a high basal metabolic energy cost. Exudates are a rich source of polysaccharides and proteins, which is an important component of marmoset diet, which can digest complex molecules with a special gut physiology (Power, 2010).

It has been argued that exudates are a rich source of calcium, essential to maintaining a balance between calcium and phosphorus for an insectivorous species

(Power, 2010). As is well known, insects are high in phosphorus and low in calcium (Power, 2010). In addition to this dietary particularity, reproductive females most often give birth to twins every five months. The weight of marmoset newborn twins can reach approximately 17% of the weight of their mother (Schradin; Anzenberger, 2001), one of the highest proportions among primates (Abbott *et al.*, 2003). Marmosets do not have lactational anestrus and may have fertile estrus within a few weeks post-partum. The breastfeeding period lasts from two to three months, during which time the reproductive female may be carrying new offspring (Tardif *et al.*, 2001). Therefore, the metabolic cost of calcium due the reproduction is high for this species, which requires a regular and abundant source to balance the calcium/phosphorus ratio (Ca:P) (Tardif *et al.*, 2001).

The choice of exudate trees for marmosets remains to be fully explained. There is evidence that the anatomical characteristics of trees, particularly the bark, influence the choice of trees to be scarified in order to obtain exudate (Francisco *et al.*, 2014). To this end, it has been suggested that marmosets randomly gnaw trees in their environment, not focusing necessarily on those that have exudations that can be used (Faria, 1983; Francisco *et al.*, 2014). The presence of nutrients may be a factor that influences the choice of exudate trees and the permanence and persistence of the use of a particular tree. Considering that calcium is an essential ingredient for the metabolism of marmosets, trees that are scarified are expected to produce exudate with a high concentration of this mineral.

In several studies on the gummivory of black-tufted marmosets in the Cerrado domain, it has been observed that the *Tapirira guianensis* Aubl tree is one of those preferred, representing up to 75% of the tree species used (faria, 1983; Lacher *et al.*, 1984; Vilela; Del-Claro, 2011). *T. guianensis* belongs to the Anacardiaceae family and is evergreen, with characteristics of a pioneer or secondary tree that can eventually reach up to 25 m in height (Souza; Lorenzi, 2005). *T. guianensis* is common in the Cerrado domain, found in riverine forest areas and in urban forests (Souza; Lorenzi, 2005).

Because *T. guianensis* is one of the most often tree used to obtain exudate, it was hypothesized that the exudate of this species is rich in calcium and water, which would be attractive to marmosets. For this purpose, exudate samples from urban forest fragments in the Cerrado domain were collected and an analysis of the mineral composition and moisture of *T. guianensis* was carried out.

## 1.1 Materials And Methods

The study was conducted in urban forest fragments belonging to the Cerrado, in the municipality of Goiânia, Goiás, Brazil. The predominant climate in the region is tropical with a dry season, type Aw according to the Köppen classification, characterized by two very distinct seasons: a cold, dry winter and a hot, rainy summer (Climate-Data, 2021). The average annual precipitation is 1,520 mm, and the average annual temperature is 23.15 °C (Climate-Data, 2021).

The study was carried out at three urban forests located in the Taquaral Municipal Park (16°41'54.86"S, 49°20'46.80"W), the Madrid Gardens Residential Condominium (16°45'3.96"S, 49°20'43.82"W), and Memorial Museum of the Cerrado (16°44'15.23"S, 49°12'52.44"W). These forests are composed of native and exotic species, with a semi-seasonal riparian forest physiognomy, associated with streams and subject to temporary flooding during the rainy season.

In each of the three areas, eight *T. guianensis* trees showing signs of scarification were randomly sampled during the morning (7 h to 9 h). To perform the chemical analysis and determine the moisture content of *T. guianensis* exudate, samples were collected from plant secretions found in the holes scarified by marmosets within the previous 24 hours. Spatulas were used to collect the samples, which were then packaged in sterile flasks that were stored in a freezer (-20 °C) for later analysis in the laboratory.

The moisture content was determined from the gravimetric difference of the material after complete drying in an oven at 100°C, carried out until reaching a constant weight, and the ash content was determined by incineration in a muffle

furnace at 600°C. For the analysis of inorganic components, the mineral solution was obtained using the dry route mineralization method (Jones, 1981), which consists of dissolving the ash from the muffle furnace in 6 N hydrochloric acid. Using an atomic absorption spectrophotometer (Varian Spectra 220 FS, USA) the following mineral elements were quantified: calcium, magnesium, copper, manganese, iron, and zinc. The colorimetric method (Pulliainen, Wallin, 1996) was used to determine the amount of phosphorus. The exudate analyses were performed at the Laboratory of Biophysics, in the Department of General Biology at UFV (Brazil), and at the Laboratory of Atomic Spectrophotometry, in the Department of Soils at the Federal University of Viçosa, Brazil.

The data were analyzed using the Statistical Package for Social Science, Windows version (SPSS 13.0, USA). To characterize the physicochemical components of the exudate, the mean and standard deviation for each analyzed variable (moisture content, ash, and mineral elements) were determined.

## 2 RESULTS AND DISCUSSION

The chemical data for each sample are shown in Table 1. The mean moisture concentration was  $61.21 \pm 3.77$  %, and the mean amount of calcium was  $551.98 \pm 251.52$  mg. The Ca:P ratio was 67:1. Iron (Fe) was detected in only one sample. The concentrations of Mg, Cu, Mn, Zn, and P varied considerably from sample to sample.

In this study, the exudates consumed by marmosets are rich in water and calcium, with traces of other minerals, with the exception of iron, which was scarce. The richness of calcium in *T. guianensis* exudates is in line with the hypothesis of the study and supporting other studies on exudates consumed by marmosets (Power, 2010; Francisco *et al*, 2014; 2016).

Table 1 – Moisture, ash (dry material, DM), and mineral concentration of *Tapirira guianensis* exudates consumed by black-tufted marmosets (*Callithrix penicillata*) in three urban forests in the city of Goiânia, GO, Brazil

Sample	Moist (%)	Ashes % / L	Ca <sup>2+</sup> (mg/100g)	P- $\mu$ mol/L	Mg <sup>2+</sup> $\mu$ mol/L	Cu <sup>2+</sup> $\mu$ mol/L	Mn <sup>2+</sup> $\mu$ mol/L	Fe <sup>2+</sup> $\mu$ mol/L	Zn <sup>2+</sup> $\mu$ mol/L
1	65.40	5.46	400.40	6.55	82.40	0.88	2.80	0.00	0.00
2	59.20	8.14	906.04	8.69		2.48	2.84	78.93	4.30
3	60.10	5.63	440.10	3.83	78.10		2.14		2.22
4	64.50	4.78	614.47	3.99	22.90	2.72	1.63	0.00	11.68
5	67.40	9.13	124.23	9.95	16.51	2.85	3.06	0.00	4.17
6	57.80	7.27	664.80	13.99	43.10	3.41	1.59	0.00	4.65
7	60.10	5.41	890.35	8.74	36.17	3.93	2.46	0.00	4.71
8	55.80	2.56	375.47	10.09	60.10	6.82	2.66	0.00	6.02
Mean and standard deviation	61.29 ±3.77	6.05 ±1.94	551.98 ±251.52	8.23 ±3.16	48.46 ±23.96	3.29 ±1.68	2.40 ±0.52	11.27 ±27.62	4.72 ±3.14

Source: Empty cell is lost data

Tree exudate in general is composed mainly of water and complex polysaccharides, in addition to proteins and minerals (Power, 2010). The high percentage of water and calcium in exudate provide important items for the metabolism of *C. penicillata* marmosets that inhabit small urban fragments where there are limited water resources due to seasonal drought in the Cerrado domain (Faria, 1983). There is no description of the water intake of *C. penicillata* in the articles, which raises doubts about the sources of water for these animals in the Cerrado. In fact, during a four-year behavioral study of three groups carried out by the authors, black-tufted marmosets were not observed drinking water in the Brasilia Botanical Garden (-15.86° S, 47.82° W), an area embedded in the Cerrado (Silva, 2008). This tends to suggest that the high moisture content of the exudates can supply the water needs of marmosets during the dry season.

As has been reported in other studies (Power, 2010; Francisco *et al.*, 2014; 2016), calcium is essential for marmosets to counterbalance their consumption of arthropods,

which are rich in phosphorus, but poor in calcium. Furthermore, calcium is essential for pregnant and lactating females due to cost of reproduction (Sousa *et al.*, 2005) and a putative receptor-binding resistance to steroids such as vitamin D (cholecalciferol), which is a prohormone essential for calcium metabolism (Kraynak *et al.*, 2019).

Few studies have reported the levels of water and calcium in the exudate ingested by marmosets. Francisco and collaborators (2016) found that *A. peregrina* gum is  $41.0 \pm 2.52\%$  water, on average, with calcium concentrations ranging from 2.958 mg/100 g to 613.046 mg/100 g DM (dry matter), for fresh and dry gum, respectively. The current study found *T. guianensis* exudate to have a moisture level almost a third higher and a calcium concentration close to the concentration found in *A. peregrina* gum. These values are high compared to the exudate of some species of trees in the Anacardiaceae family, such as *Spondias mombin* (moisture, 9.9%; calcium, 358.1 mg/100 g DM), *S. purpurea* (moisture, 8.23 %; calcium, 359.1 mg/100 g DM) and *Anacardium occidentale* (moisture ranging from 7.9 to 11.1%; calcium, 405.3 mg/100 g DM) (Leon De Pinto *et al.*, 1995). Although only *A. occidentale* gum is consumed by some marmoset species (*C. penicillata* and *C. jacchus* (Faria, 1983; Castro; Araújo, 2007), this list of trees serves to compare the difference in water and calcium concentration between exudate of different tree species of the Anacardiaceae family.

Little is known about the metabolic role in marmosets of other minerals (Mg, Cu, Mn, and Zn) found in tree exudates. The role of these minerals in mammals is well known, as they participate in many biochemical reactions necessary for bone formation, energy metabolism, and immune defense (Smith; Akinbamijo, 2000; Smith *et al.*, 2018). Therefore, the presence of these other minerals cannot be neglected as a complementary benefit for the metabolism of marmosets.

### 3 CONCLUSION

*T. guianensis* exudate appears to be essential for the nutrition of marmosets found in these urban forest fragments. The high content of water and calcium present in the

exudate of *T. guianensis* suggests that this species is important because of the exudation caused by marmosets. Therefore, it is important that forest management plan to preserve *T. guianensis* trees where the presence of marmosets is detected. It remains to be seen in future studies if the exudate has a concentration of other nutrients such as proteins, sugars, and lipids.

## ACKNOWLEDGMENTS

We thank CNPq and Universidade Federal de Viçosa for the J. Lamoglia grant. We extend our thanks to the Postgraduate Program in Environmental Sciences and Technologies at the Federal University of Southern Bahia, which partially helped with the costs of translating the article.

## REFERENCES

- ABBOTT, D. H.; BARNETT, D. K.; COLMAN, R. J.; YAMAMOTO, M. E.; SCHULTZ-DARKEN, N. J. Aspects of common marmoset basic biology and life history important for biomedical research. **Comparative Medicine**, 53(4):339-350, 2003.
- BICCA-MARQUES, J. C.; JERUSALINSKY, L.; MITTERMEIER, R.A.; PEREIRA, D.; RUIZ-MIRANDA, C.; RÍMOLI, J.; VALENÇA MONTENEGRO, M.; DO VALLE, R.R. *Callithrix penicillata*. **The IUCN Red List of Threatened Species**, 2018, e.T41519A17935797.
- CASTRO, C. S. S.; ARAÚJO, A. Diet and feeding behavior of Marmoset *Callithrix jacchus*. **Brazilian Journal of Ecology**. 7 (10): 14-19, 2007.
- CLIMATE-DATA.ORG.2021. <https://en.climate-data.org/south-america/brazil/goias/goiania-2191>. Accessed in: October 12 2021.
- FARIA, D. S. Uso de árvores gomíferas do cerrado por *Callithrix jacchus penicillata*. In: **A Primatologia no Brasil**, Sociedade Brasileira de Primatologia, Brasília, p. 83-96. 1983.
- FRANCISCO, T. M.; COUTO, D. R.; ZANUNCIO, J. C.; SERRÃO, J. E.; SILVA, I. O.; BOERE, V. Vegetable exudates as food for *Callithrix* spp. (Callitrichidae): **Exploratory patterns**. *PLoS ONE*. 9(11): e112321, 2014.
- FRANCISCO T. M.; LOPES-MATTOS, K. L. B.; PICOLI, E. A. T.; COUTO, D. R.; OLIVEIRA, J. A.; ZANUNCIO, J. C.; SERRÃO, J. E.; SILVA, I. O.; BOERE, V. Feeding habits of marmosets: A case study of bark anatomy and chemical composition of *Anadenanthera peregrina* gum. **American Journal of Primatology**. 79 (3): 1–9, 2016.



HARRISON, M. L.; TARDIF, S. D. Social implications of gummivory in marmosets. **American Journal of Physical Anthropology**. 95(4): 399-408, 1994.

JONES JR., J. B. Analytical techniques for trace elements determinations in plant tissues. **Journal of Plant Nutrition**. 3: 77-92, 1981.

KRAYNAK, M.; LEVINE, J. E.; ABBOTT, D. H. Insights gained from marmoset endocrine research. **The Common Marmoset in Captivity and Biomedical Research**. Elsevier. P. 525-542. 2019.

LACHER, T. E.; FONSECA, G. A. B.; ALVES JR., C.; Magalhaes-Castro, B. Parasitism of trees by marmosets in a Central Brazilian Gallery Forest. **Biotropica**. 16 (3): 202-209, 1984.

LEÓN DE PINTO, G.; MARTÍNEZ, M.; MENDOZA, J.; OCANDO, E.; RIVAS, C. Comparison of three Anacardiaceae gum exudates. **Biochemical Systematic and Ecology**. 23: 151-156, 1995.

POWER, M. L. Nutritional and digestive challenges to being a gum-feeding primate. In, BURROWS, A. M.; NASH, L. T. (Ed.). **The evolution of exudativory in primates**. New York: Springer, p. 25-44, 2010.

PULLIAINEN, T. K.; WALLIN, H. C. Determination of total Phosphorus in foods by colorimetry: Summary of NMKL Collaborative Study, **Journal of AOAC International**. 79 (6): 1408-1410, 1996.

SCHRADIN, C.; ANZENBERGER, G. Costs of infant carrying in common marmosets, *Callithrix jacchus*: an experimental analysis. **Animal Behaviour**. 62: 289-295, 2001.

SILVA, I. O. Socialidade e acesso a recursos alimentares em fêmeas de saguis (*Callithrix penicillata*) em grupos em ambiente natural. **Thesis**, Pos graduate Program on Animal Biology, Universidade de Brasília, DF, Brazil. 138 p. 2008.

SMITH, A. C. Influences on gum feeding in primates. In: BURROWS, A.; NASH, L. (Ed.) **The evolution of exudativory in primates**. Springer, New York, p. 109-122. 2010.

SMITH, O. B.; AKINBAMIJO, O. O. Micronutrients and reproduction in farm animals. **Animal Reproduction Science**. 60-61: 549-560, 2000.

SMITH A. D.; PANICKAR K.S.; URBAN, JR. J. F.; DAWSON, H. D. Impact of micronutrients on the immune response of animals. **Annual Review of Animal Biosciences**. 6:227-254. 2018.

SOUSA, M. B. C.; ALBUQUERQUE, A. C. S. R.; ALBUQUERQUE, F. S.; ARAÚJO, A.; YAMAMOTO, M. E.; ARRUDA, M. F. Behavioral strategies and hormonal profile of dominant and subordinate common marmoset (*Callithrix jacchus*) females in wild monogamous groups. **American Journal of Primatology**, 67 (1): 37-50, 2005.

SOUZA, V. C.; LORENZI, H. **Botânica sistemática: guia ilustrado para identificação das famílias de Angiospermas da flora brasileira, baseado em APG II**. Nova Odessa: Instituto Plantarum, 640 p., 2005.

SOUZA-ALVES, J. P.; CHAGAS ALVES, R. R. D.; HILÁRIO, R. R.; BARNETT, A. B.; BEZERRA, B. M. Species-specific resource availability as potential correlates of foraging strategy in Atlantic Forest edge-living common marmosets. **Ethology Ecology & Evolution**. DOI: 10.1080/03949370.2021.1949751.

TARDIF S. D.; POWER, M.; OFTEDAL, O. T.; POWER, R. A.; LAYNE, D. G. Lactation, maternal behavior and infant growth in common marmoset monkeys (*Callithrix jacchus*): effects of maternal size and litter size. **Behavioural Ecology Sociobiology**. 51:17–25, 2001.

VILELA, A. A.; DEL CLARO, K. Feeding behavior of the black-tufted-ear marmoset (*Callithrix penicillata*) (Primates, Callitrichidae) in a Tropical Cerrado Savanna. **Sociobiology**. 58 (2): 309-314, 2011. Authorship contribution

## Authorship contribution

### 1 - Juliane Martins Lamoglia

MSc in Animal Biology from the Federal University of Viçosa

<http://lattes.cnpq.br/0568286389730427> • [juliane\\_lamoglia@hotmail.com](mailto:juliane_lamoglia@hotmail.com)

Contribution: Conceptualization; Formal Analysis; Investigation; Methodology; Visualization  
Writing - original draft; Writing - review & editing

### 2 - Vanner Boere

PhD in Neuroscience and Behavior from the University of São Paulo

<https://orcid.org/0000-0002-2239-5782> • [itabio@hotmail.com](mailto:itabio@hotmail.com)

Contribution: Conceptualization; Formal Analysis; Investigation; Methodology; Resources;  
Supervision; Validation; Visualization Writing - original draft | Writing - review & editing

### 3 -Edgard Augusto de Toledo Picoli

PhD in Genetics and Breeding from the Federal University of Viçosa

<https://orcid.org/0000-0002-6275-2684>• [epicoli@ufv.br](mailto:epicoli@ufv.br)

Contribution: Conceptualization; Formal Analysis; Investigation; Methodology; Visualization  
Writing - original draft | Writing - review & editing

### 4 - Juraci Alves Oliveira

PhD in Agricultural Sciences from the Federal University of Viçosa

<https://orcid.org/0000-0003-0150-2291>• [jalves@ufv.br](mailto:jalves@ufv.br)

Contribution: Conceptualization; Formal Analysis; Investigation; Methodology; Visualization  
Writing - original draft | Writing - review & editing

## 5 - Carlos de Melo e Silva Neto

PhD in Agronomy from the Federal University of Goiás

<https://orcid.org/0000-0001-8624-3836> • [carlos.neto@ifg.edu.br](mailto:carlos.neto@ifg.edu.br)

Contribution: Conceptualization; Formal Analysis; Investigation; Methodology; Visualization  
Writing - original draft | Writing - review & editing

## 6 - Ita de Oliveira e Silva

PhD in Animal Biology from the University of Brasília

<https://orcid.org/0000-0003-1052-5209> • [itabio@hotmail.com](mailto:itabio@hotmail.com)

Contribution: Conceptualization; Data curation; Formal Analysis; Funding acquisition;  
Investigation; Methodology; Project administration; Resources; Supervision; Validation;  
Visualization Writing - original draft | Writing - review & editing

## How to quote this article

LAMOGLIA, J. M.; BOERE, V.; PICOLI, E. A. de T.; OLIVEIRA, J. A. ; SILVA NETO, C. de M. e; SILVA, I. de O. e. Water and mineral composition of the exudate resulting from scarification of pau-pombo trees by black-tufted marmosets. **Ciência e Natura**, Santa Maria, v. 45, e24, 2023. DOI 10.5902/2179460X68493. available in <https://doi.org/10.5902/2179460X68493>