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REGULAR ARTICLES

Organic selenium supplementation on metabolic profile of dairy goats

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Abstract

The aim of this study was to evaluate the effect of organic selenium (SE) supplementation on blood constituents related to hematology and serum biochemistry of dairy goats in the productive phase. A total of 16 lactating Saanen × Toggenburg crossbred goats, aged between 2 and 3, lactating, nonpregnant, clinically healthy, and having a body weight (BW) of 40.75 ± 8.31 kg were selected for this study. Higher SE concentrations were observed on the 42nd day of supplementation, and on the 63rd day, the SE concentrations were similar ($P > 0.05$) to the 21st and 42nd days. There was no interaction for plasma constituents comparing treatment effects and days of supplementation ($P > 0.05$). SE supplementation reduced ($P = 0.04$) plasma proteins with a gradual increase in available SE. There was no difference ($P > 0.05$) for the blood count comparing the effects of treatment and days of supplementation. There was no interaction ($P > 0.05$) for serum biochemical constituents between treatments and periods, except for urea ($P = 0.045$). Animals that received SE supplementation had similar plasma urea concentrations before and after supplementation, while animals that did not receive SE in the diet had increased serum urea concentrations. The main action of selenium in metabolism occurred in the reduction of plasma proteins and urea levels, which leads us to conclude that it influenced protein metabolism. Finally, hematology, liver function, and energy metabolism are not affected by selenium supplementation in dairy goats reared in semiarid conditions.

Keywords Blood tests · Homeothermy · Immunity · Lactation · Metabolism · Semiarid region

Introduction

Nutritional management strategies are essential to increase the production rates of farms, especially in production systems that are located in arid and semiarid regions of the world (Silveira et al., 2022). Although there is a tendency to breed locally adapted dairy goats in the northeast regions of Brazil, the existing production systems rely on a large number of animals from temperate climates, such as the Saanen, Toggenburg, and Parda Alpina breeds (Paiva et al., 2020).

Physiological changes for ruminants are generally associated with nutritional management (Ferreira et al., 2019; Silveira et al., 2021a), genetic characteristics such as the presence and/or expression of genes (Berihulay et al., 2019; Hooper et al., 2019), and environmental fluctuations that combine ambient temperature and relative humidity (Ferreira et al., 2020; Silveira et al., 2021b). The semiarid environment is characterized by high temperature and intense solar radiation throughout the year, which favors physiological changes in animals and consequently affects

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feed intake and reduction in milk production and favors the appearance of some diseases and/or metabolic disorders (Façanha et al., 2020).

Organic selenium (SE) has been used in studies which have evaluated the productive characteristics of dairy goats and their adaptation to the climatic environment of production systems. The study by Silveira et al. (2021a) found that Saanen dairy goats supplemented with SE raised erythrocyte values, allowing greater oxygenation in tissues and organs, suggesting a beneficial effect for homeothermy. Supplementation with SE is also associated with a decrease in plasma levels of blood constituents, as is the case with cortisol in the study by Dimri et al. (2010). As a mineral present in all tissues of the body and which acts as an antioxidant through the enzyme called glutathione peroxidase (GPx), SE has the function of protecting cells and preventing the formation of free radicals, in addition to assisting in the metabolism of thyroid hormones (Chauhan et al., 2014). Decreased SE concentrations associated with changes in blood metabolite concentrations may be indicative of liver problems and may also be associated with muscle development problems (Sobiech & Żarczyńska, 2020). Even so, few studies have evaluated its relationship with blood constituents (erythrogram and leukogram), which is something important because it represents the health status of the animal. The hypothesis of this study is that dairy goats supplemented with SE in their diet have an increase in serum selenium concentration and an alteration in the metabolic and hematological profile.

Therefore, the aim of this study was to evaluate the effect of SE supplementation on blood constituents related to hematology and serum biochemistry of dairy goats in the productive phase.

Material and methods

Experimental location

This study was conducted at an experimental farm in the Center for Studies and Research of Small Ruminants (*Centro de Estudo e Pesquisa de Pequenos Ruminantes*) of the *UVA*, Sobral city, Ceará, Brazil. The climate in the region is tropical semiarid (BSw'h-Koppen climate classification) with the occurrence of two periods throughout the year: rainy (January to June) and dry (July to December) according to (Alvares et al., 2013).

Animals

A total of 16 lactating Saanen × Toggenburg crossbred goats, aged between 2 and 3 years, lactating, nonpregnant, clinically healthy, and having a body weight (BW) of 40.75 ± 8.31 kg were selected for this study.

General management

These animals were submitted to a breeding station over a period of 30 days. The animals (females and males) remained in native pasture daily during the evaluation period where they were directly exposed to solar radiation, like the management system adopted in the commercial farms located in the studied region, as described by Façanha et al. (2020). The animals were later contained in a sheepfold partially covered with ceramic tiles and cement flooring in the afternoon, with an east–west orientation and a beaten-floor solarium which received direct solar radiation, and they were fed a concentrated diet associated with a mineral mixture (250 g/animal, in which 90.68% ground corn, 8.44% soybean meal, and 0.88% limestone). Males remained together with females only during the breeding period. The pregnancy of sixteen goats was confirmed after breeding using a portable veterinary ultrasound system (Kx5000, Xuzhou Kaixin Electronic Instrument). The parturition was accompanied by a professional, and the offspring remained together with the goats until the sixth day of life (colostral phase).

Diet management and experimental design

Dairy goats were distributed into two randomization treatments on the 7th day after parturition. The two animal groups received a basal diet with a ratio of 70:30%, composed of corn-based concentrate (68.7%), soybean meal (30.40%), and limestone (0.9%) during the experimental period, as recommended by the NRC (2007), with one of the groups having 0.04 g animal^{-1} day^{-1} of SE in the supplemented treatment. The diet adaptation period was 7 days. The individual total feed was 500 g/animal/day offered in two periods (7 a.m. and right after milking), as described in Table 1. Water and mineral salt were supplied ad libitum.

Salinized yeast is a pure culture of *Saccharomyces cerevisiae* that is obtained from a specially selected strain. According to the recommendations of the supplier, 15 g of yeast should be added per 100 kg of concentrate. The product's physical–chemical traits are as follows: proteins (N × 6.25) g/100 g = min. 45.0; humidity (105 ± 2 °C) g/100 g = max. 8.0; pH (10% solution) = 5.0–7.5; fat (total) g/100 g = 5–8; ash (total) g/100 g = max. 8.0; density g/l = min. 420; gross fiber g/100 g = max. 3.0; total selenium (ppm) = min. 2000; organic selenium% = min 98.0; if methionine/SE total% = > 70.0. Regarding the microbiological characteristics, total colony-forming units (CFU)/g = ≤ 10,000; total coliforms, bacterial burden most probable number (MPN)/g = ≤ 10; thermotolerant coliform MPN/g = absent; molds/yeasts FCU/g = ≤ 100; *E. coli* MPN/g = absent; salmonella/375 g = absent.

Table 1 Chemical composition, in vitro digestibility, and organic selenium (*SE*) contents of dietary components provided to the dairy goats during the experimental period

Nutrient (%)	Roughage*	Native pasture**	Concentrate
Dry matter[1]	92.70	94.00	91.10
Organic matter	90.70	91.70	96.70
Ash	9.30	7.80	3.00
Crude protein	3.90	4.20	20.90
Ether extract	1.60	5.00	2.80
Neutral detergent fiber	63.20	60.20	57.10
Acid detergent fiber	41.10	39.80	9.70
Cellulose	23.1	21.10	48.60
Lignin	2.60	2.20	1.90
In vitro digestibility	35.90	33.50	91.80
TDN[2]	59.97	67.26	72.68
ADIN[3]	0.20	0.90	0.40
NDIN[4]	0.50	1.10	2.10
Selenium (mg/kg)	0.24	0.51	0.52

*50% elephant grass (*Pennisetum purpureum Schum.*) and 50% sugarcane (*Saccharum officinarum*)

**Commelina diffusa Burm. F*, *Stylosanthes humilis*, *Ipomoea glabra Choisy*, *Hyptis suaveolens*, *Mimosa caesalpiniaefolia Benth*, *Auxemma oncocalyx*, and *Zizyphus joazeiro*

[1]Dried at 105 °C

[2]Total digestible nutrients

[3]Acid detergent insoluble nitrogen

[4]Neutral detergent insoluble nitrogen

Samples were collected from the native pasture using simulated grazing and a composite sample for the chemical and nutrient composition of the diet (Table 1). Methods described by AOAC (2019) were used to determine DM (method 930.15), ash (method 942.05), N content (Kjeldahl method 955.04), and ethereal extract (EE) (method 920.39). Organic matter (OM) was calculated as the difference between DM and ash content. The methodologies recommended by Van Soest et al. (1991) were used to determine neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, and lignin, with autoclave adaptations by Senger et al. (2008). The digestibility was performed according to the recommendations of Silva and Leão (1979) and Maynard et al. (1984). The total digestible nutrient (TDN) levels were estimated according to the National Research Council (2001), $TDN = CDP + (2.25 * EDE) + NFDC + DNDF - 7$, where CDP, EDE, NFDC, and DNDF, respectively, represent crude digestible protein, ethereal digestible extract, nonfibrous digestible carbohydrates, and digestible neutral detergent fiber. Acid detergent insoluble nitrogen (ADIN) and neutral detergent insoluble nitrogen (NDIN) were determined according to the recommendations of Van Soest et al. (1991).

Determination of SE in soil

Soil samples of the area where the animals were kept during feeding in pasture and in the planting areas of the forage offered in the trough were collected to determine the SE levels in the soil. Samples were collected at a depth of approximately 20 cm in a "zig-zag" direction, placed in sterile 50 mL falcon tubes, washed with deionized water, and dried in an oven at 39 °C. The samples were examined at the Biominerais Laboratory in Campinas, SP, using Inductively Coupled Plasma Atomic Emission Spectrometry (ICAP-6300 Thermo Scientific). The mean SE found in the soil was 0.132 mg/kg.

SE in blood

Four venous blood samples (5 mL each) were collected from fasting animals (12 h) in the morning using a vacuum system with heparinized tubes through jugular venipuncture. The samples were stored in isothermal boxes with recyclable ice and sent to determine the SE levels in the blood by Inductively Coupled Plasma Atomic Emission Spectrometry (ICAP-6300 Thermo Scientific). The collections followed the order 5th day postpartum (day zero, before starting treatments with SE supplementation), 21st day, 42nd day, and 63rd day, totaling 64 samples.

Hematological profile

Hematological tests using blood samples collected at 21, 42, and 63 days were performed at the *Veterinary Hospital of the Instituto Superior de Teologia Aplicada* (*INTA*). Plasma proteins (g/dL) and fibrinogen (g/dL) were evaluated, in addition to the erythrogram, based on an evaluation of the following variables: red blood cells ($\times 10^6$/µL), mean corpuscular volume (%), hemoglobin (g/dL), mean corpuscular hemoglobin (%), and mean corpuscular hemoglobin concentration (%). In addition, leukocytes ($\times 10^3$/µL), lymphocytes ($\times 10^3$/µL), eosinophils ($\times 10^3$/µL), and basophils ($\times 10^3$/µL) were analyzed for the leukogram.

Serum biochemical panel

Blood collections (5 mL) were performed before supplementation with SE to evaluate the serum biochemical panel and then on the 63rd day using a vacuum system with nonheparinized tubes through jugular venipuncture,

followed by centrifugation of all of the blood samples for 10 min and 3000 rpm for serum separation and later stored in 1.5 mL tubes and frozen. Serum samples were analyzed by BIOPLUS BIO-200 equipment. Thus, alanine aminotransferase (U/L), aspartate aminotransferase (U/L), alkaline phosphatase (U/L), urea (mg/dL) (kinetic method), creatinine (mg/dL) (kinetic calorimetric method), cholesterol (g/dL), triglycerides (mg/dL) (enzymatic calorimetric method), total protein (g/dL), and bilirubin (mg/dL) (calorimetric method) were determined.

Statistical analysis

First, exploratory analyses were performed for all variables under study. Outliers were identified in database through boxplots (± three standard deviations from the mean) and then imputed by the median of each variable. The effect of supplementation (SE or control) and supplementation period was considered fixed effect. The adopted design was completely randomized in a factorial arrangement using 16 experimental units. The following general linear model was used in the analysis:

$$Y_{ijk} = \mu + G_i + S_j + (G_i \times S_j) + e_{ijk}$$

where Y_{ijk} represents the responses of the set of dependent variables, μ is the general mean, G_i is the effect of the i th treatments (i = with or without selenium), S_j is the effect of the j th period (j = 0, 7, 21, 42, and 63 days), $G_i \times S_j$ is the interaction effect of treatments and periods, and e_{ijk} is the random error. The interactions were excluded from the initial model when they were nonsignificant.

The data were submitted to analysis of variance (ANOVA) to access the treatments, periods, and the interaction effects, and then, the means were compared using Tukey's test with 5% probability of error. Data were analyzed, curated, and processed using the SPPS software program (2012).

Results and discussion

Serum selenium

Higher SE concentrations ($P < 0.05$) were identified in animals that received micromineral supplementation (Table 2). Higher concentrations were observed on the 42nd day of supplementation, and on the 63rd day, the SE concentrations were similar ($P > 0.05$) to the 21st and 42nd days. Therefore, it is inferred that the SE concentration used in this study was sufficient to test our hypotheses and that significant changes were identified up to the 42nd day.

Table 2 Blood serum SE levels (μg/L) of dairy goats before and after supplementation with organic selenium (*SE*)

Treatments	Periods				Mean
	Day zero	21st day	42nd day	63rd day	
Without *SE*	89.88	116.50	134.50	130.87	117.94[b]
With *SE*	85.25	127.12	189.12	153.88	138.84[a]
Mean	87.56[c]	121.81[b]	161.81[a]	142.38[ab]	

[a–c]Different lowercase letters in the same column differ significantly by Tukey's test at 5% probability

Plasma constituents

There was no interaction for plasma constituents comparing treatment effects and days of supplementation ($P > 0.05$; Table 3). SE supplementation reduced ($P = 0.04$) plasma proteins with a gradual increase in available SE, resulting in the formation of the protein complex which reached a saturation point. With a reduction in serum concentrations of total proteins occurring when SE is administered to animals according to its availability, it can also be

Table 3 Blood plasma constituents of dairy goats supplemented with and without the inclusion of organic selenium (*SE*)

Treatments	Periods			Mean	SEM	*P* value		
	21st day	42nd day	63rd day			Period (P)	Treatment (T)	P×T
	Plasma proteins (g/dL)							
With *SE*	7.08	7.30	7.15	7.18[b]	0.128	0.48	0.04	0.58
Without *SE*	7.88	7.93	7.33	7.71[a]				
Mean	7.48	7.61	7.24					
	Fibrinogen (g/dL)							
With *SE*	237.5	275.0	250.0	254.17	12.97	0.75	0.76	0.51
Without *SE*	237.5	225.0	275.0	245.83				
Mean	237.5	250.0	262.5					

[ab]Different lowercase letters in the same column differ significantly ($P > 0.05$%) by Tukey's test at 5% probability

incorporated by selenoproteins, and GPx levels are consequently mainly regulated by selenocysteine levels (Ekholm et al., 1991). The findings in the literature on the influence of SE supplementation on plasma proteins are still very controversial. For example, Ziaei (2015) did not observe significant changes in plasma protein or albumin concentrations in Raieni goats supplemented with SE. However, Shi et al. (2018) observed an increase in plastic proteins and albumins in goats supplemented with the micromineral. We recommend investigations which evaluate the influence of SE on the digestibility and absorption of nutrients and indicators of liver metabolic stress to improve the clarification of results such as these.

Table 4 Erythrogram and white blood cell of dairy goats supplemented with and without the inclusion of organic selenium (*SE*)

Treatments	Periods			Mean	SEM	*P* value		
	21st day	42nd day	63rd day			Period (P)	Treatment (T)	P×T
Erythrogram								
	Red blood cell ($\times 10^6$/μL)							
With *SE*	10.94	10.63	11.06	10.88	0.36	0.80	0.41	0.97
Without *SE*	10.19	9.88	10.69	10.25				
Mean	10.56	10.25	10.88					
	Packet cell volume (%)							
With *SE*	21.38	21.25	22.13	21.58	0.72	0.67	0.37	0.91
Without *SE*	20.38	19.00	21.38	20.25				
Mean	20.88	20.13	21.75					
	Hemoglobin (g/dL)							
With *SE*	7.26	7.05	7.36	7.23	0.24	0.76	0.42	0.98
Without *SE*	6.86	6.50	7.09	6.82				
Mean	7.06	6.78	7.23					
	Mean corpuscular mean (%)							
With *SE*	20.00	20.00	20.00	20.00	0.0	0.38	0.32	0.38
Without *SE*	20.00	20.00	20.00	20.00				
Mean	20.00	20.00	20.00					
	Mean corpuscular hemoglobin concentration (%)							
With *SE*	33.20	33.18	33.25	33.21	0.18	0.26	0.29	0.27
Without *SE*	33.24	33.13	33.15	33.17				
Mean	33.22	33.15	33.20					
Leukogram								
	White blood cell ($\times 10^3$/μL)							
With *SE*	11,819.25	13,131.63	13,393.88	12,781.58	493.66	0.47	0.81	0.96
Without *SE*	10,795.50	12,961.00	13,243.25	12,333.25				
Mean	11,307.38	13,046.31	13,318.56					
	Eosinophil ($\times 10^3$/μL)							
With *SE*	2601.88	1995.75	2589.63	7187.25	190.96	0.49	0.73	0.87
Without *SE*	2294.75	2225.38	2113.63	6633.75				
Mean	4896.63	4221.13	4703.25					
	Basophils ($\times 10^3$/μL)							
With *SE*	0.00	0.00	0.00	0.00	0.00	–	–	–
Without *SE*	0.00	0.00	0.00	0.00				
Mean	0.00	0.00	0.00					
	Lymphocytes ($\times 10^3$/μL)							
With *SE*	3791.13	4669.75	3644.75	12,105.63	233.27	0.30	0.72	0.96
Without *SE*	3800.00	4468.00	3857.38	12,125.38				
Mean	3795.56	4568.88	3751.06					

[a,b]Different lowercase letters in the same column differ significantly by Tukey's test at 5% probability

Table 5 Serum biochemical panel of dairy goats supplemented with and without organic selenium (*SE*)

Treatments	Periods		Mean	SEM	*P* value		
	Day zero	63rd day			Period (P)	Treatment (T)	P×T
	Alanine aminotransferase (UI/L)						
With *SE*	13.36	11.81	12.59	0.80	0.48	0.60	0.83
Without *SE*	13.89	13.06	13.48				
Mean	13.63	12.44					
	Aspartate aminotransferase (UI/L)						
With *SE*	78.54	70.66	74.60	3.75	0.84	0.14	0.21
Without *SE*	80.25	91.19	85.72				
Mean	79.39	80.93					
	Alkaline phosphatase (UI/L)						
With *SE*	56.55	56.23	56.39	2.91	0.95	0.75	0.91
Without *SE*	57.84	58.95	58.39				
Mean	57.19	57.59					
	Creatine (mg/dL)						
With *SE*	1.04	1.09	1.06	0.23	0.14	0.14	0.68
Without *SE*	0.95	1.04	0.99				
Mean	0.99	1.06					
	Urea (g/dL)						
With *SE*	39.24^{aA}	35.74^{aA}	37.49	1.39	0.43	0.74	0.04
Without *SE*	32.68^{aB}	40.51^{aA}	36.59				
Mean	35.96	38.13					
	Total protein (g/dL)						
With *SE*	7.96	7.54	7.75	1.92	0.89	0.54	0.42
Without *SE*	7.88	8.18	8.03				
Mean	7.92	7.86					
	Total bilirubin (mg/dL)						
With *SE*	0.14	0.14	0.14	2.28	0.44	0.80	0.44
Without *SE*	0.13	0.16	0.14				
Mean	0.13	0.15					
	Right bilirubin (mg/dL)						
With *SE*	0.05	0.04	0.04	0.21	0.81	0.11	0.81
Without *SE*	0.09	0.09	0.09				
Mean	0.07	0.06					
	Left bilirubin (mg/dL)						
With *SE*	0.10	0.10	0.10	0.11	0.76	0.14	0.76
Without *SE*	0.06	0.08	0.07				
Mean	0.08	0.09					
	Cholesterol (g/dL)						
With *SE*	46.04	45.20	45.62	0.13	0.890	0.183	0.940
Without *SE*	40.40	40.15	40.28				
Mean	43.22	42.67					
	Triglyceride (mg/dL)						
With *SE*	34.25	33.56	33.91	0.01	0.805	0.106	0.924
Without *SE*	27.13	25.56	26.34				
Mean	30.69	29.56					

[a,b]Different lowercase letters in the same column differ significantly by Tukey's test at $P < 0.05$ probability

[A,B]Different uppercase letters in the same line differ significantly by Tukey's test at $P < 0.05$ probability

Hematology

There was no difference ($P > 0.05$) for the erythrogram comparing the effects of treatment and days of supplementation (Table 4). Moreover, there was no difference ($P > 0.05$) between treatments and periods for any variable evaluated. Studies evaluating the effect of dietary supplementation of SE-enriched yeasts on the hematological values of lactating goats are quite limited in the literature. In the present study, SE did not affect the red blood cell count, which corroborates the study by Shi et al. (2018) in native goats. Contrary to our results, Silveira et al. (2021a) reported that SE supplementation increased some constituents of the erythrogram of Saanen goats, but the major limitation of this study is that the authors did not evaluate the effect of SE supplementation on erythrocytes, while they did evaluate the supplementation period (0, 21, and 42 days). Therefore, the reduction observed at 42 days in both groups (with and without SE supplementation) may be related to heat stress (for example, hemoconcentration) and not to the effect of SE supplementation, since the variation in blood constituents is multifactorial (Habibu et al., 2018).

Interestingly, the WBC constituents were not influenced by SE supplementation in the present study, but there are studies in literature which report an increase in leukocytes in animals supplemented with the micromineral. This is because SE is the cofactor of glutathione peroxidase, a potent antioxidant that protects cells from oxidative stress damage (Wang et al., 2020). Recently, Shi et al. (2018) reported that the increase in leukocytes in pregnant goats supplemented with SE is justified by the increase in lymphocytes and monocytes. However, the authors point out that there are controversial results in literature, and they report that the increase in the body's defense cells depends on several factors such as animal species, sex, age, physiological condition, level, and SE source in the diet.

Serum biochemistry

There was no interaction ($P > 0.05$) for serum biochemical constituents between treatments and periods, except for urea ($P = 0.045$; Table 5). Animals that received SE supplementation had similar plasma urea concentrations before and after supplementation, while animals that did not receive SE in the diet had increased serum urea concentrations, inferring that SE prevented the reduction of urea. This result corroborates the study by Taheri et al. (2018), who observed that SE supplementation in the diet of lactating goats affects nitrogen utilization in lactating goats.

The values of creatinine, protein, and bilirubin (direct and indirect) presented values equivalent to those of Kaneko et al. (1989). On the other hand, cholesterol and triglycerides, both indicators of energy intake, were also not influenced by SE supplementation. This result corroborates the study by Ziaei (2015) who evaluated the effect of SE supplementation on these variables and did not observe differences with the control group (without supplementation).

ALT, AST, and alkaline phosphatase values present concentrations below the reference values proposed by Kaneko et al. (1989). Interestingly, these enzymes are indicators of liver functionality, where the metabolism of proteins and nitrogenous compounds occurs, which was influenced by SE supplementation, but we did not find any influence of the micromineral on these parameters. For Mehdi and Dufrasne (2016), a large proportion of selenium is directed to the liver during its absorption, which is considered a selenium storage organ. Selenium accumulates in the liver; in the case of excess selenium compared to requirements, part of the selenium stored in the liver is excreted in the bile. Another more important part is excreted by the kidneys. Therefore, since we found no change in the biochemical profile, we can infer that the SE dosage used in this study was not sufficient to observe the antioxidant effect of SE in the metabolic profile of the animals under study, even with higher concentrations in the SE supplementation period (Table 2).

Finally, caution is needed in order to interpret these results, since the animals under study are adapted to climatic conditions and semiarid pastures and the negative effects caused by SE deficiency can be minimized because of the long-term physiological adaptation to the environment.

Conclusions

The main action of selenium in metabolism occurred in the reduction of plasma proteins and urea levels, which leads us to conclude that it influenced protein metabolism. Finally, hematology, liver function, and energy metabolism are not affected by selenium supplementation in dairy goats reared in semiarid conditions.

Author contribution A.M. de Vasconcelos, M.R.C. Rios, T.P. Martins, and J.M. Bonfim: conceptualization, data collection, data curation, data analysis, methodology, writing (original draft), text editing, and final review. Y.A. Magalhães, RR. Pinheiro, M.C.P. Rogério, and D.A.E. Façanha: data curation, methodology, writing (original draft), and final review. J. Ferreira and R.M.F. Silveira: data curation, data analysis, writing (original draft), text editing, and final review.

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Data availability Not applicable.

Code availability Not applicable.

Declarations

This work was carried out as a result of the Master in Animal Science of Marcelo Rezende de Carvalho Rios (2018).

Ethics approval This experiment was approved by the Ethics Committee of the State University of Acaraú Valley (*UVA*) (process number: 004.04.014.*UVA*. 504.01).

Consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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