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Clinical parameters of goats infected with gastrointestinal nematodes and treated with condensed tannin

Parâmetros clínicos de caprinos infectados por nematoides gastrintestinais e tratados com tanino condensado

Danilo Rodrigues Barros Brito[1*]; Livio Martins Costa Júnior[2]; João Luis Garcia[3]; Daniel Praseres Chaves[4]; José Antonio Alves Cutrim Júnior[1]; Washington Luis Ferreira Conceição[1]; Anna Vanniezy Marinho de Brito[5]

Highlights:
The use of *Mimosa caesalpiniifolia* did not affect the hepatic enzyme studied.
The hematocrit of least parasitized animals did not differ from the most parasitized.
The use of condensed tannin did not change the hematological parameters.

Abstract

Small ruminants are affected by gastrointestinal nematodes that cause great economic losses in sheep and goat farming. Alternatives have been studied to control these parasites, such as the use of taniniferous plants; however, few studies have reported the effects of condensed tannins on blood parameters. This study aimed to verify the effect of condensed tannin for the treatment of goats infected by gastrointestinal nematodes on hematological, biochemical, and serum protein parameters. Blood samples were collected weekly from 24 six-month-old male Boer goats experimentally infected with gastrointestinal nematodes weighing 15 ± 2.5 kg live weight and reared in a feedlot system for 28 days. The animals were divided into four groups of six animals, one group was treated with *Mimosa caesalpiniifolia* condensed tannin (CT), the second group was treated with CT and polyethylene glycol (CT + PEG), the third group was treated with 5 mg kg^{-1} BW^{-1} monepantel (positive control), and the fourth group did not receive any treatment (negative control). The results obtained for erythrocytes, hemoglobin, hematocrit, and total plasma protein showed no statistically significant differences among the groups, and neither did the biochemical variables alkaline phosphatase, aspartate aminotransferase, urea, creatinine, glucose, iron, calcium, phosphorus, and magnesium. Proteinogram data were evaluated, including total protein, albumin, ceruloplasmin, transferrin, haptoglobin, and α1-acid glycoprotein. There was no statistically significant difference among the groups for ceruloplasmin, transferrin, haptoglobin, and α1-acid glycoprotein. Therefore, the treatment of goats infected by gastrointestinal nematodes with *M. caesalpiniifolia* CT did not interfere in hematological, biochemical, and serum protein parameters.
Key words: Hematology. Small ruminants. Worms.

[1] Profs., Instituto Federal do Maranhão, IFMA, Campus Maracanã, São Luís, MA, Brasil. E-mail: danilobrito@ifma.edu.br; cutrimjunior@ifma.edu.br; wascon@ifma.edu.br
[2] Prof., Universidade Federal do Maranhão, UFMA, São Luís, MA, Brasil. E-mail: livioslz@yahoo.com
[3] Prof. Dr., Universidade Estadual de Londrina, UEL, Centro de Ciências Agrárias, CCA, Departamento de Medicina Veterinária Preventiva, Londrina, PR, Brasil. E-mail: joaoluisgarcia10@gmail.com
[4] Prof., Universidade Estadual do Maranhão, UEMA, São Luís, MA, Brasil. E-mail: daniel@cernitas.com.br
[5] Discente de Graduação Curso de Biologia, UFMA, São Luís, MA, Brasil. E-mail: vanniezy@hotmail.com
[*] Aurhor for correspondence

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Resumo

Os pequenos ruminantes são acometidos por nematoides gastrintestinais que causam grandes prejuízos econômicos na ovinocaprinocultura. Alternativas têm sido estudadas para controle desses parasitas, como o uso de plantas taniníferas. Poucas pesquisas relatam os efeitos causados pelos taninos condensados sobre aspectos sanguíneos. Este trabalho teve como objetivo verificar o efeito do tanino condensado no tratamento de caprinos infectados por nematoides gastrintestinais sobre os parâmetros hematológicos, bioquímicos e proteinograma sérico. Foram coletadas amostras sanguíneas semanalmente de 24 caprinos mestiços da raça Boer, experimentalmente infectados com nematoides gastrintestinais, com seis meses de idade e pesando 15 ± 2,5 Kg de peso vivo (PV), criados em sistema de confinamento, durante 28 dias. Os animais foram divididos em quatro grupos de seis animais, sendo um grupo tratado com tanino condensado (TC) da *Mimosa caesalpinifolia*, o segundo grupo tratado com Tanino Condensado e Polietilenoglicol (TC+PEG), o terceiro grupo com monepantel (5mg kg^{-1}/PV) (controle positivo) e o quarto grupo que não recebeu nenhum tipo de tratamento (controle negativo). Os resultados obtidos com eritrócitos, hemoglobina, hematócrito e proteína plasmática total não apresentaram diferenças estatisticamente significativas, bem como as variáveis bioquímicas fosfatase alcalina, aspartato aminotransferase, ureia, creatinina, glicose, ferro, cálcio, fósforo e magnésio. Foram avaliados dados de proteinograma, como proteína total, albumina, ceruloplasmina, transferrina, haptoglobina e α1-glicoproteína ácida. Não houve diferença estatisticamente significativa entre os grupos para ceruloplasmina, transferrina, haptoglobina e α1-glicoproteína ácida. Conclui-se que o tratamento de caprinos infectados por nematoides gastrintestinais com *M. caesalpinifolia* não interferiu nos parâmetros hematológicos, bioquímicos e proteinograma sérico.

Palavras-chave: Hematologia. Pequenos ruminantes. Verminose.

Introduction

Physiologically, animals react differently to frequent exposure to variations in temperature, humidity, and other environmental factors, and changes may occur in various physiological parameters. Among these physiological factors are hematological parameters, which are an important tool for evaluating both the health status of the animal and the degree of stress to which it is being submitted (Roberto, Souza, Silva, Justiniano, & Freitas, 2010).

According to González and Sheffer (2002), serum biochemical profiles are excellent subsidies for the diagnosis of metabolic disorders because they reflect cellular integrity and organic function, and thus can evaluate tissue damage, organ functioning disorders, the adaptation of animals to nutritional and physiological challenges, and metabolic or nutritional origin imbalances.

Serum protein profile changes in goats naturally infected with gastrointestinal nematodes are poorly known. The analysis of this profile is important for the assessment of nutritional status and may indicate metabolic alterations and assist in the clinical diagnosis of several diseases (Barioni, Fonteque, & Paes, 2001). Several studies have reported the serum protein values of goats, including Castro, Dhindsa and Hoversland (1977) and Sharma, Chauhan and Agrawal (2001), who found averages of 6.7 and 7.3 g dL^{-1} for total protein, respectively. Castro et al. (1977) also observed an average of 1.1 g dL^{-1} for gammaglobulin and 1.2 for the albumin/globulin (A/G) ratio.

Studying red blood cells, hemoglobin, and hematocrit values in healthy goats from Paraíba semi-arid region, Roberto et al. (2010) measured averages of 12.02×10^6 μL^{-1}, 10.45 g dL^{-1}, and 29.50%, respectively. S. L. Silva, Fagliari and Cesco (2004) evaluated the serum activity of aspartate aminotransferase (AST), alkaline phosphatase (ALP), and GGT enzymes in healthy goats from São Paulo state and reported values of 80.66, 253.07, and 43.26 U L^{-1}, respectively.

According to Cardoso et al. (2010), who evaluated the hematological profile in peripartum ewes raised in the coastal lowland of Rio de Janeiro, the increase of FEC in these animals was directly related to the decrease in hemoglobin concentration. When studying the immune response of *Typha domingensis* and *Operculina hamiltonii* treated animals on goat gastrointestinal nematodes, C. F. Silva et al. (2011) observed that the mean values of medium globular volume, erythrocytes, hematocrit, and hemoglobin were within normal limits compared to international reference values (Jain, 1993). According to Mattos, Oliveira, Lustosa, Lacerda and Terra (2005), goats parasitized by *Haemonchus contortus* showed lower erythrocyte and hematocrit values compared to non-parasitized goats.

Mimosa caesalpiniifolia may be effective in combating gastrointestinal nematodes, owing to the condensed tannin (CT) concentrations (5% to 14%) in its leaves and stems. This plant occurs naturally in areas of several states of the northeast region of Brazil and is characterized by fast growth, high regeneration capacity, and drought resistance. It is widely consumed by animals during the rainy season and is used as a dietary supplement in periods of scarcity (Barbosa, 1997).

By studying the influence of *M. caesalpiniifolia* CT on goats infected with gastrointestinal nematodes, changes in the clinical parameters of the animals can be verified. Thus, the objective of the present study was to verify the effect of CT in the treatment of goats infected by gastrointestinal nematodes on hematological, biochemical, and serum proteinogram parameters.

Materials and Methods

All procedures were approved by the Committee of Ethics and Animal Experimentation of the State University of Maranhão under number: 015/2012.

Twenty-four experimentally infected crossbred Boer goats that were six months old, weighed 15 ± 2.5 kg live weight, and reared in a feedlot system were used. Before the beginning of the experimental period, all animals were measured for natural parasites using the fecal egg count (FEC) and it was established that the goats had to be reinfected due to the low natural parasitic load (average FEC of 300). This reinfection occurred orally with approximately 16,000 larvae comprising the genera *Haemonchus* (8000), *Trichostrongylus* (6560), and *Oesophagostomum* (1440) for each animal. These larvae were obtained from fecal co-culture of the experimental animals. After 30 days of artificial infection, the experimental period began.

During the experimental period of 28 days, the animals were maintained in individual pens, with a cleaning and disinfection procedure undertaken with flame throwers. A stall was provided with a drinker and feeders, one for bulky food and one for the supplement. The diet was composed of Tifton grass hay (*Cynodon* spp.) and concentrate (35% corn, 7% soybean meal, and 9% wheat bran) supplied in an amount corresponding to 3% of live animal weight, calculated daily. Based on individual body weight, vitamin-mineral supplement (caprinofós®) and water was provided ad libitum. This diet was provided to the animals 15 days before the commencement of the experimental period.

The animals were divided into four groups of six animals each. Goats in the first group (CT group) received 64.3 mg kg^{-1} BW^{-1} per day of CT during the first week from *M. caesalpiniifolia* leaves for seven consecutive days, and during the third week the same animals received 128.7 mg kg^{-1} BW^{-1} per day of CT from *M. caesalpiniifolia* leaves, also for seven consecutive days. The second group (CT + PEG group) received the same concentration of CT as that of the CT group plus 10 g of polyethylene glycol (PEG) per day. PEG was used as a non-nutritive synthetic polymer that can bind to CTs, forming a complex and inactivating with the tannins. Goats in the third group (positive control group) received oral monepantel (Zolvix® 5 mg kg^{-1} BW^{-1}) at the beginning of the experimental period and the

animals in the fourth group (negative control group) received no treatment.

Fecal samples were collected weekly from the rectum of the animals and were processed immediately to measure the elimination of nematode eggs. FECs were performed according to the modified Gordon and Whitlock technique (Ueno & Gonçalves, 1998). Coprocultures were undertaken during the experimental period, following the technique of Roberts and O'Sullivan (1950). The identification of third stage larvae was based on the descriptions of Ueno and Gonçalves (1998).

Hematological tests

For hematological examination, blood was collected weekly (days 1, 8, 15, 22, and 28) by puncture of the jugular vein, using 25 × 7 mm disposable needles, after previous disinfection of the site with iodinated alcohol, with the first collection taken on the first day of the experiment after parasitic reinfection. Blood was deposited directly into a vacutainer vial containing 0.05 mL of a 10% aqueous sodium ethylenediamine tetracetate solution for each 5 mL of blood.

Erythrocyte counts were performed in a Neubauer chamber and the hematocrit was determined using the microhematocrit technique. To determine the hemoglobin content of the blood, a technique described by Jain (1993) was performed with the cyanometahemoglobin method, using a semi-automatic biochemical analyzer (Bioplus 200E), with the aid of a Labtest commercial kit for hemoglobin measurement. These tests were performed according to routine techniques following the methods described by Coles (1984). Total plasma protein was determined by refractometry.

Biochemistry and proteinogram

To perform the biochemical tests and proteinogram, blood was collected weekly (days 1, 8, 15, 22, and 28) by puncture of the jugular vein and deposited directly in a vacutainer vial without anticoagulant. The collections were made in the morning before food was supplied.

Serum concentrations of total calcium (Labtest method), phosphorus (Basques-Lustosa method), magnesium, iron (Goodwil method), total protein (biuret method), albumin (bromocresol blue method), urea (urease method), creatinine (kinetic method), and glucose (orthotoluidine method) as well as serum activities of the enzymes AST (Reitman-Frankel method) and ALP. Labtest commercial reagents were used to perform the tests. Biochemical parameter readings were taken on a semi-automatic spectrophotometer at specific wavelengths for each constituent.

The fractions of α1-acid glycoprotein, haptoglobin, ceruloplasmin, and transferrin proteins were obtained by sodium dodecyl sulfate polyacrylamide gel electrophoresis following the procedure described by Laemmli (1970). After fractionation, the gel was stained for two hours in Coomassie blue solution. It was then bleached in methanol and acetic acid solution. Protein concentrations were determined using a computerized densitometer (Densitometer CS9301-Shimadzu, Tokyo-Japan). As a reference, a marker solution (Sigma Marker, Wide Range, Saint Louis, USA) with various molecular weights, ranging from 6,500 to 200,000 Daltons, as well as purified α1-glycoprotein acid, haptoglobin, ceruloplasmin, and transferrin proteins were used.

Statistical analysis

The variables were subjected to analysis of variance for completely randomized experiments. When the interaction between factors was significant or when there was an independent response to the factors analyzed, the means were compared by Tukey's test at 5% significance (Pimentel-Gomes, 1987). Statistical analysis was performed using the InStat statistical program (GraphPad Software Oberlin, San Diego-CA, USA).

Results and Discussion

The FECs performed at the beginning of the research showed a similar degree of parasitism among the studied groups (Figure 1). However, during the experiment, there was a statistically significant difference among the positive control group (monepantel) and the other groups (CT, CT + PEG, and negative control) on days 8, 15, 22, and 28 ($P < 0.05$).

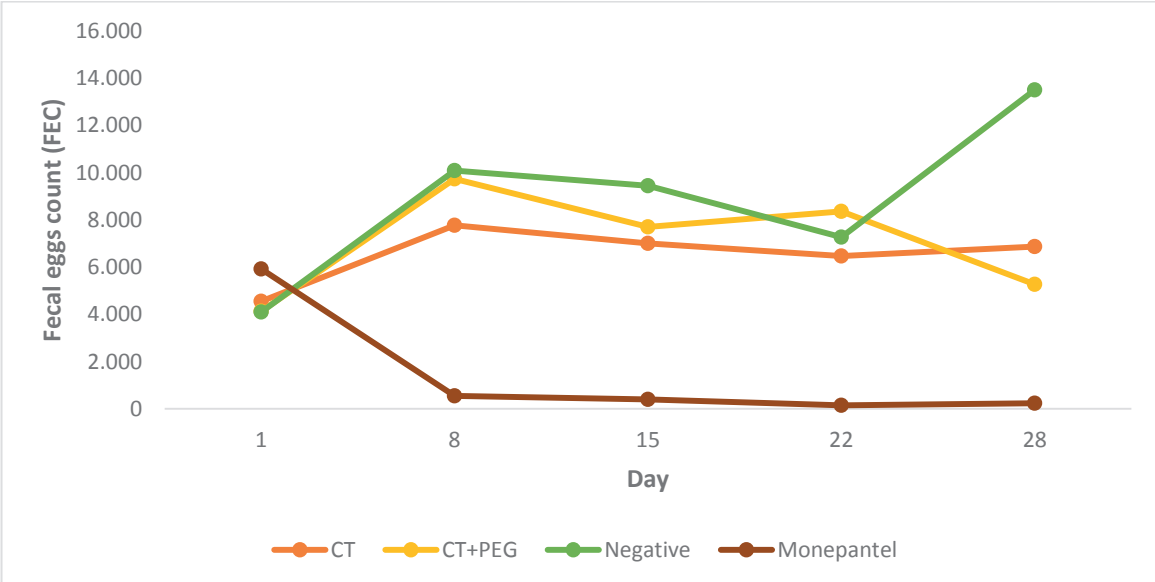

Figure 1. Mean values of quantity fecal egg counts (FECs) from experimental groups of *Haemonchus*, *Trichostrongylus* and *Oesophagostomum* infected goats.
CT - condensed tannin; CT + PEG - condensed tannin plus polyethylene glycol; Negative - control group; Monepantel – positive control group.

The averages obtained in the present study for erythrocytes, hematocrit, hemoglobin, and total plasma protein are summarized in Table 1. The values found for erythrocytes considering all groups and days 1 and 15 were within the range of what is normally observed for goats (Bezerra et al., 2008; E. M. N. Silva et al., 2008). However, the negative control group had red blood cell counts below the reference value (8.0–18.0 × 10^6 μL^{-1}) on days 8, 22, and 28. This might be due to a high parasitic load, as measured by the FEC of this group as shown in Figure 1. However, even for erythrocytes, there was no statistically significant differences among the experimental groups ($P > 0.05$). C. F. Silva et al. (2011) found that the erythrocyte numbers were within the reference values in their 28-day experiment that evaluated the hematological response of *T. domingensis* and *O. hamiltonii* treated goats on gastrointestinal nematodes, with no differences among the groups treated and those of the control group ($P > 0.05$). These results were similar to those found in the present study.

Table 1
Mean ± standard deviation of erythrocytes (Er), hematocytes (Ht), hemoglobin (Hg), and total plasma protein (TPP) evaluated on days 1, 8, 15, 22 and 28 of experiment in goats infected with gastrointestinal nematodes and treated with condensed tannin from *Mimosa caesalpiniifolia*

Variable	Group	Day 1	Day 8	Day 15	Day 22	Day 28
Er (x10^6/µL)	CT	16.1±3.5$^{(a)}$	9.8±1.3$^{(a)}$	9.0±1.3$^{(a)}$	8.9±2.7$^{(a)}$	9.2±2.1$^{(a)}$
	CT+PEG	17.4±4.2$^{(a)}$	10.3±3.2$^{(a)}$	10.6±3.7$^{(a)}$	10.9±3.3$^{(a)}$	8.2±0.7$^{(a)}$
	Negative	14.0±3.4$^{(a)}$	7.1±1.8$^{(a)}$	8.7±2.7$^{(a)}$	6.6±1.7$^{(a)}$	7.5±1.5$^{(a)}$
	Monepantel	12.2±3.3$^{(a)}$	8.2±0.6$^{(a)}$	9.7±1.4$^{(a)}$	10.2±3.2$^{(a)}$	8.9±1.3$^{(a)}$
Ht (%)	CT	29.2±4.2$^{(a)}$	21.2±3.7$^{(a)}$	24.5±3.9$^{(a)}$	23.0±5.5$^{(a)}$	22.0±4.2$^{(a)}$
	CT+PEG	25.0±3.9$^{(a)}$	24.0±1.1$^{(a)}$	22.0±3.6$^{(a)}$	21.0±4.7$^{(a)}$	22.5±3.1$^{(a)}$
	Negative	24.0±3.0$^{(a)}$	22.0±3.1$^{(a)}$	19.5±2.6$^{(a)}$	19.5±4.3$^{(a)}$	19.5±7.4$^{(a)}$
	Monepantel	23.2±5.6$^{(a)}$	21.5±3.4$^{(a)}$	21.0±3.4$^{(a)}$	21.0±3.9$^{(a)}$	22.2±3.5$^{(a)}$
Hg (g dL^{-1})	CT	9.2±1.8$^{(a)}$	11.1±2.6$^{(a)}$	3.2±0.6$^{(a)}$	10.5±2.4$^{(a)}$	6.7±2.0$^{(a)}$
	CT+PEG	8.3±1.5$^{(a)}$	8.2±0.4$^{(a)}$	3.2±0.6$^{(a)}$	9.1±2.2$^{(a)}$	7.3±0.7$^{(a)}$
	Negative	7.1±1.1$^{(ab)}$	8.8±2.7$^{(a)}$	2.8±0.5$^{(a)}$	8.6±2.3$^{(a)}$	6.2±2.2$^{(a)}$
	Monepantel	4.8±2.0$^{(b)}$	8.3±2.1$^{(a)}$	3.2±0.8$^{(a)}$	9.8±1.9$^{(a)}$	7.2±1.2$^{(a)}$
TPP (g dL^{-1})	CT	6.5±0.7$^{(a)}$	6.2±0.7$^{(a)}$	6.6±0.5$^{(a)}$	6.8±0.5$^{(a)}$	6.3±0.5$^{(a)}$
	CT+PEG	5.9±1.2$^{(a)}$	5.8±1.2$^{(a)}$	5.7±1.8$^{(a)}$	5.7±1.8$^{(a)}$	6.5±0.4$^{(a)}$
	Negative	6.3±0.7$^{(a)}$	6.0±0.6$^{(a)}$	6.2±0.8$^{(a)}$	5.8±1.3$^{(a)}$	6.0±1.0$^{(a)}$
	Monepantel	6.3±0.7$^{(a)}$	6.3±0.6$^{(a)}$	6.4±0.8$^{(a)}$	6.9±0.5$^{(a)}$	6.8±0.3$^{(a)}$

CT - condensed tannin; CT + PEG - condensed tannin with the addition of polyethylene glycol.
In each variable, values followed by lowercase letters in the same column do not differ from each other by the Tukey test ($p > 0.05$).

Levels of parasitic infection by digestive hematophagous worms correlate negatively with hematological parameters and measurements of these indices including hematocrit and hemoglobin are good indicators of the presence of these parasites (Mattos et al., 2005). The reference values for goat hematocrit is 19%–38% (Jain, 1993). The findings of the present study were within this range and there was no significant difference among the groups studied, similar to the results found by Costa et al. (2006). For hemoglobin, there was a statistically significant difference among the monepantel group (4.8 g dL-¹) and the other groups (CT = 9.2 g dL-¹, CT + PEG = 8.3 g dL-¹, and negative control = 7.1 g dL-¹) on day 1 ($P < 0.05$). Regarding the other days, there was no significant difference among the groups, with values below the reference value (8.0–12.0g dL^{-1}) observed on days 15 and 18 for all groups. These results are related to the collection period and not to the degree of parasitism because the same result was found in all studied groups. The goat hemoglobin concentration in the present study differed from the results of Mattos et al. (2005), who observed that parasitized and ivermectin-treated goats had values within the reference range on days 7 and 14 post-treatment. This difference can be explained because of the resistant ivermectin-sensitive *H. contortus* used in the latter research.

There was no statistically significant difference among the treated groups for total plasma protein (range 5.7 to 6.9 g dL^{-1}) ($P > 0.05$) (reference values 6.4–7.0 g dL^{-1}) (Kaneko, Harvey, & Bruss, 1997), demonstrating that the animals did not present dehydration problems or other elevation factors, such as antigenic stimulation.

Table 2 shows the values of serum ALP and AST activities and the concentrations of urea, creatinine, and glucose in goats treated with *M. caesalpiniifolia* CT. There was no statistically significant difference in these variables among the groups studied ($P > 0.05$).

Table 2
Mean ± standard deviation of alkaline phosphatase (ALP), aspartate aminotransferase (AST), urea (Ure), creatinine (Cre) and glucose (Glu) evaluated on days 1, 8, 15, 22 and 28 of goats infected with gastrointestinal nematodes and treated with condensed tannin of *Mimosa caesalpiniifolia*

Variable	Group	Day 1	Day 8	Day 15	Day 22	Day 28
ALP (UI L^{-1})	CT	19.4±9.1	22.2±15.6	30.9±21.2	38.1±30.8	42.5±31.3
	CT+PEG	23.1±10.7	34.3±22.4	43.1±23.0	48.3±24.7	42.8±23.2
	Negative	25.5±12.5	23.4±16.1	33.9±14.1	41.9±19.3	40.7±16.6
	Monepantel	13.5±4.2	19.3±11.6	31.4±19.3	44.2±23.0	41.5±27.3
AST (UI L^{-1})	CT	51.2±15.9	45.3±4.2	52.0±6.7	56.6±15.0	53.9±10.4
	CT+PEG	43.1±4.1	34.6±10.9	50.7±7.2	69.9±33.0	44.8±8.6
	Negative	41.2±13.2	39.9±11.1	44.4±7.5	51.0±23.9	49.5±13.3
	Monepantel	45.4±12.5	38.8±9.3	49.8±10.8	50.4±19.9	49.6±11.6
Ure (mg dL^{-1})	CT	48.2±14.4	42.5±13.1	32.7±6.2	31.7±5.4	36.1±10.7
	CT+PEG	53.9±17.5	42.8±6.8	40.4±9.3	43.5±11.1	34.1±14.3
	Negative	44.6±10.1	49.5±10.8	38.1±9.9	35.4±2.5	41.9±14.8
	Monepantel	45.5±6.2	48.6±16.1	38.1±8.8	40.6±10.6	44.8±16.3
Cre (mg dL^{-1})	CT	0.57±0.11	0.52±0.08	0.68±0.27	0.81±0.45	0.62±0.23
	CT+PEG	0.70±0.23	0.53±0.13	0.71±0.27	0.75±0.35	0.88±0.24
	Negative	0.62±0.15	0.53±0.00	0.79±0.23	0.82±0.52	0.81±0.32
	Monepantel	0.53±0.05	0.67±0.18	0.88±0.45	0.64±0.33	0.61±0.18
Glu (mg dL^{-1})	CT	39.4±2.7	60.7±17.1	56.8±10.7	54.9±12.3	53.8±16.6
	CT+PEG	41.4±8.7	43.7±7.5	62.4±20.2	52.5±18.2	45.9±7.0
	Negative	44.4±11.1	54.5±10.8	65.5±14.9	57.4±8.7	42.7±8.7
	Monepantel	32.8±9.7	48.1±6.1	67.7±13.8	48.0±7.5	49.0±10.6

CT - condensed tannin; CT + PEG - condensed tannin with the addition of polyethylene glycol.
There was no significant difference between group means by Tukey test ($p > 0.05$).

No significant increase in serum ALP activity was observed throughout the experimental period for all groups; however, the activity of this enzyme remained below the reference value (93–387 IU L^{-1}) for goats, according to Kaneko et al. (1997). Therefore, the intake of *M. caesalpiniifolia* CT did not influence the hepatobiliary and/or bone function of the animals. Serum AST activity showed small oscillations, decreasing below the reference value (43–132 IU L^{-1}) on day 8 in all groups except for the CT group. Overall, serum AST activity remained within the reference value for caprine species (González, Barcellos, & Patiño, 2000). Therefore, the liver function of the *M. caesalpiniifolia* CT-fed goats was not affected with sufficient severity to increase the serum activity of these enzymes.

Research conducted on sheep showed that animals infected with *H. contortus* had an AST value above 200 IU L^{-1}, which was higher than that of the uninfected sheep and the reference value. For ALP, infected animals also had higher serum activity (above 150 IU L^{-1}) than that of uninfected sheep, but remained within the normal range (E. M. N. Silva et al., 2008).

A study evaluating the essential oil of *Cymbopogon schoenanthus* in sheep experimentally infected with *H. contortus* found no difference among the groups treated with 180 and 360 mg Kg^{-1} and the control group ($P > 0.05$) for AST and ALP, and the values found were within the reference value for this species (Katiki et al., 2011). Similar results were found by Botura et al. (2011) when studying the anthelmintic effect of *Agave sisalana* on gastrointestinal nematodes of young goats, where all experimental groups presented values below the reference after eight days of treatment.

For urea concentration, there was no statistical difference among the groups surveyed ($P > 0.05$) in the present study. Results were within the reference value for goats, which is 21.4 to 42.8 mg dL^{-1} (Kaneko et al., 1997), except for groups on day 1 (all groups), day 8 (negative control and monepantel), and day 28 (monepantel). Increased blood urea was an indicator of a reduction in the glomerular filtration rate. All groups had a creatinine concentration below the reference value (1.0–1.8 mg dL^{-1}), with no statistical difference among the groups ($P > 0.05$). In a study evaluating the concentration of urea and creatinine in goats treated with *A. sisalana* (1.7 g kg^{-1}) and Levaisol (6.3 mg kg^{-1}), values above the reference value for urea were observed, similar to those found in the present study. For creatinine, the values were all within the normal range, differing from the results found in the present study (Botura et al., 2011).

Plasma glucose levels increased with oscillations for all groups on day 15 compared to day 1. Most values were within the goat reference value of 50 to 75 mg dL^{-1}. There was no statistically significant difference between the groups ($P > 0.05$). The decrease in plasma glucose levels might have been caused using this metabolite as an energy source, causing a reduction in body reserves (Nelson & Cox, 2002; Sacks, 1998).

Assessing urea, creatinine, and glucose concentrations in 96 *Trichostrongylus* infected goats in South Africa, Gwaze, Chimonyo and Dzama (2010) found that 61.4%, 22.9%, and 39.6% of the animals presented urea, creatinine, and glucose concentrations within the reference range, respectively. Thus, gastrointestinal nematode infection altered these biochemical variables in goats. Alterations were also found in the present study, since all groups were infected, but there was no significant difference between the groups treated with CT and the negative control.

The iron, calcium, phosphorus, and magnesium mineral contents in the goats treated with *M. caesalpiniifolia* CT and monepantel are summarized in Table 3.

Serum iron concentration increased in all groups, except for the CT group that showed a decrease from day 15. There was no statistically significant difference in iron content among groups, remaining within the reference range (57–233 mg dL^{-1}) (González et al., 2000). Iron decrease may be due to malabsorption and anemia; however, among the monepantel group that presented low FEC and the other groups that presented high FEC there was no significant difference and all presented a progressive increase of iron concentration during the 28 days of the experiment.

Total calcium content in the studied groups was below the reference value (8.9–11.7 mg dL^{-1}) on days 15, 22, and 28, with no significant difference ($P > 0.05$) among groups for the entire trial period. Hypocalcemia can be caused by calcium malabsorption in the intestine and is affected by the parasitism of gastrointestinal nematodes. The phosphorus content was within the reference value, which is 4.2 to 9.1 mg dL^{-1}, except for the negative and monepantel groups on day 28 that presented values above the reference value. There was no statistically significant difference among the groups. Phosphorus deficiencies do not have immediate effects, as is the case with calcium, but in the long run they can cause retarded growth, progressive osteoporosis, infertility, and low production. Severe phosphorus deficiency manifested by blood levels leads to the depravity of appetite (González & Silva, 2008).

Table 3
Mean ± standard deviation of iron (Iro), total calcium (Ca), phosphorus (P), and magnesium (Mg) evaluated on days 1, 8, 15, 22, and 28 of experiment in goats infected with gastrointestinal nematodes and treated. with condensed tannin from *Mimosa caesalpiniifolia*

Variable	Group	Day 1	Day 8	Day 15	Day 22	Day 28
Iro (mg dL^{-1})	CT	85.0±25.9	160.9±85.7	261.2±61.7	162.3±60.3	177.4±68.5
	CT+PEG	103.3±21.6	188.4±102.7	249.2±41.1	211.4±74.2	286.0±119.1
	Negative	91.7±27.1	155.5±105.5	228.8±102.2	238.3±47.0	254.2±129.1
	Monepantel	83.3±23.4	182.2±58.4	223.7±79.5	223.4±38.9	244.9±141.5
Ca (mg dL^{-1})	CT	9.3±1.1	9.5±1.6	7.3±0.8	7.4±1.0	8.1±2.0
	CT+PEG	9.4±1.0	9.9±1.8	7.7±0.9	6.3±1.3	8.5±1.5
	Negative	9.8±1.7	10.6±3.2	7.1±1.1	6.3±1.1	8.0±1.2
	Monepantel	9.6±0.4	9.8±0.9	6.9±1.0	7.9±0.8	7.4±0.7
P (mg dL^{-1})	CT	6.4±3.0	7.2±2.9	7.0±1.8	11.0±3.9	7.7±2.9
	CT+PEG	5.4±2.9	5.7±3.1	8.5±1.1	8.2±1.8	8.9±3.1
	Negative	7.6±2.4	7.6±1.7	8.5±2.4	9.2±3.6	10.4±3.8
	Monepantel	5.9±2.2	8.7±2.4	9.2±2.4	9.3±2.7	11.0±1.9
Mg (mg dL^{-1})	CT	3.2±0.5	3.2±1.2	3.4±1.1	3.5±1.7	4.3±1.4
	CT+PEG	3.1±0.4	3.6±0.9	3.2±0.9	2.9±0.6	4.0±1.8
	Negative	3.6±0.6	4.1±0.7	3.0±0.9	3.2±1.3	3.6±1.4
	Monepantel	3.7±0.5	3.1±0.7	3.3±1.0	3.8±1.6	3.5±0.7

CT - condensed tannin; CT + PEG - condensed tannin with the addition of polyethylene glycol.
There was no significant difference between group means by Tukey test ($p > 0.05$).

Phosphorus concentration was verified in a previous study looking at the effect of *Schinopsis* (quebracho) CT on gastrointestinal nematodes of sheep. The administration did not affect the phosphorus concentration in the studied groups until day 28 (4%, 8%, and 16% extract of broach), but from day 30 there was a decrease in all groups from 2.97 to 2.69 nmol. L^{-1} (Athanasiadou, Kyriakis, Jackson, & Coop, 2001). Determining the biochemical profile of Saanen lactating goats, Simplício, Cotrim, Fagliari and Nogueira (2009) did not find values different from those of the normal ranges for calcium and phosphorus contents.

In a previous study, goats were infected with *H. contortus* and fed a mixture of leaves of *Psidium guajava* and *Carissa spinarum* that are rich in CT (Jan et al., 2015). The biochemical parameters of calcium and phosphorus were evaluated during the 90 days of the experiment and the calcium content was maintained in the three groups studied (infected-untreated, infected-treated, and uninfected) within the reference values, differing from the results found in the present study because after day 15 of the experiment the calcium content was below the reference value. The phosphorus results were similar to those found in our study, presenting values within the normal range (Jan et al., 2015).

The magnesium content was above the reference value (2.2–2.8 mg dL^{-1}) for sheep, showing no influence of *M. caesalpiniifolia* CT ingestion. The increase of magnesium did not cause major inconvenience, as is the case when it is decreased because hypomagnesia can lead to death of ruminants.

Table 4 shows the serum concentrations of total protein, albumin, ceruloplasmin, transferrin, haptoglobin, and α1-acid glycoprotein.

Table 4
Mean ± standard deviation of total protein (PT), albumin (Alb), ceruloplasmin (Cer), transferrin (Tra), haptoglobin (Hap) and α1-acid glycoprotein (α1-G) evaluated on days 1, 8, 15, 22 and 28 of experiment in goats infected with gastrointestinal nematodes and treated with condensed tannin of *Mimosa caesalpiniifolia*

Variable	Group	Day 1	Day 8	Day 15	Day 22	Day 28
PT (g L^{-1})	CT	6.1±0.8	5.8±1.3	6.4±0.6	5.5±1.2	5.2±1.6
	CT+PEG	5.9±1.2	5.3±1.6	5.6±1.5	4.9±1.9	5.5±1.6
	Negative	6.1±0.8	5.7±1.6	5.9±1.4	6.0±1.9	4.4±1.7
	Monepantel	6.2±0.7	6.2±0.4	7.0±1.1	6.2±1.4	6.0±1.3
Alb (g dL^{-1})	CT	3.8±0.9	3.2±1.1	3.6±0.8	3.3±1.0	2.8±0.9
	CT+PEG	3.4±1.0	3.1±1.3	3.2±1.1	2.8±1.6	3.4±0.7
	Negative	3.4±0.7	3.1±1.2	3.3±1.1	3.3±1.4	2.7±0.9
	Monepantel	3.7±0.7	3.5±0.6	3.9±0.8	3.7±1.2	3.4±1.0
Cer (mg dL^{-1})	CT	12.0±5.8	21.6±6.3	22.7±10.2	13.7±4.6	28.1±13.6
	CT+PEG	19.5±11.3	23.0±4.4	23.8±11.8	26.6±11.3	26.4±10.7
	Negative	18.6±9.9	21.2±5.7	24.9±12.0	30.3±16.7	30.2±21.4
	Monepantel	12.4±5.0	20.4±9.9	22.8±9.6	17.3±6.5	29.5±8.2
Tra (mg dL^{-1})	CT	330.3±98.6	388.0±90.4	375.4±131.4	388.9±66.0	209.5±120.8
	CT+PEG	349.6±36.8	331.9±109.2	466.7±156.1	312.4±95.5	246.5±94.0
	Negative	334.9±70.7	344.0±107.9	407.9±115.0	393.9±108.8	224.4±118.5
	Monepantel	394.7±87.9	388.6±135.7	495.6±79.2	301.8±128.7	225.4±91.1
Hap (mg dL^{-1})	CT	24.1±6.2	19.7±8.6	29.2±9.2	24.7±9.6	20.6±7.5
	CT+PEG	28.9±6.3	30.3±13.0	26.6±7.1	23.1±7.2	22.1±5.5
	Negative	25.1±2.8	25.7±10.5	33.6±14.1	20.6±6.3	17.2±9.5
	Monepantel	23.9±4.9	20.1±3.6	33.5±10.4	29.3±12.9	22.4±7.7
α_1**-G**(mg dL^{-1})	CT	30.9±20.5	40.9±16.4	44.5±24.9	32.5±10.4	37.4±18.3
	CT+PEG	51.3±33.9	56.2±23.8	58.4±33.0	56.2±36.7	54.9±41.3
	Negative	55.5±23.4	50.6±44.0	36.4±13.3	48.7±37.9	36.6±24.5
	Monepantel	33.1±17.4	41.6±28.2	64.7±39.2	47.7±34.6	40.9±15.3

CT - condensed tannin; CT + PEG - condensed tannin with the addition of polyethylene glycol.
There was no significant difference between group means by Tukey test (p> 0.05).

All groups showed a decrease in total protein concentration on all the days surveyed, except for the monepantel group, which at all times maintained its total protein within the reference value range, which for goats is 6.0 to 7.5 g dL^{-1} (Jain, 1993). There was no statistically significant difference among the groups (P > 0.05). Total protein concentration is decreased in liver failure, intestinal and renal disorders, bleeding, or food deficiency (González & Silva, 2008). This may explain the total protein values below the normal range for the CT, CT + PEG, and negative control groups because all presented a high FEC throughout the experiment. No clinical signs were observed due to the low total protein concentration; however, these alterations may have manifested subclinically.

Protein parameters were evaluated in goats infected with gastrointestinal nematodes and treated with *Agave sisalana* juice (Domingues et al., 2010). Two groups of animals were treated with 0.92 g kg^{-1} *A. sisalana* for 4 and 8 days and one group was treated with doramectin at 200 µg kg^{-1}. There was no significant difference among the groups and an average of 7.2, 6.8, and 7.8 g dL^{-1} of total protein, respectively, was found. The proteinogram of goats of the Pardo-alpina breed naturally infected with gastrointestinal parasites was evaluated by Fernández et al. (2006) and animals with FEC above 5,000 had a total protein concentration below 6.0 g

dL^{-1}, corroborating the results found in the present study, except for the monepantel-treated group.

Fausto et al. (2014) evaluated total protein and albumin in lambs experimentally infected with *H. contortus* and supplemented with selenium and copper. All four groups surveyed (selenium-supplemented, copper- and selenium-infected, and untreated-infected) showed total protein within the reference value for sheep species, with a statistically significant difference between the selenium- and copper-supplemented group with other groups. This group had higher values for total protein and a lower FEC compared to other groups. Albumin remained within the reference range and the selenium- and copper-supplemented group had the highest values, with no statistical difference between the groups ($P > 0.05$).

The serum albumin content for all groups was within the normal range for goat species (2.7–3.9 g dL^{-1}). There was no significant difference among the groups ($P > 0.05$). These results are similar to those found by Katiki et al. (2011), who also observed albumin within the normal range for lambs experimentally infected with *H. contortus* and treated with *C. schoenanthus* essential oil at 180 and 360 mg kg^{-1}. However, in goats infected with gastrointestinal nematodes, with an average of 4,613 larvae per gram of feces of the genus *Haemonchus*, an average albumin content of 2.4 g dL^{-1} was found, differing from those found in the present study (Fernández et al., 2006).

Ceruloplasmin is a protein that increases its serum concentration in response to the infection process and is known as a positive acute phase protein. Transferrin, on the other hand, decreases its serum concentration under the same stimulus and is named an acute negative phase protein (Thomas, 2000). Ceruloplasmin increased in all groups from an average of 15.6 mg dL^{-1} on day 1 to an average of 28.5 mg dL^{-1} on day 28, remaining within the reference values of 9.2 to 59.5 mg mL^{-1} (Saut et al., 2009; Thomas, 2000) for goat species. This result is compatible with gastrointestinal nematode infection in the groups studied, even the monepantel group that had a low FEC at the end of the experiment, suggesting that there was a short time for the animals in the positive group to re-establish the concentration of such proteins. However, serum transferrin concentration decreased over the experimental period for all groups (reference value: 233.0 to 651.9 mg mL^{-1}) (Saut et al., 2009; Simplício, 2011), presenting a mean on day 1 of 341.1 mg dL^{-1} and on day 28 of 226.4 mg dL^{-1}, corroborating the literature reporting its decrease in infection/inflammation situations, due to the mechanisms that develop anemia. There was no statistically significant difference among the groups for ceruloplasmin and transferrin ($P > 0.05$).

There are few studies showing proteinograms in goats, previous studies have mainly concentrated on animals infected by gastrointestinal parasites. Heptoglobin did not change significantly, as the average on day 1 was 25.5 mg dL^{-1} and on day 28 was 20.6 mg dL^{-1}, remaining within the reference value range, which is from 16.88 to 31.95 mg mL^{-1} for goats (Saut et al., 2009). The negative group, which had a high FEC, had a decreasing haptoglobin concentration throughout the experiment, contradicting previous studies that affirmed the increase of this protein was due to the infection process. The α1-acid glycoprotein protein showed similar results to that of haptoglobin, as it did not change significantly either, with an average of 42.7 mg dL^{-1} on day 1 and 42.4 mg dL^{-1} on day 28 (reference value: 2.52 to 40.0 mg mL^{-1}) (Saut et al., 2009). There was no statistically significant difference for haptoglobin and α1-acid glycoprotein among the groups studied ($P > 0.05$).

Conclusion

The use of *M. caesalpiniifolia* CT for the treatment of goats infected by gastrointestinal nematodes did not significantly alter the hematological, biochemical, and serum proteinogram parameters.

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Referências

Athanasiadou, S., Kyriakis, I., Jackson, F., & Coop, R. L. (2001). Direct anthelmintic effects of condensed tannins towards different gastrointestinal nematodes of sheep: *in vitro* and *in vivo* studies. *Veterinary Parasitology*, *99*(3), 205-219. doi: 10.1016/S0304-4017(01)00467-8

Barbosa, H. P. (1997). *Tabela de composição de alimentos do estado da Paraíba, "setor agropecuário"*. João Pessoa: FAPEP/UFPB.

Barioni, G., Fonteque, J.H., & Paes, P. R. O. (2001). Valores séricos de cálcio, fósforo, sódio, potássio e proteínas totais em caprinos fêmeos da raça parda alpina. *Ciência Rural*, *31*(3),435-438. doi: 10.1590/S0103-84782001000300011

Bezerra, L. R., Ferreira, A. F., Camboin, E. K. A., Justiniano, S. V., Machado, P. C. R., & Gomes, B. B. (2008). Perfil hematológico de cabras clinicamente sadias criadas no Cariri Paraibano. *Ciência e Agrotecnologia*, *32*(3), 955-960. doi: 10.1590/S1413-70542008000300037

Botura, M. B., Silva, G. D., Lima, H. G., Oliveira, J. V. A., Souza, T. S., Santos, J. D. G.,... Batatinha, M. J. M. (2011). In vivo anthelmintic activity of an aqueous extract from sisal waste (*Agave sisalana* Perr.) against gastrointestinal nematodes in goats. *Veterinary Parasitology*, *177*(1-2),104-110. doi: 10.1016/j.vetpar.2010.11.039

Cardoso, E. C. I., Oliveira, D. R., Dourado, A. P., Araújo, C. V., Ortalani, E. L., & Brandão, F. Z. (2010). Peso e condição corporal, contagem de OPG e perfil metabólico sanguíneo de ovelhas da raça Santa Inês no periparto, criadas na região da Baixada Litorânea do Estado do Rio de Janeiro. *Revista Brasileira de Ciência Veterinária*, *17*(2),77-82. doi: 10.4322/rbcv.2014.148

Castro, A., Dhindsa, D. S., & Hoversland, A. S. (1977). Serum proteins and protein electrophoretic pattern in normal pygmy goats. *American Journal of Veterinary Research*, *38*(5), 665-667.

Coles, E. H. (1984). *Patologia clínica veterinária* (3th ed.). São Paulo: Editora Manole.

Costa, C. T. C., Bevilaqua, C. M. L., Maciel, M. V., Camurça-Vasconcelos, A. L. F., Morais, S. M., Monteiro, M. V. B.,... Souza, M. M. C. (2006). Anthelmintic activity of *Azadirachta indica A. Juss* against sheep gastrointestinal nematodes. *Veterinary Parasitology*, *137*(3-4),306-310. doi: 10.1016/j.vetpar.2006.01.002

Domingues, L. F., Botura, M. B., Cruz, A. C. F. G., Yuki, C. C., Silva, G. D., Costa, M. S.,... Batatinha, M. J. M. (2010). Evaluation of anthelmintic activity of liquid waste of *Agave sisalana* (sisal) in goats. *Revista Brasileira de Parasitologia Veterinária*, *19*(4),270-272. doi.org/10.1590/S1984-29612010000400018

Fausto, G. C., Pivoto, F. L., Costa, M. M., Lopes, S. T. A., França, R. T., Molento, M. B.,... Leal, M. L. R. (2014). Protein profile of lambs experimentally infected with *Haemonchus contortus* and supplemented with selenium and copper. *Parasites & Vectors*, *355*(7), 1-6. doi: 10.1186/1756-3305-7-355

Fernández, S. Y., Jesus, E. E. V., Paule, B. J. A., Uzêda, R. S., Almeida, M. A. O., & Guimarães, J. E. (2006). Proteinograma de caprinos da raça Pardo-Alpina infectados naturalmente por parasitos gastrintestinais. *Arquivos Brasileiros de Medicina Veterinária e Zootecnia*, *58*(2), 279-282. doi: 10.1590/S0102-09352006000200019

González, F. H. D., & Scheffer, J. F. S. (2002). Perfil sanguíneo: ferramenta de análise clínica, metabólica e nutricional. In González, F. H. D., & Scheffer, J. F. S. *Avaliação metabólico-nutricional de vacas leiteiras por meio de fluidos corporais* (Chap. 1, pp. 5-17). Porto Alegre: UFRGS.

González, F. H. D., & Silva, S. C. (2008). *Patologia clínica veterinária: texto introdutório*. Porto Alegre: UFRGS.

González, F. H. D., Barcellos, J., & Patiño, H. O. (2000). *Perfil metabólico em ruminantes - seu uso em nutrição e doenças nutricionais*. Porto Alegre: UFRGS.

Gwaze, F. R., Chimonyo, M., & Dzama, K. (2010). Relationship between nutritionally-related blood metabolites and gastrointestinal parasites in Nguni goats of South Africa. *Asian-Australasian Journal Animal Science*, *23*(9),1190-1197. doi: 10.5713/ajas.2010.90547

Jain, N. C. (1993). *Essentials of Veterinary Hematology*. Philadelphia: Lea e Febinger.

Jan, O. Q., Kamili, N., Ashraf, A., Iqbal, A., Sharma, R. K., & Rastogi, A. (2015). Haematobiochemical parameters of goats fed tannin rich *Psidium guajava* and *Carissa spinarum* against *Haemonchus contortus* infection in India. *Journal Parasitic Diseases*, *39*(1),41-48. doi: 10.1007/s12639-013-0278-5

Kaneko, J. J., Harvey, J. W., & Bruss, M. L. (1997). *Clinical biochemistry of domestic animals* (5th ed.). San Diego: Academic Press.

Katiki, L. M., Chagas, A. C. S., Takahira, R. K., Juliani, H. R., Ferreira, J. F. S., & Amarante, A. F. T. (2011). Evaluation of *Cymbopogon schoenanthus* essential oil in lambs experimentally infected with *Haemonchus contortus*. *Veterinary Parasitology*, *186*(3-4),312-318. doi: 10.1016/j.vetpar.2011.12.003

Laemmli, U. K. (1970). Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature*, *277*(5259), 680-685. doi: 10.1038/227680a0

Mattos, M. J. T., Oliveira, C. M. B., Lustosa, A., Lacerda, L. A., & Terra, S. (2005). Influência do parasitismo por nematódeos sobre o perfil hematológico de caprinos. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, *57*(1), 133-135. doi: 10.1590/S0102-09352005000100018

Nelson, D. L., & Cox, M. M. (2002). *Leninger princípios de bioquímica* (3th ed.). São Paulo: Câmara Brasileira do Livro.

Pimentel-Gomes, F. (1987). *Curso de estatística experimental* (12th ed.). Piracicaba: Nobel.

Roberto, J. V. B., Souza, B. B., Silva, A. L. N., Justiniano, S. V., & Freitas, M. M. S. (2010). Parâmetros hematológicos de caprinos de corte submetidos a diferentes níveis de suplementação no semiárido paraibano. *Revista Caatinga*, *23*(1), 127-132.

Roberts, F. H. S., & O'Sullivan, J. P. (1950). Methods for egg counts and larval cultures for strongyles infesting the gastrointestinal tract of cattle. *Australian Journal of Agricultural Research*, *1*(1), 99-102. doi: 10.1071/AR9500099

Sacks, D. B. (1998). Glicídeos. In: C. A. Burtis & E. R. Ashwood (Eds.). *Fundamentos de química clínica* (4th ed., Chap. 7, pp. 341-363). Rio de Janeiro: Guanabara Koogan.

Saut, J. P. E., Souza, R. M., Birgel, D. B., Pogliani, F. C., Cavalcante, C. Z., Miyashiro, S. I.,... Birgel, E. H., Jr. (2009). Influência do puerpério sobre o proteinograma sérico de caprinos da raça Saanen obtido por eletroforese em gel de poliacrilamida. *Semina: Ciências Agrárias*, *30*(3), 661-670. doi: 10.5433/1679-0359.2009v30n3p661

Sharma, D. K., Chauhan, P. P. S., & Agrawal, R. D. (2001). Changes in the levels of serum enzymes and total protein during experimental haemonchosis in Barbari goats. *Small Ruminant Research*, *42*(2), 119-123. doi: 10.1016/S0921-4488(01)00241-3

Silva, C. F., Lôbo, K. M. S., Athayde, A. C. R., Silva, W. W., Lima, E. Q., & Pequeno, N. F. (2011). Avaliação da resposta hematológica dos animais tratados com *Typha domingensis Pers e Operculina hamiltonii* sobre nematoides gastrintestinais de caprinos. *Ciência e Agrotecnologia*, *35*(3), 568-574. doi: 10.1590/S1413-70542011000300019

Silva, E. M. N., Souza, B. B., Silva, G. A., Cézar, M. F., Freitas, M. M. S., & Benício, T. M. A. (2008). Avaliação hematológica de caprinos exóticos e nativos no Semiárido Paraibano. *Ciência e Agrotecnologia*, *32*(2), 561-566. doi: 10.1590/S1413-70542008000200033

Silva, S. L., Fagliari, J. J., & Cesco, F. T. R. S. (2004). Atividade sérica das enzimas AST, ALP e GGT de caprinos das raças anglo-nubiana e saanen criados nos estados de São Paulo e Paraíba. *Ars Veterinaria*, *20*(1), 22-27.

Simplício, K. M. M. G. (2011). *Leucograma e proteínas de fase aguda de ruminantes domésticos sadios e enfermos*. Dissertação mestrado, Universidade Estadual Paulista, Jaboticabal, SP, Brasil.

Simplício, K. M. M. G., Cotrim, F., Fagliari, J. J., & Nogueira, C. A. S. (2009). Perfil bioquímico de cabras lactantes das raças saanen e anglo-nubiana. *Ciência Animal Brasileira*, Suplemento 1, 266-270.

Thomas, J. S. (2000). Overview of plasma proteins. In: B. F. Feldman, J. G. Zinkl & N. C. Jain. *Schalm's veterinary hematology* (5th ed., Chap. 15, pp. 891-898). Philadelphia: Blackwell Publishing.

Ueno, H., Gonçalves, P. C. (1998). *Manual para diagnóstico das Helmintoses de ruminantes* (4th ed.). Tókio: JICA.