

ANTIMICROBIAL RESPONSE AND BACTERIAL OCCURRENCE IN THE ORAL CAVITY OF SNAKES IN ZOOS IN SANTA CATARINA, BRAZIL

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ABSTRACT

Wild animals are exposed to numerous infectious and parasitic agents. The oral cavity microbiota of snakes can be a concerning source of infection, especially in animals under human care, such as those in zoos. The majority of diagnosed bacteria are associated with opportunistic profiles. The oral microbiota of snakes is diverse, with variations influenced by the species of the animal, environmental conditions, health status, diet, feeding type, and feeding time. Thirty-one samples of oral cavity secretions were collected from non-venomous snake species and one venomous snake for bacterial identification. The animals were sampled regardless of age, sex, or oral cavity lesions, from two zoos located in the state of Santa Catarina, Brazil. The samples were collected between September and October 2019. The isolated bacteria included *Escherichia coli*, *Klebsiella oxytoca*, *Klebsiella ozaenae*, *Pseudomonas aeruginosa*, *Proteus mirabilis*, *Acinetobacter baumannii*, *Burkholderia cepacia*, *Chromobacterium violaceum*, *Enterobacter aerogenes*, *Flavobacterium odoratum*, *Staphylococcus aureus*, and *Staphylococcus epidermidis*, with *Pseudomonas aeruginosa* being the most common among the 31 analyzed snakes. The majority of antibiotics tested in the antibiogram showed good response against the bacterial isolates. *P. aeruginosa*, the most frequent bacteria, showed resistance to cefazolin and polymyxin in the sensitivity test. The study was important for assessing the sanitary situation regarding the bacterial microbiota of the oral cavity in snakes kept in the two zoos in Santa Catarina state. Routine monitoring of stressful situations that can affect these animals is necessary to prevent secondary infections involving other microorganisms and to preserve the snakes' lives.

Keywords: Snakes; Bacterial microbiota; Oral cavity; Zoo.

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INTRODUCTION

Reptiles comprise a highly diverse group of animals. Currently, 744 species are known in Brazil: 36 turtles, six alligators, 248 lizards, 68 amphisbaenians, and 386 snakes (PAZINATO et al., 2013). Snakes have a wide geographic distribution, and the most relevant families for human health in Brazil are: Boidae (parrot snake, anaconda, boa constrictor, salamanta), Dipsadidae (false coral snakes, muçuranas, water snakes, green snakes), Colubridae (vine snake, caninana, and exotic snakes - *milk*snakes and *corn*snakes), Viperidae (rattlesnakes and lancehead vipers), Elapidae (coral snakes), and Pitonidae (pythons), which are exotic in Brazil (CUBAS; SILVA; CATÃO-DIAS, 2014).

Although the breeding of snakes in enclosed environments is under the care of trained professionals with knowledge of handling, accidents can still occur. The term "ophidism" is used to describe snake aggression towards humans or animals through biting, represented by the families Colubridae, Elapidae, and Viperidae (LEMA, 2002). The World Health Organization (WHO) has included ophidism in the list of neglected tropical diseases. In 2019, it is estimated that globally there were 2.7 million cases of snakebite envenomation annually, resulting in 81,000 to 138,000 deaths (FEITOSA; MISE; MOTA, 2020).

In addition to accidents caused by wild snakes, it is important to highlight the number of zoos that allow observation and interaction with wildlife, along with their handling teams (JHO et al., 2011).

The organs of the gastrointestinal tract in vertebrates, such as mouth, stomach, colon, cloaca, among others, harbor a microbiome that plays important roles for the hosts, including digestion, nutrient acquisition, and immunity (KRISHNANKUTTY et al., 2018; SMITH; COLSTON; SILER, 2021).

The oral microbiota of snakes encompasses a wide variety of aerobic and anaerobic microorganisms, especially Gram-negative bacteria. The presence of these bacteria is associated with feeding habits, where the prey is consumed, and fecal material containing gastrointestinal bacteria ends up colonizing the oral cavity of snakes. Microbiological culture from prey and venom of various snakes has shown correlations primarily with enterobacteria such as *Morganella* spp., *Escherichia coli*, *Streptococcus* Group D, *Aeromonas* spp., and with anaerobic microorganisms such as *Clostridium* spp. (GARG et al., 2009; RÉSIÈRE et al., 2018).

According to Malik et al. (2018), any stressful situation depresses the immune system of snakes and makes them more susceptible to infections. Different microorganisms can cause infectious stomatitis in these animals, including viruses, bacteria, and fungi. Among the most common bacteria are primarily the genus *Aeromonas* spp., as well as other Gram-negative bacteria such as *Pseudomonas* spp., *Salmonella* spp., *Klebsiella* spp., and *Mycobacterium* spp. (MALLIK et al., 2018).

Snakebite accidents can lead to infections due to the presence of pathogens from the skin and mucous membranes of the oral cavity, which in turn can result in wounds with bacterial colonization, thereby worsening the clinical condition. Regarding animals, knowing the bacteria present is important to understand the causes of secondary infections and assist in the selection of effective antibiotics for the treatment of stomatitis and care of captive snakes (PANDA; PADHI; SAHOO, 2019; PEREIRA et al., 2017).

The aim of the study was to investigate the bacterial microbiota of snakes kept in confinement in zoos in order to determine the most prevalent microorganisms and identify the most effective antimicrobial agents for the bacterial isolates.

1 MATERIAL AND METHODS

A total of 31 samples of oral cavity secretions from non-venomous snakes and one from a venomous snake were collected for bacterial identification (Table 1). The animals were sampled regardless of age, sex, and presence of lesions, and they originated from two zoos in the state of Santa Catarina, Brazil. The samples were collected between September and October 2019.

Table 1. "List of species and common names of the snakes sampled in the research.

Snake species	Common name	Number of samples
<i>Epicrates cenchia</i>	Rainbow boa constrictor	10
<i>Pantherophis guttatus</i>	Corn snake	07
<i>Boa constrictor</i>	Boa constrictor	06
<i>Python regis</i>	Ball python	03
<i>Boa constrictor amarali</i>	Amaral's boa constrictor	01

Continuação da tabela

<i>Bothrops jararaca</i>	Jararaca	01
<i>Corallus hortulanus</i>	Amazon tree boa	01
<i>Morelia spilota</i>	Carpet python	01
<i>Spilotes pullatus</i>	Caninana	01
Total		31

The methodology used for sample collection followed the guidelines outlined by Passos (2009), taking into consideration the anatomical and behavioral characteristics of the species involved in the study. To minimize stress on the snakes, handling of the animals was carried out in collaboration with specialized professionals experienced in handling and routine procedures, adhering to international biosafety and animal welfare standards.

Initially, the animals were identified, and information regarding their dietary habits (last food offering to the animals) was obtained. The collection was performed using a sterile alginate cotton swab, obtaining samples of the oral cavity secretions of each snake, as depicted in figure 1.



Figure 1 - Sampling of the oral cavity was performed using a sterile swab in *Boa constrictor amarali*.

The swabs containing the secretions were placed in Stuart transport medium (Laborclin®) and then sent to the Microbiology Laboratory of the University of Planalto Catarinense (UNIPLAC) in the city of Lages, Santa Catarina. The swabs were removed from the Stuart medium and inoculated into *Brain Heart Infusion* (BHI) enrichment broth (Kasvi®) and incubated in a bacteriological incubator at 37°C for 24 hours.

For bacterial isolation, a portion of the enrichment broth was inoculated onto solid culture media using a platinum loop by the streak plate technique. One plate contained blood agar, while another plate contained MacConkey agar (Kasvi®). The inoculated plates were also incubated in a bacteriological incubator at 37°C for 24 hours.

From the growth of colonies on the culture media, Gram staining was performed to identify the morphological and staining characteristics of the bacteria. For presumptive differentiation of Gram-positive bacteria, catalase tests and Mannitol agar medium (Kasvi®) were used to identify *Staphylococcus aureus*.

The colonies grown on MacConkey agar were identified using commercial kits for fermentative enterobacteria, including TSI (*Triple Sugar Iron Agar*), MIO (Motility Indole Ornithine), LIA (*Lysine Iron Agar*), Citrate (Simmons Citrate Agar), and Urea (Urea Agar Base). These tests aimed to perform biochemical screening of colonies that grew on the selective medium for Gram-negative bacteria belonging to the Enterobacteriaceae family.

For bacterial isolates that showed a negative lactose test on MacConkey agar, the oxidase test was used, allowing the identification of non-fermenting Gram-negative microorganisms. The non-fermenting Gram-negative bacilli were then subjected to the Bactray 3® identification system, which consists of CET (Cetrimide), ACE (Acetamide), MAL (Malonate), CIT (Citrate), MLT (Maltose), ESC (Esculin), CTL (Arginine Control), ARG (Arginine), URE (Urea), and IND (Indole).

After identifying all the isolated bacterial microorganisms, the most frequent and clinically significant ones were selected and inoculated onto Müller-Hinton agar plates (Kasvi®) for antimicrobial susceptibility testing using the disc diffusion method, following standardized procedures with antimicrobial agent discs provided by the National Health Surveillance Agency (ANVISA).

In relation to the artificial environment in the two zoos for snake maintenance, a semi-extensive system is provided, with mechanisms of environmental enrichment including the use of rocks, sand, available water, and vegetation. Each enclosure may contain one to two animals of the same species (Figure 2).



Figure 2. Enclosure of the animals in the breeding system at the Santa Catarina Zoo, Brazil.

Regarding the food source provided to the animals, they are fed rodents that are bred in on-site vivariums and maintained under zoosanitary conditions. The prey is offered to the snakes according to their species and size. In the study, it was found that the snakes had been fed fifteen days prior to the study being conducted.

The research obtained approval from the System for Authorization and Information on Biodiversity (Sistema de Autorização e Informação em Biodiversidade - SISBIO) under the number 70711.

2 RESULTS AND DISCUSSION

Out of the total of 31 swab samples containing oral cavity secretions, 83,87% (26/31) showed bacterial growth. Gram-negative and Gram-positive bacteria were isolated in 70,96% (22/31) and 16,12% (5/31) of the samples, respectively.

In relation to bacterial isolates by snake species, *P. aeruginosa* was the most frequent among different snakes, followed by other Gram-positive and Gram-negative bacteria, as shown in Table 2.

Table 2. Bacteria present in the oral cavity of snakes in the two zoos in the state of Santa Catarina, Brazil.

SPECIES OF ISOLATED MICROORGANISMS	%
<i>Pseudomonas aeruginosa</i>	16,12
<i>Enterobacter aerogenes</i>	12,90
<i>Staphylococcus aureus</i>	12,90
<i>Chromobacterium violaceum</i>	9,67
<i>Escherichia coli</i>	9,67
<i>Acinetobacter baumannii</i>	6,45
<i>Klebsiella ozaenae</i>	6,45
<i>Burkholderia cepacia</i>	3,22
<i>Flavobacterium odoratum</i>	3,22
<i>Klebsiella oxytoca</i>	3,22
<i>Proteus mirabilis</i>	3,22
<i>Staphylococcus epidermidis</i>	3,22

Based on the findings, it can be understood that snakes are exposed to numerous infectious agents, and the isolated microorganisms in this study highlight the fact that the oral cavity of snakes can be a source of infection, especially when it comes to animals under human care, as is the case in zoos. There is a predominance of bacteria with opportunistic profiles. According to Long et al. (2022), 75% of snake diseases are caused by bacterial infections, and many of these pathogens are opportunistic and not derived from the intestinal flora.

In the study, Gram-negative bacteria were found to be the most prevalent in the oral cavity of snakes. These findings are consistent with the results reported by Chuang et al. (2022) regarding the oral cavity microbiota of venomous snakes in Taiwan. Like other vertebrates, the oral cavity of snakes is a suitable site for bacterial growth, and certain species are part of the normal microbiota. Studies on the bacterial flora of snakes have used microbiological cultures as the most common method, resulting in the identification of different species in various snake species. These differences may arise due to the animal species, environmental conditions, health status, diet, and time since ingestion (SHEK et al., 2009).

The predominance of bacteria from the Enterobacteriaceae family in snake

isolates is mentioned in several other studies conducted on both wild snakes and those kept in captive environments. These findings were also reported in the study by Pereira et al. (2017). According to Cubas, Silva, and Catão-Diaz (2006), Gram-negative bacteria are important causes of diseases in snakes and can act as secondary agents for viral or parasitic infections, as they are opportunistic and can serve as an entry point for other microorganisms.

Fonseca et al. (2009) conducted a study on the oral cavity microbiota of ten snake species within the families Elapidae, Colubridae, Boidae, and Viperidae. The most prevalent bacteria found were *Actinomyces* spp., *Bulkholderia* spp., *Moraxella* spp., *Proteus* spp., *Sarcina* spp., *Bacillus subtilis*, *Staphylococcus aureus*, coagulase-negative *Staphylococcus*, and *Yersinia enterocolitica*.

In a study conducted by Dehghani et al. (2016) in Iran, the most prevalent bacterial isolates among venomous and non-venomous snakes were coagulase-negative *Staphylococcus*, *Escherichia coli*, and, to a lesser extent, *P. aeruginosa*. This differs from the present study, where *P. aeruginosa* was the most commonly isolated bacterial microorganism in the oral cavity of snakes. The presence of this microorganism was also found to be more prevalent in the study by Krishnankutty et al. (2018) in venomous and non-venomous free-living snakes in India. According to the authors, the presence of this bacterium highlights its opportunistic nature, particularly concerning its importance for humans.

In Table 3, the bacterial isolates are represented in relation to the snake species.

Table 3. Association between snake species and the species of microorganisms found.

Snake species	Bacterial isolates
<i>Epicrates cenchia</i>	<i>Pseudomonas aeruginosa</i> <i>Klebsiella ozaenae</i> <i>Klebsiella oxytoca</i> <i>Chromobacterium violaceum</i> <i>Staphylococcus aureus</i>
<i>Pantherophis guttatus</i>	<i>Escherichia coli</i> <i>Proteus mirabilis</i> <i>Acinetobacter baumannii</i> <i>Staphylococcus aureus</i> <i>Chromobacterium violaceum</i>
<i>Boa constrictor</i>	<i>Staphylococcus epidermidis</i> <i>Escherichia coli</i> <i>Pseudomonas aeruginosa</i> <i>Enterobacter aerogenes</i> <i>Acinetobacter baumannii</i>

Continuação da tabela

<i>Python regius</i>	<i>Escherichia coli</i> <i>Enterobacter aerogenes</i>
<i>Spilotes pullatus</i>	<i>Burkholderia cepacia</i>
<i>Morelia spilota</i>	<i>Staphylococcus aureus</i>
<i>Corallus hortulanus</i>	<i>Enterobacter aerogenes</i>
<i>Boa constrictor amarali</i>	<i>Flavobacterium odoratum</i> <i>Staphylococcus aureus</i>

The species *Epicrates cenchria*, *Pantherophis guttatus*, and *Boa constrictor* exhibited the highest diversity among the bacterial isolates. Meanwhile, Résière et al. (2018) mentioned *Morganella morganii*, *Klebsiella pneumoniae*, *Bacillus* spp., and *Enterococcus* spp. as the most prevalent bacteria in *Bothrops lanceolatus*, based on a study conducted in Martinique.

No bacterial growth was observed in the sample of oral cavity secretion from the species *Bothrops jararaca*. Regarding the microbiota of healthy *Bothrops jararaca*, Bastos et al. (2008) and Pereira et al. (2017) found bacteria from the Enterobacteriaceae family, with *Salmonella* spp., *E. coli*, and *Citrobacter* spp. being the most prevalent. In the present study, no microorganisms were isolated from the oral cavity of this snake species, which could be attributed to the aggressive nature of the animal, requiring greater caution during handling and impeding proper sample collection.

According to Santos and Galli (2017), 90% of snake pathologies are related to incorrect handling, highlighting the importance of obtaining the necessary information and knowledge among those involved in the management of these animals in order to provide a healthy life for them.

In the study, no oral cavity lesions compatible with stomatitis were identified. This may be due to the absence of *Aeromonas* spp., which is often reported in studies as a cause of stomatitis (MALIK et al., 2018).

According to Hardt et al. (2017), the occurrence of stomatitis, a common pathology in snakes and lizards in confined environments, is primarily attributed to *Salmonella* spp. The lesions are a result of these animals having a distinct microbiota in the oral cavity, particularly an imbalance between the presence of Gram-positive and Gram-negative bacteria. The presence of Gram-positive bacteria plays an important role as a protective barrier by occupying cell receptors and secreting substances that inhibit the growth of enterobacteria, thus regulating the bacterial microbiota.

For the antibiogram, the most prevalent bacteria and those of greater importance to humans were selected. The antibiotics used for the antibiogram testing against Gram-negative bacteria were: Azithromycin (AZI), Cefotaxime (CTX), Ofloxacin (OFX), Amikacin (AMI), Ticarcillin with Clavulanic Acid (TAC), Amoxicillin with Clavulanic Acid (AMC), Ampicillin and Sulbactam (APS), Cefazolin (CFZ), Polymyxin (POL), and Sulfadiazine with Trimethoprim (STZ). For the antibiogram against Gram-positive bacteria, the antibiotics used were: Ofloxacin, Polymyxin (POL), Vancomycin (VAN), Ampicillin and Sulbactam (APS), and Sulfadiazine with Trimethoprim (STZ). The cutoff points were based on the diameters of inhibition zones, indicating antibacterial activity (Table 4).

Table 4. "Antibiogram results regarding the bacterial isolates from the oral cavity of snakes from two zoos in the state of Santa Catarina, Brazil.

	AZI	AMI	APS	AMC	CFZ	SZT	POL	CTX	OFX	TAC	VAN
<i>Escherichia coli</i>	S	I	S	S	R	S	R	S	S	S	-
<i>Klebsiella</i> spp.	S	S	R	S	R	R	R	S	S	S	-
<i>Acinetobacter</i> spp.	S	S	S	R	R	S	S	R	S	S	-
<i>Enterobacter</i> spp.	S	S	S	S	R	S	R	S	S	S	-
<i>Flavobacterium</i> spp.	S	S	R	S	R	S	R	R	S	S	-
<i>Chromobacterium</i> spp.	S	S	S	S	R	S	R	R	S	S	-
<i>Pseudomonas</i> spp.	S	S	S	S	R	S	R	S	S	S	-
<i>Burkholderia</i> spp.	S	S	S	S	R	S	R	S	S	S	-
<i>Staphylococcus</i> spp.	-	-	S	-	-	S	R	-	S	-	S

S= SENSITIVE; R= RESISTANT; I= INTERMEDIATE

Antimicrobial susceptibility testing allows for the evaluation of the most effective drugs for successful treatment in cases of snakebite accidents, while also preventing potential mechanisms of bacterial resistance. It helps determine the appropriate antimicrobial therapy for infectious processes in snakes. Regarding the potential use of antibiotic therapy, the majority of antibiotics tested in the antibiogram showed a good response against the bacterial isolates. This result is significant as it allows for the utilization of treatment with different spectrums in cases of snake pathologies or accidents involving snakes from closed environments.

In the previously mentioned study with *Bothrops lanceolatus*, 66.7% of the bacterial isolates were resistant to amoxicillin with clavulanic acid, but they were

sensitive to third-generation cephalosporins such as cefotaxime and ceftazidime (RÉSIÈRE et al., 2018).

P. aeruginosa isolated from a *Boa constrictor amarali* rescued by the environmental police in Uberlândia (MG) and referred to the Hospital of the Federal University of Uberlândia with a case of stomatitis, showed susceptibility to the antibiotics amikacin, gentamicin, and polymyxin B, as well as resistance to cephalixin, ceftiofur, chloramphenicol, and enrofloxacin (MARTINS et al., 2021). For some of these mentioned antibiotics, the *P. aeruginosa* isolates showed similar results to our study.

In confined or domesticated environments, the development of infections is facilitated by the compromised immune system due to frequent exposure to new pathogens in a hostile environment, as well as the continuous stress of handling (SCHUMACHER, 2006). Stress is one of the most important factors in reptiles, leading to a decrease in the inflammatory response and interfering with antibody production, thus contributing to pathological conditions (GIRÃO; SOARES; QUEIROZ, 2018).

The breeding system of snakes in enclosures with good sanitary and management conditions can provide the animals with a safe environment, allowing them to exhibit behaviors more similar to their life in their natural habitat. This can reduce stress and minimize the effect of opportunistic bacteria, as found in this study.

CONCLUSION

The study was important to assess the sanitary situation regarding the bacterial microbiota of the oral cavity of snakes raised in two zoos in the state of Santa Catarina, as it was the first study conducted in the state on this topic. The diagnosis, mainly of *P. aeruginosa*, an opportunistic bacterium already recorded in various studies, demonstrates the need for routine monitoring of stressful situations that may affect these animals, in order to prevent secondary infections involving other microorganisms and thereby compromise the snakes' lives. Knowledge of the bacteria present in snakes serves to alert veterinarians, biologists, or individuals who need to handle snakes in zoos, research centers, or conservation environments in case of accidents.

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REFERENCES

- CUBAS, Z. S. et al. **Treaty of wild animals**. São Paulo: Roca, p. 68-85, 2006.
- CHUANG, P. C. et al. Oral Bacteria and their antibiotic susceptibilities in taiwanese venomous snakes. **Microorganisms**, v. 10, p.1-10, 2022.
- DEGHANI, R. et al. The identification of bacterial flora in oral cavity of snakes. **Comparative Clinical Pathology**, v. 25, p. 279–283, 2016.
- FEITOSA, S. B. et al. Snakebite envenomation in Tocantins: ecological analysis of determinants and high-risk areas, 2007-2015. **Epidemiologia e Serviços de Saúde**, Brasília, v. 29, n.4, p. 1-13, 2020.
- FONSECA, M. G. et al. Oral microbiota of Brazilian captive snakes. **Journal of venomous animals and toxins including tropical diseases**, Botucatu, v. 15, n. 1, p. 54-60, 2009.
- HARDT, I. et al. Inclusion body disease and *Salmonella* sp. spondylitis in a *Boa constrictor constrictor*. **Pesquisa Veterinária Brasileira**, v. 37, n. 9, p. 984-990, 2017.
- KRISHNANKUTTY, S. P. et al. Next-generation sequencing analysis reveals high bacterial diversity in wild venomous and non-venomous snakes from India. **Journal of Venomous Animals and Toxins Including Tropical Diseases**, v. 24, n. 41, p. 1-11, 2018.
- LEMA, T. **Os répteis do Rio Grande do Sul**. Porto Alegre: EDIPUCRS, 2002. p 264.
- MARTINS, N. B. et al. Caseous stomatitis caused by *Pseudomonas aeruginosa* in *Boa constrictor amarali*. **Acta Scientiae Veterinariae**, v. 49 (suppl. 1), p. 1-5, 2021.
- PANDA, S. K. et al. Evaluation of cultivable aerobic bacterial flora from Russell's viper (*Daboia russelii*) oral cavity. **Microbial Pathogenesis**, v. 134, p. 1-7, 2019.
- PÁRAMO, L. et al. Bactericidal activity of Lys49 and Asp49 myotoxic phospholipases A2 from Bothrops asper snake venom Synthetic Lys49 myotoxin II-(115-129) – peptide identifies its bactericidal region. **European Journal of Biochemistry**, Oxford, v. 253, n. 2, p. 452-461, 1998.
- PASSOS, R. R. F. C. F. **Contenção física de serpentes: técnicas e precauções**. Dissertação (Mestrado) - Universidade Federal de Uberlândia, Programa de Pós-Graduação em Ciências Veterinárias, Minas Gerais, 2009.

PAZINATO, D. M. M. et al. Diversidade de répteis em uma área da região central do Rio Grande do Sul, Brasil. **Perspectiva**, v.37, n.137, p.115-122, 2013.

PEREIRA, H. C. et al. Oral microbiota in healthy *Bothrops atrox* (Serpentes: Viperidae) and in snakes with stomatitis. **Acta Veterinaria Brasilica**, v. 11, p. 180-183, 2017.

RÉSIÈRE, D. et al. Oral Microbiota of the Snake *Bothrops lanceolatus* in Martinique. **International Journal of Environmental Research and Public Health**, v. 15, p. 21-22, 2018.

SANTOS, G. O. et al. O. Most common conditions affecting captive snakes. **Revista Conexão Eletrônica**, v. 14, n. 1, p. 1913-1923, 2017.

SHEK K. C. et al. Oral bacterial flora of the Chinese cobra (*Naja atra*) and bamboo pit viper (*Trimeresurus albolabris*) in Hong Kong SAR, China. **Hong Kong Medical Journal**; v. 15, n. 3, p.183–190, 2009.

SCHUMACHER, J. Selected Infectious Disease of Wild Reptiles and Amphibians. **Journal of Exotic Pet Medicine**, v. 15, n. 1, p. 18-24, 2006.

SINGH, J. et al. Infectious stomatitis in an Indian rock python (*Python molurus*) and its therapeutic management. **Journal of Entomology and Zoology Studies**, v.6, n.4, p 392-394, 2018.

SMITH S. N. et al. Venomous snakes reveal ecological and phylogenetic factors influencing variation in gut and oral microbiomes. **Frontiers in Microbiology**, v. 12, p. 1-12, 2021.