Short Note

Mariana Muñoz-Romo^{a,*} and Paolo Ramoni-Perazzi^b

Unraveling the leaf-dropping behavior behind bat folivory: do bats use biological control against roost parasites?

<https://doi.org/10.1515/mammalia-2019-0027>

Received March 14, 2019; accepted July 12, 2019; previously published online August 9, 2019

Keywords: behavior; biological control; folivory; leaves; parasites.

Abstract: Folivory in bats, the behavior of chewing bites of leaves to extract the liquid portion and discard the fiber as oral pellets, is seen as a strategy that might provide vitamins, micronutrients and proteins not always available in fruits, and even secondary metabolites (hormonal precursors) that stimulate/inhibit reproductive processes. While examining chewed leaves, we noticed an important amount of completely intact leaves below the roosts of *Artibeus amplus* and *Artibeus lituratus*, and decided to systematically quantify them during a year. We recovered 639 intact leaves from six plant species and found that both species are constantly feeding on leaves, but invariably leaving 26–78% of these intact, dropping them on the floor just below their roosting sites. These large proportions of dropped, intact leaves suggest a completely different, novel, non-nutritional use by bats. Several studies in birds have revealed that fresh leaves are effectively used in nests to control diverse organisms that include blood sucking ectoparasites, protozoans, fungus and bacteria. We report for the first time this biological control behavior performed by bats by selecting, bringing and dropping intact leaves below their roosting sites. The chemical properties of the leaves need to be investigated to reveal those active components against specific pathogens.

Folivory has been reported in eight species of phyllostomid bats from the genera *Artibeus* (Leach 1821), *Platyrrhinus* (Saussure 1860) and *Carollia* (Gray 1838) (Greenhall 1957, Van der Pijl 1957, Zortéa and Mendes 1993, Kunz and Ingalls 1994, Kunz and Díaz 1995, Zortéa 1996, Bernard 1997, Esberard et al. 1998, Aguiar 2005, Acosta and Aguanta 2006, Novaes and Nobre 2009, Bobrowiec and Cunha 2010, Ruiz-Ramoni et al. 2011, Cordero-Schmidt et al. 2016, da Rocha et al. 2016, Pereira et al. 2017). Most observations of leaf consumption document bats chewing small portions of the leaf, extracting the leaf liquids and discarding the remaining fibers (Kunz and Díaz 1995), with the exception of one case [*Carollia perspicillata* (Linnaeus 1758)] of young leaves which were consumed whole, presumably because they were less fibrous and more digestible (Pereira et al. 2017). Folivory is seen as a strategy that might provide vitamins and micronutrients not always available in fruits, and/or proteins that are particularly important during pregnancy and lactation but usually scarce in fruits. Moreover, secondary metabolites (hormonal precursors) that stimulate/inhibit reproductive processes could also be obtained from leaves (Kunz and Díaz 1995). Finally, folivory has been recently postulated as a phenomenon to obtain water in arid environments (Cordero-Schmidt et al. 2016).

During the examination of chewed leaves for folivory studies (Duque-Marquez 2011, Ruiz-Ramoni et al. 2011) in two Neotropical bats [*Artibeus amplus* (Handley 1987) and *Artibeus lituratus* (Olfers 1818)], we noticed that completely intact leaves were dropped below the roost sites of both species, living in different environments. To confirm it, we decided to systematically study this unexpected finding, and wondered how many intact leaves do bats regularly drop below their roosting sites, which plant species do bats bring, and ultimately, why? To answer these questions, we visited the cave of Parque Las Escaleras [08°00' N; 71°43' W; 1320 m above sea level (asl), Pregonero,

^aPresent address: Smithsonian Tropical Research Institute, Gamboa, Panama

^bPresent address: Laboratory of Ecology and Conservation of Mammals, Federal University of Lavras (UFLA), PO Box 3037, Lavras, Minas Gerais, 37200-000, Brazil

*Corresponding author: Mariana Muñoz-Romo, Laboratory of Applied Zoology, Department of Biology, Faculty of Sciences, University of the Andes (ULA), Merida 5101, Venezuela, e-mail: munozml@si.edu

Paolo Ramoni-Perazzi: Laboratory of Applied Zoology, Department of Biology, Faculty of Sciences, University of the Andes (ULA), Merida 5101, Venezuela

Venezuela] to collect leaves found below the roosting site of the colony of *A. amplus* (ca. 50 individuals) once a month from December 2008 to November 2009. One collection per month was sufficient, as the leaf remains were protected within the cave. The cave has only one small entrance and is therefore completely dark, and is not ventilated. Individuals of *A. amplus* clustered 20 m away from the entrance and 2 m above the ground. The colony of *A. lituratus* (ca. 14 individuals) was located in a residential area called “La Hacienda” [08°36' N, 71°11' W, 1400 m asl, Mérida, Venezuela], and leaves found below the roosting site were collected 4 times a month from November 2008 to October 2009. We collected leaves more frequently than for the previous species, because there was more human disturbance and potential leaf removal. Individuals of *A. lituratus* clustered beneath the palm leaf (Genus *Washingtonia* Wendland 1879) in a ventilated space (see Muñoz-Romo et al. 2008) and 4 to 8 m above the ground.

Our visits to the cave allowed us to recover samples of fresh (i.e. green) and old (i.e. brown) leaves that presumably corresponded to the accumulation for a month

(Figure 1A). We validated our leaf sampling at the cave by occasionally placing a 4×4 m black plastic sheet just below the roost, immediately after bat emergence, and recover the sample of leaves next morning at 7:00 h (Figure 1B). Intact leaves were invariably recovered during all sampling events (Figure 1C and D). We explored the potential relationship between frequencies of intact leaves and precipitation patterns to test whether bats dropped more leaves during the rainy season, using precipitation information provided by the Climate Hazards group Infra-red Precipitation with Stations (CHIRPS, <http://chg.geog.ucsb.edu/data/index.html>) V2.0.

A total of 517 intact leaves were recovered during a year below the roost of *Artibeus amplus*, whereas 122 were recovered below the roost of *Artibeus lituratus*. All recovered leaves were mature. *Aspidosperma cruentum* (Woodson 1935, Apocynaceae) and *Tapura amazonica* (Poepp. 1843, Dichapetalaceae) were the most common leaves recovered intact below the roost of *A. amplus*, followed by *Erythrina poeppigiana* [(Walpers) O.F. Cook 1901, Fabaceae; Table 1]. Most leaves of *Brosimum* sp. (Swartz

Figure 1: Sample of recovered leaves from a month (A) and a night (B). Note that intact leaves were common in both sampling events; largest leaves belong to *Aspidosperma cruentum* in both pictures. Intact fresh samples of *Tapura amazonica* (C) and *Ficus insipida* (D) brought by *Artibeus amplus* to the cave of Parque Las Escaleras, Pregonero, Tachira, Venezuela. Marker used as a size reference is 125 mm.

Table 1: Total number of consumed and intact leaves recovered in a year at both study sites and their relative importance (%).

	Leaves			
	Consumed	%	Intact	%
<i>Artibeus amplus</i>				
<i>Aspidosperma cruentum</i>	492	74	169	26
<i>Tapura amazonica</i>	225	60	147	40
<i>Erythrina poeppigiana</i>	172	61	111	39
<i>Brosimum</i> sp.	15	22	54	78
<i>Ficus insipida</i>	36	50	36	50
<i>Artibeus lituratus</i>				
<i>Erythrina poeppigiana</i>	169	59	119	41
<i>Solanum</i> sp.	130	98	3	2

1788, Moraceae; ca. 80%) were brought to the roost and dropped intact by bats, and just a few were observed partially consumed (Table 1). A half of the leaves of *Ficus insipida* (Willdenow 1806, Moraceae) were partially eaten, and the other half was kept intact by bats (Table 1). *Artibeus amplus* brought an average number of 14 intact leaves of *A. cruentum* and 12 of *T. amazonica* every month, whereas less than 10 intact leaves of *E. poeppigiana*, *Brosimum* sp.

and *F. insipida* (Figure 2). The fact that leaves of *Brosimum* sp. were more commonly recovered intact than consumed (Table 1) would support a stricter, non-nutritional use for this plant species used throughout the year (Figure 2). Leaves of *E. poeppigiana* were the most common and almost the only species recovered intact below the roost of *A. lituratus* (Table 1). Similar average numbers of intact leaves of *E. poeppigiana* were brought by both species of bats to their roosting sites (Figure 2), and the largest amount of leaves of *E. poeppigiana* was brought in October 2009 by both bat species. *Aspidosperma cruentum* (linear leaves), *T. amazonica* (elliptic leaves), *Ficus insipida* (elliptic leaves) and *Brosimum* sp. (obtus leaves) all have waxy surfaces, whereas *E. poeppigiana* (deltoid leaf-lets) and *Solanum* sp. (Linnaeus 1753) (obtus leaves) both have rough surfaces. None of them is sticky, has spines or is even pubescent. All of them have entire margins. We did not find clear relationships between the frequencies of intact leaves and precipitation patterns; thus leaves are used regardless of the season.

Roosting sites of other frugivorous and insectivorous bat species have been observed with intact leaves on the floor. For example, the only leaves of *Piper amalago*, found

Figure 2: Total number of intact leaves monthly recovered below the roost of *Artibeus lituratus* (A) and *Artibeus amplus* (B). The blue line represents precipitation data provided by the Climate Hazards group Infrared Precipitation with Stations (CHIRPS, <http://chg.geog.ucsb.edu/data/index.html>) V2.0.

below the roost of *Carollia perspicillata* in Laranjeiras (Brazil), were completely intact, and the authors suggested that these might have been carried to the cave accidentally by bats (Pereira et al. 2017). These authors also showed a picture of an intact composite leaf of *Senna georgica* (H.S. Irwin and Barneby) found below the roost site in the cave. Wilson (1971) also found unidentified leaves below the roosting site of the insectivorous bat, *Micronycteris hirsuta* (Peters 1869), and Ross (1967) frequently found leaves below the roosting site of the also insectivorous species, *Macrotus waterhousii* (Gray 1843). Both Ross (1967) and Wilson (1971) suggested that leaves are carried back accidentally along with the insects, but this has never been observed and confirmed. It is likely that other species of bats can display this behavior, but this has been unnoticed until now.

Why bats would bring intact leaves, investing energy in costly (Alexander 2002) round trips, and drop them on the floor, just below their roosting sites? The answer seems to clearly be related to the chemical properties of the leaves. There are numerous pharmacological properties of leaves, although the specific chemical profiles of each leaf species (i.e. plant) are not always available in the literature. Dropping leaves on nests has been postulated to contribute to drive away parasites and bacteria in many bird species (Collias and Collias 1984). Antimicrobial properties of leaves are common (Ovington 1956, Cowan 1999, Hussein and El-Ansary 2018), but the specific effect against microorganisms would need specific testing experiences. The nest-protection hypothesis (Clark 1991) suggests that some of the fresh plants brought to the nest contain secondary compounds that repel parasites or mask the chemical cues that parasites use to find the host. Berkunsky et al. (2017) observed green leaves inside the nests of the turquoise-fronted parrot (*Amazona aestiva* Linnaeus 1758), and indicated that secondary compounds present in green leaves could reduce the presence of ectoparasites (Bucher 1988, Aramburuú et al. 2002). Secondary compounds were presumably used by coatis in Panama to deter ectoparasites, as they were observed grooming *Trattinnickia aspera* (Standl.) Swart 1942 resin vigorously against the fur (Gompper and Hoylman 1993). Moreover, Lambrechts and Dos Santos (2000) hypothesized that even more effective would be using a mixture of plants (i.e. “potpourri effect”) that provides even more benefits than using a single plant species in the nest. Lafuma et al. (2001) performed experiments to test the potential repellent effect of aromatic plant species against the mosquito *Culex pipiens* (Linnaeus 1758), and found that the mixture of aromatic plants was the most efficient in repelling mosquitos, although some aromatic plants also had significant effects when used individually.

It remains to be tested whether leaves found here may have any effect against bacteria, fungi and/or specific life cycle stages of endo/ectoparasites. In a previous study, sampling of bacteria around the roosting site in the same cave (from Parque Las Escaleras) showed that all but one sample belonged to Proteobacteria (Mérida-León et al. 2016) and these have been reported to be potentially pathogenic to humans (Rizzatti et al. 2017) and, presumably, other living organisms. It remains to be determined whether a particular combination of leaves would be functionally important for bats, as mixing leaves might increase specific effects or become functionally effective (Lafuma et al. 2001). Diverse biological effects (e.g. controlling, repellent) against several organisms that include fungus, bacteria, protozoans, helminths, insects and/or mites have been reported for species of *Aspidosperma* Martius & Zuccarini (Aguiar et al. 2015, de Almeida et al. 2019), *Tapura* Aublet (Taljaard 2014), *Erythrina* Linnaeus (Sato et al. 2003, Kumari et al. 2017), *Brosimum* Swartz (Coqueiro et al. 2014, Borges et al. 2017) and *Ficus* Linnaeus (de Amorin et al. 1999, Romeh 2013, Wan et al. 2017). Plant volatiles from leaves are extremely common and very diverse (Pichersky et al. 2006, Courtois et al. 2009). Green leaf volatiles (GLVs), which are present in almost every green plant, consist of a family of C_6 compounds, including aldehydes, alcohols and esters, and their fragrance sometimes is easily perceived by humans (Scala et al. 2013). Some of these volatile compounds produced by leaves may act as defensive molecules against arthropods, affecting insect fecundity (Hildebrand et al. 1993). For example, volatile six-carbon compounds in plant tissues reduced tobacco aphid fecundity at certain concentrations when added to headspace vapor to which aphids were exposed (Hildebrand et al. 1993). Repelling organisms from the floor could increase pup survival by driving away potentially dangerous organisms that could negatively affect non-volant pups that could fall from roost sites to the cave floor where they can die unless retrieved by an adult (Bohn et al. 2009). For example, specific chemicals from leaves could increase the survival of fallen pups by keeping away spiders, well known as predator of bats (Nyffeler and Knörnschild 2013), by allowing time for mothers to come and grab them. Specific plant volatiles from leaves brought by bats need to be identified and their effects especially tested against diverse organisms.

Our observations provide strong evidence of a new behavior that requires further research and experiments to be fully understood. Reporting this behavior for the first time in bats reinforces the need for further detailed investigation: Does dropping leaves involve other bats species

regardless of their trophic preferences? Are coexisting bat species using the same available plants as biological controllers of pathogens? Are females and males equally dropping leaves?

Acknowledgments: For the valuable field and laboratory assistance, we thank D. Ruiz-Ramoni, A. Duque, G. Bianchi-Pérez and L.M. Otero. We are grateful to L.E. Gámez for his help in identifying some plant species, and Marcelo Passamani for his recommended reference. We are grateful to Associate Editor Stéphane Aulagnier and two anonymous reviewers for their valuable comments and recommendations to improve the revised version of this manuscript. MMR dedicates this work to Keanu Reeves. This research was supported by Consejo de Desarrollo Científico, Humanístico y Tecnológico (CDCHT, Universidad de Los Andes), project C-1649-09-01-B, and Laboratorio de Zoología Aplicada, Universidad de Los Andes.

References

- Acosta, L. and F. Aguanta. 2006. Un nuevo aporte en el conocimiento de la dieta de los murciélagos frugívoros *Artibeus lituratus* y *A. jamaicensis*. [New contribution on the diet of the frugivorous bats *Artibeus lituratus* and *A. jamaicensis*]. *Kempfiana* 2: 127–133.
- Aguiar, L.M. 2005. First record on the use of leaves of *Solanum lycocarpum* (Solanaceae) and fruits of *Emmotum nitens* (Icacinaeae) by *Platyrrhinus lineatus* (E. Geoffroy) (Chiroptera, Phyllostomidae) in the Brazilian Cerrado. *Rev. Bras. Zool.* 22: 509–510.
- Aguiar, A.C., A.C. Cunha, I.P. Ceravolo, R.A. Gonçalves, J.A. Oliveira and A.U. Krettl. 2015. *Aspidosperma* (Apocynaceae) plant cytotoxicity and activity towards malaria parasites. Part II: experimental studies with *Aspidosperma ramiflorum* in vivo and in vitro. *Mem. Inst. Oswaldo Cruz, Rio de Janeiro* 110: 906–913.
- Alexander, R.M. 2002. The merits and implications of travel by swimming, flight and running for animals of different sizes. *Integr. Comp. Biol.* 42: 1060–1064.
- Aramburú, R., A. Cicchino and E. Bucher. 2002. Material vegetal fresco en cámaras de cría de la Cotorra Argentina *Myiopsitta monachus* (Psittacidae). [Green plant material in breeding chambers of the monk parakeet *Myiopsitta monachus* (Psittacidae)]. *Ornitol. Neotrop.* 13: 433–436.
- Berkunsky, I., L.N. Segura, R.A. Ruggera, S.I.K. Faegre, C. Trofino-Falasco, F. López, M.A. Velasco, F.P. Kacolis, R.M. Aramburú and J.C. Rebores. 2017. Reproductive parameters of the turquoise-fronted parrot (*Amazona aestiva*) in the dry Chaco forest. *Avian Conserv. Ecol.* 12: 6.
- Bernard, E. 1997. Folivory in *Artibeus concolor* (Chiroptera: Phyllostomidae): a new evidence. *Chiropt. Neotrop.* 3: 77–79.
- Bobrowiec, P.E.D. and R.M. Cunha. 2010. Leaf-consuming behavior in the big fruit-eating bat, *Artibeus lituratus* (Olfers, 1818) (Chiroptera: Phyllostomidae), in an urban area of Southeastern Brazil. *Chiropt. Neotrop.* 16: 595–599.
- Bohn, K.M., C.F. Moss and G.S. Wilkinson. 2009. Pup guarding by greater spear-nosed bats. *Behav. Ecol. Sociobiol.* 63: 1693–1703.
- Borges, J.D.C., M.C. Perim, R.O. de Castro, T.A.S. Araújo, T.J.D.S. Peixoto Sobrinho, A.C.O. da Silva, S.M.B. Mariano, S.C. Carreiro and M.C.D.S. Pranchevicius. 2017. Evaluation of antibacterial activity of the bark and leaf extracts of *Brosimum gaudichaudii* Trécul against multidrug resistant strains. *Nat. Product Res.* 31: 2931–2935.
- Bucher, E.H. 1988. Do birds use biological control against nest parasites? *Parasitol. Today* 4: 1–3.
- Clark, L. 1991. The nest protection hypothesis: the adaptive use of plant secondary compounds by European starlings. In: (J.E. Loye and M. Zuk, eds.) *Bird – parasite interaction, ecology, evolution and behaviour*. Oxford University Press, Oxford. pp. 204–221.
- Collias, N. and E. Collias. 1984. *Nest building behavior in birds*. Princeton University Press, New Jersey. pp. 358.
- Coqueiro, A., L.O. Regasini, G.M. Leme, L. Polese, C.T. Nogueira, M.L. Del Cistia, M.A.S. Graminha and V da S. Bolzani. 2014. Leishmanicidal activity of *Brosimum glaziovii* (Moraceae) and chemical composition of the bioactive fractions by using high-resolution gas chromatography and GC-MS. *J. Braz. Chem. Soc.* 25: 1839–1847.
- Cordero-Schmidt, E., M. Medeiros-Guimarães, J.C. Vargas-Mena, B. Carvalho, R. Lopes Ferreira, B. Rodriguez-Herrera and E.M. Venticinque. 2016. Are leaves a good option in Caatinga's menu? First record of folivory in *Artibeus planirostris* (Phyllostomidae) in the semiarid forest, Brazil. *Acta Chiropterol.* 18: 489–497.
- Courtois, E.A., C.E.T. Paine, P.A. Blandinières, D. Stien, J.M. Bessière, E. Houel, C. Baraloto and J. Chave. 2009. Diversity of the volatile organic compounds emitted by 55 species of tropical trees: a survey in French Guiana. *J. Chem. Ecol.* 35: 1349–1362.
- Cowan, M.M. 1999. Plant products as antimicrobial agents. *Clin. Microb. Rev.* 12: 564–582.
- da Rocha, P.A., A.S. Pereira, S.M. Silvestre, J.P. Santana, R. Beltão-Mendes, M. Zortéa and S.F. Ferrari. 2016. Consumption of leaves by *Platyrrhinus lineatus* (Chiroptera, Stenodermatinae): are these bats primarily frugivorous or broadly phytophagous? *Zoology* 121: 44–48.
- de Almeida, V.L., C.G. Silva, A.F. Silva, P.R.V. Campana, K. Foubert, J.C.D. Lopes and L. Pieters. 2019. *Aspidosperma* species: a review of their chemistry and biological activities. *J. Ethnopharmacol.* 1: 125–140.
- de Amorin, A., H.R. Borba, J.P. Carauta, D. Lopes and M.A. Kaplan. 1999. Anthelmintic activity of the latex of *Ficus* species. *J. Ethnopharmacol.* 64: 255–258.
- Duque-Márquez, A. 2011. Estudio comparativo de la folivoría en los murciélagos *Artibeus lituratus* y *A. amplus* (Chiroptera: Phyllostomidae) y análisis químico de la hoja más consumida Trabajo de Licenciatura en Biología, Universidad de Los Andes, Mérida, Venezuela. [Comparative study of folivory in the bats *Artibeus lituratus* and *A. amplus* (Chiroptera: Phyllostomidae) and chemical analysis of the most consumed leaf. Licentiate Thesis, University of The Andes, Merida, Venezuela].
- Esberard, C.E.L., A.S. Chagas, E.M. Luz, R.A. Carneiro, L.F.S. Martins and A.L. Peracchi. 1998. Aspectos da biologia de *Artibeus fimbriatus* Gray, 1838, no Estado do Rio de Janeiro, Brasil (Chiroptera, Phyllostomidae). [Biological aspects of *Artibeus fimbriatus*

- Gray, 1838, in the state of Rio de Janeiro, Brazil (Chiroptera, Phyllostomidae)]. *Bol. Soc. Biol. Concepción* 69: 109–114.
- Gompper, M.E. and A.M. Hoylman. 1993. Grooming with *Trattinnickia* resin: possible pharmaceutical plant use by coatis in Panama. *J. Trop. Ecol.* 9: 533–540.
- Greenhall, A.M. 1957. Food preference of Trinidad fruit bats. *J. Mammal.* 38: 409–410.
- Hildebrand, D.F., G.C. Brown, D.M. Jackson and T.R. Hamilton-Kemp. 1993. Effects of some leaf-emitted volatile compounds on aphid population increase. *J. Chem. Ecol.* 19: 1875–1887.
- Hussein, R.A. and A.A. El-Anssary. 2018. Plants secondary metabolites: the key drivers of the pharmacological actions of medicinal plants. In: (P.F. Builders, ed.) *Herbal medicine*. IntechOpen, London. pp. 11–30.
- Kumari, P., S.K. Singh and C. Kumari. 2017. Phytochemical screening and antibacterial activity of *Erythrina variegata* L. (leaf extract). *Int. J. Curr. Microbiol. App. Sci.* 6: 2500–2505.
- Kunz, T.H. and K.A. Ingalls. 1994. Folivory in bats: an adaptation derived from frugivory. *Funct. Ecol.* 8: 665–668.
- Kunz, T.H. and C.A. Díaz. 1995. Folivory in fruit-eating bats, with new evidence from *Artibeus jamaicensis* (Chiroptera: Phyllostomidae). *Biotropica* 27: 106–120.
- Lafuma, L., M.M. Lambrechts and M. Raymond. 2001. Aromatic plants in bird nests as a protection against blood-sucking flying insects? *Behav. Proc.* 56: 113–120.
- Lambrechts, M.M. and A. Dos Santos. 2000. Aromatic herbs in Corsican blue tit nests: the 'Potpourri' hypothesis. *Acta Oecol.* 21: 175–178.
- Mérida-León, M., G. Fermin, P. Ramoni-Perazzi and M. Muñoz-Romo. 2016. Culturable γ and β proteobacteria sampled at the bat species-rich cave 'Las Escaleras' (Táchira, Venezuela): evidence of potential human impact. *J. Cave Karst Stud.* 78: 174–182.
- Muñoz-Romo, M., E.A. Herrera and T.H. Kunz. 2008. Roosting behavior and group stability of the big fruit-eating bat *Artibeus lituratus* (Chiroptera: Phyllostomidae). *Mammal. Biol.* 73: 214–221.
- Novaes, R.L.M. and C.C. Nobre. 2009. Dieta de *Artibeus lituratus* (Olfers, 1818) em área urbana na cidade do Rio de Janeiro: frugivoria e novo registro de folivoria. [Diet of *Artibeus lituratus* (Olfers, 1818) in urban areas in the city of Rio de Janeiro: frugivory and a new report of folivory]. *Chirop. Neotrop.* 15: 487–493.
- Nyffeler, M. and M. Knörnschild. 2013. Bat predation by spiders. *PLoS One* 8: e58120.
- Ovington, J.D. 1956. The composition of tree leaves. *Forestry: Int. J. For. Res.* 29: 22–28.
- Pereira, A.S., P.A. da Rocha, J.P. Santana, R. Beltrão, J. Ruiz-Esparza and S.F. Ferrari. 2017. Consumption of leaves by *Carollia perspicillata* (Chiroptera, Phyllostomidae): a new dimension of the species' feeding ecology. *Mammalia* 82: 1–5.
- Pichersky, E., J.P. Noel and N. Dudareva. 2006. Biosynthesis of plant volatiles: nature's diversity and ingenuity. *Science* 311: 808–811.
- Rizzatti, G., L.R. Lopetuso, G. Gibiino, C. Binda and A. Gasbarrini. 2017. Proteobacteria: a common factor in human diseases. *Biomed. Res. Int.* 2017: 1–7.
- Romeh, A.A. 2013. Phytochemicals from *Ficus sycomorus* L. leaves act as insecticides and acaricides. *Afr. J. Agri. Res.* 8: 3571–3579.
- Ross, A. 1967. Ecological aspects of the food habits of insectivorous bats. *Proc. West. Found. Vert. Zool.* 1: 205–264.
- Ruiz-Ramoni, D., M. Muñoz-Romo, P. Ramoni-Perazzi, Y. Aranguren and G. Fermin. 2011. Folivory in the giant fruit-eating bat *Artibeus amplus* (Phyllostomidae): a non-seasonal phenomenon. *Acta Chiropterol.* 13: 195–199.
- Sato, M., H. Tanaka, R. Yamaguchi, T. Oh-Uchi and H. Etoh. 2003. *Erythrina poeppigiana*-derived phytochemical exhibiting antimicrobial activity against *Candida albicans* and methicillin-resistant *Staphylococcus aureus*. *Lett. Appl. Microbiol.* 37: 81–85.
- Scala, A., S. Allmann, R. Mirabella, M.A. Haring and R.C. Schuurink. 2013. Green leaf volatiles: a plant's multifunctional weapon against herbivores and pathogens. *Int. J. Mol. Sci.* 14: 17781–17811.
- Taljaard, M. 2014. Isolation and identification of the toxic compounds of *Tapura fischeri*. Master Thesis, University of Pretoria.
- Van der Pijl, L. 1957. The dispersal of plants by bats (Chiropterochory). *Acta Bot. Neerland.* 6: 291–315.
- Wan, C., C. Chen, M. Li, Y. Yang, M. Chen and J. Chen. 2017. Chemical constituents and antifungal activity of *Ficus hirta* Vahl. fruits. *Plants (Basel)* 6: 44.
- Wilson, D.E. 1971. Food habits of *Micronycteris hirsuta*. *Mammalia* 35: 107–110.
- Zortéa, M. 1996. Folivory in *Platyrrhinus (Vampyrops) lineatus*. *Bat Res. News* 34: 59–60.
- Zortéa, M. and S.L. Mendes. 1993. Folivory in the big fruit-eating bat, *Artibeus lituratus* (Chiroptera: Phyllostomidae) in eastern Brazil. *J. Trop. Ecol.* 9: 117–120.