

# Hematological and Biochemical Profile of Spider Monkey (*Ateles geoffroyi* Kuhl) in Captivity

Pérez-Brígido, Carlos David<sup>1,3</sup>; Romero-Salas, Dora<sup>1\*</sup>; Cruz-Romero, Anabel<sup>1</sup>; Serna-Lagunes, Ricardo<sup>2</sup>; Bravo-Ramos, José Luis<sup>1</sup>; Sánchez-Montes, Sokani<sup>3</sup>; Esparza-González, Sandra Cecilia<sup>4</sup>; Anabel Elisa Rodríguez<sup>5</sup>

<sup>1</sup> Universidad Veracruzana. Facultad de Medicina Veterinaria y Zootecnia. Laboratorio de Parasitología. Unidad de Diagnóstico. Rancho Torreón del Molino. Carretera Federal Veracruz-Xalapa km 14.5, Col. Valente Diaz, Veracruz, Veracruz, México. C. P. 91697.

<sup>2</sup> Universidad Veracruzana. Facultad de Ciencias Biológicas y Agropecuarias Región Córdoba-Orizaba. Laboratorio de Bioinformática y Bioestadística. Calle Josefa Ortiz de Domínguez s/n Col. Centro, Peñuela, Amatlán de Los Reyes, Veracruz, México. C. P. 94945.

<sup>3</sup> Universidad Veracruzana. Facultad de Ciencias Biológicas y Agropecuarias Región Tuxpan. Carretera Tuxpan-Tampico km 7.5, Tuxpan, Veracruz, México. C. P. 92870.

<sup>4</sup> Universidad Autónoma de Coahuila. Facultad de Odontología Unidad Saltillo. Maestría en Ciencias Odontológicas. Blvd. Venustiano Carranza S/N, Col. República Oriente, Saltillo, Coahuila, México. C. P. 25280. <sup>5</sup>Instituto de Patobiología Veterinaria (IPVET). Instituto Nacional de Tecnología Agropecuaria (INTA)-Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Buenos Aires, Argentina.

\* Corresponding author: dromero@uv.mx

## ABSTRACT

**Objective:** To estimate the hematological and biochemical reference values in *Ateles geoffroyi* individuals in captivity.

**Design/Methodology/Approach:** Eleven males and 23 females were captured and blood was collected from the coccygeal vein; conventional techniques were used to analyze the samples.

**Results:** Mean corpuscular volume (MCV;  $P < 0.03$ ) and platelets (PLT;  $P < 0.04$ ) were significantly higher in females than in males. In relation to biochemical blood values, the difference was not significant in male and female groups.

**Study Limitations/Implications:** Hematological and biochemical reference values of *A. geoffroyi* are within normal health parameters; they are between the ranges reported for other species of Neotropical primates and can be used as a reference in the health management of this species in captivity.

**Findings/Conclusions:** Hematological and biochemical parameters of captive specimens of *A. geoffroyi* are described, which provide reference indicators for the health management of the species.

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**Keywords:** reference values, Neotropical primates, blood chemistry, hematology.

## INTRODUCTION

Anthropogenic activities impact the habitat of populations of wild primates, as is the case of the spider monkey (*Ateles geoffroyi*). This species inhabits from the southeast of Mexico to the northwest of Colombia (Di Fiore *et al.*, 2008), and it fulfills an important role in the ecosystems as disperser of tropical forest tree seeds, and as prey of top predators (Chaves *et al.*, 2011).

Arroyo-Rodríguez and Mandujano (2006) mention that when the habitat is fragmented, the species of primates can reduce their ability to move in the habitat to obtain quality foods, which has an impact on physiological alterations at the hematological and biochemical levels. In this sense, it is possible that *A. geoffroyi* is under risk of extinction according to the Red List of Threatened Species because the

ecological characteristics required by the species for their diet are so sensitive that due to the fragmentation of their habitat their populations have reduced in size (Cuarón *et al.*, 2008), and they possibly present changes in their hematological and biochemical profiles, so it is important to study and record their parameters to generate preventive health measures.

A way to generate information about the hematological and biochemical parameters is to evaluate the individuals of *A. geoffroyi* in captivity in zoos and other captivity models in Mexico, since in absence of local reference values for wild populations of *A. geoffroyi* or in captivity, reference values of another species of the same genus are used (Ríos, 2015; Zambrano, 2016). For this reason, the objective of the study was to describe the reference values for the hematological and biochemical profiles of adult males and females of *A. geoffroyi* under conditions of captivity. The parameters generated in the study can be considered as reference values to determine the health status of this species in captivity and as reference of the physiological functions in the wild primate populations and those in captivity.

## **MATERIALS AND METHODS**

**Specimens studied and biological material collection:** During the years 2018 to 2019, 15 specimens of *A. geoffroyi* were captured in the zoo, *Parque Zoológico y Jardín Botánico Miguel Ángel de Quevedo* (ZOOMAQ), registered as Property and Facility for Wild Life Management (*Predio e Instalación para el Manejo de Vida Silvestre*, PIMVS) and located in the city of Veracruz, Veracruz. Another 19 specimens of *A. geoffroyi* (9 monkeys from the Pipiapan locality and 10 from the locality of Tanaxpi) were studied in the Management Unit for Wild Life Conservation (*Unidad de Manejo para la Conservación de la Vida Silvestre*, UMA) “Hilda Ávila de O’Farril”, a unit devoted to the research of primates. This UMA is located in the Catemaco-Coyame highway, municipality of Catemaco, Veracruz, Mexico (geographic coordinates of location: 18.46122 N, -95.04587 W). In total, both from the ZOOMAQ and the UMA, 11 males and 23 females of *A. geoffroyi* were captured in captivity. The monkeys were anesthetized with darts with syringes of 3 mL with a dose of 5 mg kg<sup>-1</sup> of ketamine chlorhydrate (Ketani1®, Wildlife Pharmaceuticals, Windsor, USA), loaded in a CO<sub>2</sub> rifle (JM Standard®, Daninjet, Børkop, Denmark).

From each specimen, 4 mL of blood tissue were obtained from the coccygeal vein and placed in tubes with ethylenediaminetetraacetic acid (EDTA) and the rest of the sample was placed in serum separating tubes. All the samples were conserved at 4 °C and 6 h after the harvest they were processed. The animals captured were subjected to a complete physical exam and each was weighed, and then the specimen was placed in a cage until complete recovery from anesthesia.

**Hematic cytometry:** The total recount of erythrocytes (red blood cells - RBC) was carried out, and packaged cells volume (PCV), hemoglobin (Hb), leukocytes (white blood cells - WBC), and platelets (PLT) were estimated; RBC indexes: mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). Blood smears stained with fast hemocolor were

carried out (Diff-Quick™, Hycel, Mexico), where 100 cells were counted in each of them for the differential recount of leukocytes. This information was generated with a complete hemogram in an MD-8® automatic analyzer (Beckman Coulter, California, USA).

**Blood chemistry:** The concentration of glucose, ureic nitrogen in blood, urea, total protein, albumin, globulin, albumin/globulin rate, creatinine, cholesterol, triglycerides, alkaline phosphatase, calcium and iron. These parameters were quantified with a chemical analyzer ARCHITECT® ci16200, Abbott Core Laboratory (Abbott, Abbott Park, Illinois, USA).

**Data analysis:** The values obtained from the erythrocyte parameters and blood chemistry were described through descriptive statistics by group (Zoo vs UMA) and by sex (females vs males) of the primates sampled. These parameters were compared through the Kolmogorov-Smirnov test that compares the median and the ranges at 95% of reliability between group of primates (Zoo vs UMA) and by sex (females vs males); the comparison included 10000 bootstrap resamples as a method to evaluate the reference ranges at 95% of reliability; the inferior reference limit was defined at 2.5% percentile and the superior limit at 97.5% percentile; to determine whether there were differences between the values of the groups studied, the Mann-Whitney's *U* test at  $P < 0.05$  was applied. The analyses were carried out with the SPSS V. 19 software.

## RESULTS AND DISCUSSION

The average weight of females was  $5.5 \pm 0.6$  kg and the size 65-70 cm, while the males had  $6.0 \pm 1.3$  kg of average weight and a size of 80-90 cm. The hematological and biochemical values analyzed in males and females are presented in Table 1 and 2. The MCV ( $P < 0.03$ ) and PLT ( $P < 0.04$ ) were significantly higher in females than in males, without significant differences between the hematological and biochemical values. The values of platelets ( $p = 0.018$ ), neutrophils ( $p = 0.021$ ), eosinophils ( $p = 0.002$ ), basophils ( $p = 0.009$ ), lymphocytes ( $p = 0.006$ ) and monocytes ( $p = 0.042$ ) were significantly different (Table 3), which is associated to the type of management of the monkey population (Zoo vs UMA), such as exposure to different infectious agents, diet, weight, age and characteristics of captivity (Chen *et al.*, 2002; Xie *et al.*, 2013).

The hematological values provided important data about the health of the monkeys studied such as the analytes, which are biomarkers of the possible presence of a disease. On the other hand, this report of reference values for *A. geoffroyi* constitutes basic information to be contrasted with other populations of the species in captivity and to determine their health status (Ríos, 2015; Zambrano, 2016).

Most of the hematological indexes obtained in this study were similar to those reported by Ríos (2006) in *A. chamek* and they are within the parameters proposed by International Species Information System (ISIS, Calle and Joslin, 2015), but they were lower than those reported in *A. fusciceps* (Zambrano 2016); the red blood cell count was higher in this study, and it can be conditioned to the altitude where the monkeys are in captivity, as index of lower oxygen pressure (Castañeda *et al.*, 2013).

**Table 1.** Blood parameters of *Ateltes geoffroyi* specimens in captivity.

Analyte	Females n=23					Males n=11					U-test p-value
	Mean ±SD	Median	Min-Max	95% CI	Mean ±SD	Median	Min-Max	95% CI			
RBC ( $\times 10^{12} L^{-1}$ )	5.2±0.6	5.3	3.3-6	5.1-5.6	5.4±0.3	5.3	4.7-5.8	4.9-5.5	0.4		
Hb (g dL <sup>-1</sup> )	14.2±1.4	13.7	12.3-17.2	13.2-15.1	14.2±1.7	14.4	9.3-17	13.4-14.9	0.6		
HCT (%)	41.2±4.7	42.6	28-47.9	39.1-43.2	41±2.2	40.3	36.4-44.5	39.4-42.5	0.3		
MCH (pg)	27.4±2	27.4	24.5-31.6	26.6-28.3	26.1±1.8	25.9	23.5-30	24.9-27.3	0.08		
MCHC (g dL <sup>-1</sup> )	34.4±1.5	34.2	31.1-38	33.8-35.1	34.5±1.8	34.2	32.2-38.6	33.3-35.7	0.7		
MCV (fL)	79±3.6	77.8	73.7-85.1	77.4-80.6	75.7±3.4	75.3	70.4-83.7	73.4-78.1	0.03		
WBC ( $\times 10^3 mm^3$ )	11.2±3.4	10.6	5.5-21.2	9.7-12.7	9.9±3.8	8.6	5.5-19.1	7.2-12.5	0.16		
PLT ( $\times 10^3 mm^3$ )	342.4±96.2	338	191-542	300.8-384	272±142.6	263	65-571	176.2-367.9	0.04		
Band neutrophils ( $\times 10^3 L^{-1}$ )	0.1±0.1	0.08	0.0-0.4	0.07-0.1	0.07±0.09	0	0.0-0.2	0.0-0.1	0.1		
Segmented neutrophils ( $\times 10^3 L^{-1}$ )	6.6±3.2	6.1	1.9-17.3	5.2-8.1	6±3.1	5.8	2.2-13.8	3.9-8.1	0.4		
Eosinophils ( $\times 10^9 L^{-1}$ )	1±1.8	0.3	0.0-6.8	0.2-1.8	0.7±1.3	0.3	0-4.6	0.1-1.5	0.6		
Basophils ( $\times 10^9 L^{-1}$ )	0.04±0.06	0	0.0-0.2	0.01-0.07	0.06±0.1	0	0.0-0.3	0.01-0.1	1		
Lymphocytes ( $\times 10^9 L^{-1}$ )	2.8±1	3.1	0.4-4.8	2.3-3.3	2.7±1.1	2.6	0.9-4.4	1.9-3.4	0.8		
Monocytes ( $\times 10^9 L^{-1}$ )	0.4±0.4	0.3	0.0-2.1	0.2-0.6	0.3±0.2	0.2	0.0-0.7	0.1-0.4	0.7		
Band neutrophils % de WBC	0.6±0.6	1	0-0-2	0.3-0.8	0.8±0.6	1	0.0-2.0	0.4-1.2	0.3		
Segmented neutrophils % de WBC	61.1±12.3	65	36.0-82	55.7-66.4	60.6±10.3	60	45-77	53.6-67.8	0.7		
Eosinophils % de WBC	4.2±2.7	4	0-0-11	3.0-5.4	4.1±2.1	5	1-8	2.7-5.6	0.9		
Basophils % de WBC	0.5±0.5	1	0-0-1	0.3-0.7	0.4±0.5	0	0.0-1.0	0.1-0.8	0.7		
Lymphocytes % de WBC	30.3±11.3	29	16.0-57	25.3-35.2	30.6±9.5	33	14.0-43.0	24.1-37.7	0.6		
Monocytes % de WBC	3.1±3.7	2	0-0-17	1.5-4.7	3.2±3.4	3	0-0-12	0.9-5.6	0.8		

**Table 2.** Biochemical values of *Ateles geoffroyi* in captivity.

Analyte	Females n= 23				Males n=11				U-test p-value
	Mean±SD	Median	Min-Max	95% CI	Mean±SD	Median	Min-Max	95% CI	
Glucose (mg dL <sup>-1</sup> )	103.5±1.8	103.5	101-106	102-105	102.5±3.8	101.5	99.3-110.5	101.2-109.5	0.9
BUN (mg dL <sup>-1</sup> )	26.8±4	27	24.5-28.4	25.2-30.4	22.5±1.7	22	20.4-25.5	19.2-24.8	0.1
Total proteins (g dL <sup>-1</sup> )	5.9±0.8	6	4.9-7.2	4.9-6.8	4.9±1.2	4.7	3.9-5.8	4.2-5.6	0.4
Albumin (g dL <sup>-1</sup> )	2.5±0.9	2.4	1.9-4.1	1.8-3.5	2.0±0.4	1.9	1.6-3.8	1.9-3.5	1
Globulins (g dL <sup>-1</sup> )	4.2±0.6	4.4	3.6-5.4	3.2-4.9	3.8±1.4	3.7	3.0-5.0	3.2-4.5	0.9
Alb/Glob Relationship	0.8±0.2	0.8	0.5-1.2	0.4-1.0	0.65±0.02	0.65	0.54-0.70	0.62-0.68	1.2
Creatinine (mg dL <sup>-1</sup> )	0.6±0.1	0.57	0.4-0.8	0.5-0.8	0.5±0.3	0.5	0.33-0.70	0.4-0.6	0.8
Cholesterol (mg dL <sup>-1</sup> )	92.1±4.9	89.7	91.4-98.2	90.9-97.8	96.5±3.3	96	93.4-98.2	94.5-98.1	0.3
Triglycerides (mg dL <sup>-1</sup> )	118.5±15.7	115.1	100.4-150.3	117.1-148.6	120.4±10.4	118.4	110.5-149.5	117.8-140.5	0.7
AP (U L <sup>-1</sup> )	300.4±8.4	300.4	295.5-320.3	299.8-318.4	290.3±11.3	300.5	285.6-315.5	288.5-314.2	0.3
Calcium (mg dL <sup>-1</sup> )	5.4±0.7	5.5	4.6-6.1	4.2-6.6	4.2±0.2	4.2	4.0-5.6	4.0-4.9	0.8
Phosphorus (mg L <sup>-1</sup> )	4.1±1.1	4.1	2.4-5.6	3.8-5.9	3.5±1.5	3.5	2.9-5.0	3.1-5.0	1
Iron (ug dL <sup>-1</sup> )	99.7±7.7	100.4	89.5-110.4	92.4-108.8	100.3±14.4	100.5	88.9-116.5	98.2-112.5	0.6
AST (SGOT) (IU L <sup>-1</sup> )	79.7±6.2	79.3	70.4-90.8	71.3-89.2	82.9±1.5	82	80.0-85.6	81.2-84.3	0.4
ALT (SGPT) (IU L <sup>-1</sup> )	20.4±6.0	19.2	12.3-29.4	18.2-27.6	18.4±4.0	18.2	14.5-26.0	17.8-23.0	0.7
CK (IU L <sup>-1</sup> )	291.6±23.7	290.1	250.3-320.2	264.6-319.2	289.5±35.7	289	260.4-315.9	270.8-310.6	0.9
LDH (IU L <sup>-1</sup> )	237.8±33.5	247.9	190.5-250.5	188.6-249.6	232.4±40.4	235	180.4-243.5	210.3-239.6	0.7
LDT (mg dL <sup>-1</sup> )	18.5±4.4	18.6	10.5-25.5	9.4-21.2	20.2±3.2	20	17.6-24.6	19.7-23.4	0.5
HDT (mg dL <sup>-1</sup> )	8.8±4.6	7.15	4.5-18.4	5.5-16.7	7.5±5.6	7	5.6-12.3	7.0-10.4	1.2
Amylase (U L <sup>-1</sup> )	315.3±24.0	305	287.4-350.2	298.5-345.5	329.4±35.6	330	289.0-360.4	310.5-350.3	0.9
Lipase (U L <sup>-1</sup> )	81.9±7.6	83.6	70-92	79.2-91	85.4±3.4	85.5	80.4-85.7	81.2-83.3	0.2

**Table 3.** Comparison of hematological values of *A. geoffroyi* in captivity.

Hematological values	UMA Hilda O		ZOOMAQ	p
	Pipiapan n=9	Tanaxpi n=10	n=15	
RBC ( $\times 10^{12} L^{-1}$ )	5.0 $\pm$ 0.91	5.28 $\pm$ 0.44	5.45 $\pm$ 0.36	0.550
Hb (g dL <sup>-1</sup> )	13.4 $\pm$ 2.07	15.14 $\pm$ 1.50	14.09 $\pm$ 1.18	0.137
HCT (%)	39.4 $\pm$ 5.53	42.3 $\pm$ 3.3	41.44 $\pm$ 3.3	0.344
WBC ( $\times 10^3 mm^3$ )	11.14 $\pm$ 3.7	11.3 $\pm$ 3.0	10.22 $\pm$ 4.0	0.403
PLT ( $\times 10^3 mm^3$ )	400 $\pm$ 101	319 $\pm$ 68.47	271.9 $\pm$ 127.5	0.018
Segmented neutrophils	52 $\pm$ 12.78	67.6 $\pm$ 5.42	61.93 $\pm$ 10.97	0.021
Eosinophils % de WBC	6.33 $\pm$ 2.54	4.8 $\pm$ 2.29	2.6 $\pm$ 1.63	0.002
Basophils % de WBC	0.22 $\pm$ 0.44	0.9 $\pm$ 0.316	0.4 $\pm$ 0.5	0.009
Lymphocytes % de WBC	39.7 $\pm$ 11.62	23.7 $\pm$ 6.41	29.33 $\pm$ 8.7	0.006
Monocytes % de WBC	1.22 $\pm$ 0.97	2.3 $\pm$ 1.05	5.0 $\pm$ 4.73	0.042

The red blood cells found in this study when comparing them to other non-human primates, indicate a balance of erythropoiesis and destruction of erythrocytes (Ihrig *et al.*, 2001; Yu *et al.*, 2019; Yeo *et al.*, 2019). The hematocrit (HCT) was found to be higher in the monkeys studied, which indicates a state of balance in terms of the water balance regulator mechanism (Armstrong and Johnson, 2018), while the recount of white blood cells (WBC) was found within the normal parameters (García-Feria *et al.*, 2017) and the recount of platelets was similar in comparison to other values in primates (Ferreira *et al.*, 2018). However, the increase of eosinophils found is attributed to helminthic infections in the monkeys studied (Rahimi and Khanaliha, 2018).

In this study there was no evidence of any effect from the sex (male *vs* female) on the biochemical parameters of the monkeys studied, effect that has also not been reported in other studies of Neotropical primates (Rovirosa-Hernández *et al.*, 2012; Canales-Espinosa *et al.*, 2015; García-Feria *et al.*, 2017).

In this study, the males had significantly higher weight and size than the females, resulting from their sexual dimorphism (de Thosy *et al.*, 2001), but with similar concentrations of creatinine, as a result of a similar diet, since the dietetic intake and the muscular mass promote similarities in the content of creatinine (Kaneko, 1989). The levels of cholesterol, triglycerides, HDL and LDL of the monkeys studied suggest that they have an intake rich in proteins, while the transaminases, alanine aminotransferase (ALT), aspartate aminotransferase (AST), and blood ureic nitrogen (BUN) suggest a normal hepatic function (Rovirosa-Hernández *et al.*, 2012; Canales-Espinosa *et al.*, 2015; García-Feria *et al.*, 2017).

## CONCLUSIONS

This study describes the hematological and biochemical parameters of specimens in captivity of *A. geoffroyi*, with reference values that provide indicators for the health management of this species in captivity.

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## Compliance with ethical standards

This project was approved by the Bioethical and Animal Welfare Commission of the Veterinary Medicine and Animal Science School of the Universidad Veracruzana.

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