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Tannins in the diet for lactating goats from different genetic groups in the Brazilian semiarid: Nitrogen, energy and water balance

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A R T I C L E I N F O

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A B S T R A C T

This study aimed to evaluate intake, milk production, nitrogen balance, energy balance, and water balance of lactating goats given diets with and without condensed tannin. Twenty-two multiparous, lactating goats, from three genotypes: 8 Saanen (49.05 ± 7.93 kg initial body weight; 1.38 kg milk/day), 8 Repartida (33.62 ± 1.92 kg initial body weight; 0.40 kg of milk/day) and 6 Canindé (36.48 ± 5.79 kg initial body weight; 0.38 kg milk/day), with an average age of 5 years and 30 days of lactation, were distributed in a factorial arrangement of 3 (genetic groups) x 2 (diets - control and with the inclusion of 5% tannin, on a dry matter basis). The experimental period lasted 30 days, with 25 days for adaptation of animals and 5 days for data collection. There was an effect of the genetic group for the intake of crude protein ($P = 0.001$) and neutral detergent fiber ($P = 0.009$), milk yield ($P = 0.002$); contents of ingested N, absorbed N, excreted N in urine and N in milk ($P < 0.05$); gross energy (GE) ingested, GE lost in urine, GE of milk produced and GE lost in digestion gases ($P < 0.05$); digestible energy ($P = 0.009$) and metabolizable energy ($P = 0.009$); water intake via drinking fountain, water intake via food, total water intake, water absorbed, water retained, water excretion via feces and water excretion via urine ($P < 0.05$). Tannin-added diets had greater excretion of water via feces ($P = 0.003$) and a higher concentration of retained water ($P = 0.013$). On the other hand, they provided a lower excretion of water via urine ($P = 0.040$) in relation to the control diet. There was an interaction effect between genetic groups and diets for the absorbed water: total water intake ($P = 0.010$) and retained water: total water intake ($P = 0.010$). In the experimental conditions, the inclusion of 5% CT in the diet for Repartida, Canindé and Saanen dairy goats do not affect the intake of dry matter and nutrients, or milk production. Nevertheless, it increased the efficiency of water use by animals. The genetic group has influence on intake, and nitrogen, energy and water balances.

Abbreviations: EB, energy balance; WB, water balance; NB, nitrogen balance; GE, gross energy; DE, digestible energy; ME, metabolizable energy; NDF, neutral detergent fiber; DM, dry matter; CP, crude protein; CT, condensed tannins.

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1. Introduction

Goats are known for their adaptation to survive in dryland regions, where food resources are heterogeneous and limited in quantity and quality. This is explained by the physiological and behavioral mechanisms that allow these animals to assess food resources through visual, tactile and chemosensory stimuli. The stimuli emit responses through anatomical and physiological adaptations (digestion and detoxification), generating preferences or aversions for different foods (Egea et al., 2019).

Forage plants consumed by small ruminants in semiarid regions contain nutrients that fully or partially meet the nutritional demand of animals (Abdalla Filho et al., 2017). Nevertheless, some forage plants have chemical defenses to reduce herbivory, such as secondary compounds. Tannins represent one of the secondary compounds commonly found in plants which have aroused interest in different areas of science (Adamczyk et al., 2017).

Tannins are polymers of phenolic compounds with high molecular weight (Lima et al., 2019), resulting from the secondary metabolism of plants. They provide a means of defense against bacteria, fungi, viruses, environmental stress and attack by herbivores, and can provide the plant with characteristics such as bitter taste, repulsive odor and causing intoxications or antinutritional effects in predators (Amesa and Asfaw, 2018). Among the tannins are condensed tannins (CT) or proanthocyanidins, found in forage legumes, trees and shrubs that occur in the Caatinga biome, with the property of forming hydrogen bonds with proteins and acting as antioxidants (Gesteira et al., 2018).

Condensed tannins are associated with reduced nutrient intake and digestibility (Mezzomo et al., 2011; Wang et al., 2018; Nawab et al., 2020) and animal performance (Naumann et al., 2017), when present at high concentrations (>55 g CT/kg DM; Mkhize et al., 2018). On the other hand, low levels of CT (15–40 g CT/kg DM; Pathak et al., 2017) are considered beneficial in the diet of small ruminants and may increase nitrogen use efficiency and milk production and decrease internal parasitic load and enteric methane (Lucena et al., 2018; Mkhize et al., 2018; Lima et al., 2019).

In the context of dairy goat farming, it is important to consider that the effects of CT on milk production and composition depend on factors such as its concentration, structure and molecular weight (Avila et al., 2020). In addition to these factors, it is convenient to consider the genotype, especially the most exploited goat genotypes for milk production in the semiarid region. In this sense, farmers in semiarid regions select dairy breeds, such as the Saanen. However, due to its low rusticity and greater predisposition to illnesses, goat breeds more adapted to semiarid climate and that are also good milk producers have been selected (Pequeno et al., 2017; Vasconcelos et al., 2019), such as the native breeds Canindé and Repartida.

The results on the use of tannin in diets for dairy goats are controversial (Abo-Donia et al., 2017; Lucena et al., 2018; Mkhize et al., 2018) and, to the best of our knowledge, inclusion of tannin in diets for dairy goats of different genetic groups in Brazilian semiarid regions has not been sufficiently studied. Thus, we hypothesized that the inclusion of 5% condensed tannins in diets for dairy goats of different genetic groups, increases the intake of proteins and the nitrogen content absorbed, and reduces the nitrogen content in feces. Thus, this study aimed to evaluate intake, milk production, nitrogen balance, energy balance and water balance of lactating goats given diets with and without tannin.

2. Material and methods

2.1. Experimental site and ethical aspects

The experiment was conducted in the facilities of the Laboratório de Exigência e Metabolismo Animal (LEMA), belonging to the Agricultural Sciences Campus of the Universidade Federal do Vale do São Francisco (UNIVASF), Petrolina, state of Pernambuco, Brazil (9º19'28" South latitude, 40º33'34" West longitude, 393 m altitude). The climate, according to the classification of Köppen and Geiger (1928), is hot semiarid, with rainy season (BSh), and average annual rainfall of 376 mm.

This study was approved and certified by the Ethics and Deontology Committee in Studies and Research of UNIVASF (protocol 0002/120215 - CEDEP/CEUA).

2.2. Animals, treatments and experimental diets

Twenty-two multiparous, lactating goats, from three genotypes: 8 Saanen (49.05 $\pm$ 7.93 kg initial body weight; 1.38 kg milk/day), 8 Repartida (33.62 $\pm$ 1.92 kg initial body weight; 0.40 kg of milk/day) and 6 Canindé (36.48 $\pm$ 5.79 kg initial body weight; 0.38 kg of milk/day), with an average age of 5 years, were used in the experiment. The experimental period started when the goats had 30 days of lactation.

Goats were confined in a shed without walls, with a concrete floor and covered with metal tiles. The experimental period lasted 30 days, with 25 days for adaptation of the animals to the facilities, management, and experimental diet, and 5 days for data collection. During adaptation, goats were identified, weighed, treated for ecto- and endoparasites and randomly housed in individual pens (1.25m $\times$ 2.24m) provided with feeders and drinking fountains, previously identified according to the treatments.

The animals were individually confined and a completely randomized design with a 3 $\times$ 2 factorial arrangement was used, with three genetic groups and 2 diets (control diet (without tannin) and diet with tannin (inclusion of 5% commercial tannin (Weibull® Tanac, Montenegro, RS, Brazil)) on a dry matter basis). Tannin used was extracted from *Acacia mearnsii*, with a concentration of approximately 70 % total tannins.

Experimental diets consisted of chopped fresh elephant grass (*Pennisetum purpureum* Schun), ground corn, soybean meal and mineral mixture (Caprinofós, Tortuga, São Paulo, Brazil), formulated to be isoproteic, with a forage: concentrate ratio of 60: 40 (Table 1), to meet the nutritional requirements of multiparous lactating goats with dual purpose, following the recommendations of the NRC (2007). Commercial tannin was added to the concentrate provided to animals selected for treatment with the tannin-added diet.

2.3. *Milking*

Milking was performed manually, in the morning and afternoon, before food supply. Milking procedures followed the recommendations of the "Regulamento Técnico de Produção, Identidade e Qualidade do leite de cabra" (BRASIL, 2000). Milk production was estimated daily through individual weighing of milk (g/kg $BW^{0.75}$). Milk samples were collected for further laboratory analysis.

2.4. *Intake and nutrient digestibility*

Diets were supplied as complete feed twice a day, at 08:00 h and at 16:00 h, after milking. Water was supplied at will. The amount of food offered was calculated according to the intake of the previous day, not allowing leftovers greater than 10 % amount offered. Samples of the food offered and leftovers were collected and stored at -20 °C for later laboratory analysis.

Dry matter intake (DMI) was obtained by the difference between values of dry matter offered and dry matter in leftovers. Nutrient intake was determined as the difference between nutrients offered and nutrients in leftovers. Results were expressed in g/kg $BW^{0.75}$.

Animal feces were collected from the final portion of the rectum. Samples were stored at −20 °C, for further laboratory analysis. Before analysis, feces samples from the 5 collections of each animal were homogenized and a subsample of 10 % of the total was obtained.

Fecal output was estimated using indigestible acid detergent fiber (iADF) as an internal indicator. Samples of feces, feed and leftovers were incubated in non-woven bags (TNT - 100 g/m^2) and were inserted into rumen of a fistulated bovine (*in situ*) for 288-h (Huhtanen et al., 1994). The animals were fed with a diet similar to the control diet of lactating goats, being composed of elephant grass (*Pennisetum purpureum*), concentrated based on ground corn and soybean meal. After incubation, bags were washed with water and boiled with acid detergent for 1-h in an autoclave at 105 °C. Then, the bags were washed again with distilled water and acetone (Detmann et al., 2012) for subsequent drying in a forced ventilation oven (55 °C) for 72-h.

To calculate the iADF content, the following formula was used: iADF (%DM) = (iADF/SD) x 100, were iADF (%DM): Percentage of indigestible acid detergent fiber based on dry matter; iADF: Percentage indigestible acid detergent fiber based on the air-dried sample; SD%: oven-dried sample. Fecal dry matter output (kg DM/day) was estimated based on the quantity of the indicator consumed and its concentration in feces, using the equation described by Silva and Leão (1979): Feces (kg DM/day) = (ADFi ingested (g/day)/ADFi concentration in feces (g/day)) × 100.

Spot urine samples were collected immediately after milking, during spontaneous urination of the goats. The urine was collected in plastic bottles. The collected volume of all spot samples of each day was quantified and the value was recorded. Samples were filtered through gauze and a 10 mL aliquot was separated and diluted with 40 mL sulfuric acid (0.036 N) (Valadares et al., 1999), to prevent nitrogen losses through volatilization. Samples were stored in a freezer at -10 °C, for later laboratory analysis.

The total urine production was estimated through the concentration of urinary creatinine as an internal marker, determined calorimetrically using a commercial kit (Doles Reagentes, Goiânia, Brazil). The urine production was estimated by the equation: Urinary volume (UV) = (average daily excretion of creatinine x body weight)/creatinine concentration in the urine spot sample (CCUspot) (Santos et al., 2017). Following the recommendation of Pereira et al. (2021), it was assumed that each animal excreted 17.05 mg of creatinine per kilogram of animal body weight (BW). The daily excretion of creatinine (DEC) was determined by the equation: DEC = CCUspot × UV/BW.

Table 1
Proportion and chemical composition of experimental diets.

Ingredients	Diets	
	Without tannin (Control)	With commercial tannin
Elephant grass (% dry matter basis)	60.00	60.00
Ground corn (% dry matter basis)	27.00	21.00
Soybean meal (% dry matter basis)	12.00	13.00
Mineral mixture (% dry matter basis)	1.00	1.00
Commercial tannin (% dry matter basis)	–	5.00
Chemical composition of diets		
Dry matter (% natural matter)[a]	48.61	48.49
Organic matter (% dry matter basis)	92.64	92.42
Mineral matter (% dry matter basis)	7.36	7.58
Crude protein (% dry matter basis)	15.35	15.36
Ether extract (% dry matter basis)	3.48	3.27
Neutral detergent fiber (% dry matter basis)	47.25	46.70
Acid detergent fiber (% dry matter basis)	42.15	42.02
Total tannins (% dry matter basis)	1.01	5.17

2.5. Nitrogen balance

The nitrogen (N) analysis of feeds, leftovers, feces and urine was performed as described by Detmann et al. (2012). The nitrogen balance (NB) was determined by the following equation (Decandia et al., 2000): NB (%) = [N ingested - (N feces + N urine) / N ingested] × 100.

2.6. Energy balance

Gross energy (GE) content of the samples of the offered food, leftovers, feces, urine and milk were determined in an adiabatic calorimeter (Parr Instrument, model 208, São Paulo, Brazil) according to the methodology of Silva and Queiroz (2006).

To obtain the energy balance (EB), the value of digestible energy (DE) and metabolizable energy (ME) were calculated according to Blaxter and Clapperton (1965), where: DE = GE intake - GE lost in the feces; and ME = DE - GE losses in urine and gas. The gas energy was represented by methane production and was estimated by the equation: Cm = 0.67 + 0.062D, where Cm = methane production (kcal / 100 kcal of energy intake) and D = apparent digestibility of gross energy.

2.7. Water balance

Water intake was assessed daily. Water was supplied in plastic buckets, with a capacity of 8 L, and weighed before being supplied and weighed again 24-h later. The water lost through evaporation was considered in the calculation of water intake. This variable was estimated using buckets distributed in the shed, close to the animals' pens, with the same amount of water offered to each animal, and the difference in weight over 24-h was determined.

Water balance (WB) was calculated following the recommendations of Church (1976), where: Water intake via drinking fountain (WID) = supplied water – (leftover water + evaporated water); Total water intake (TWI) = WID + water intake via feed (WIF); Absorbed water = TWI - Water excretion via feces (WEF); Retained water = TWI – (Water excretion via feces + Water excretion via urine).

2.8. Chemical analysis

Samples of the food offered, leftovers and feces were pre-dried in a forced air oven at 55 °C for 72-h. Then, samples were ground in a knife mill (Wiley Mill, Marconi, MA-580, Piracicaba, Brazil) using 1- and 2-mm mesh sieves. Considering the methods described by AOAC (2016), samples were analyzed for content of dry matter (DM; method 967.03), mineral matter (MM; method 942.05), crude protein (CP; method 981.10) and ether extract (EE; method 920.29) and acid detergent fiber (ADF; method 973.18). The neutral detergent fiber (NDF) content was determined using the methodology described by Detmann et al. (2012).

Total tannins were quantified by a colorimetric assay for total phenols (Folin-Ciocalteu tannic acid - Merck GmbH, Darmstadt, Germany) according to Makkar (2003).

2.9. Statistical analysis

Data were tested for normality of residuals and homogeneity of variances. For analyzed of variance, all data were analyzed using the MIXED procedure (PROC MIXED) of Statistical Analysis System (SAS, Version 9.1). Data normality (Shapiro-Wilk at 5% probability) was checked using the UNIVARIATE procedure (PROC UNIVARIATE), from SAS. The standard error of the mean was obtained from the original data. The means were compared by the Tukey test. Differences between treatments were considered significant when $P \leq 0.05$.

The following statistical model was adopted: $Y_{ij} = \mu + R_i + Nj + RN_{ij} + Eij$, where: Y_{ij} = value observed for the study variable referring to the i-th treatment in the j-th repetition; μ = overall constant; r_i = effect of genetic group ($i = 1, 2$); nj = effect of diet ($j = 1, 2$); rn_{ij}=effect of the interaction between the genetic group and the diet; eij = random error associated with observation Y_{ij}.

Table 2
Intake and milk production of goats from different genetic groups receiving diets with and without tannin.

Variables	Genetic group			SEM	Diets		SEM	*P value*		
	Repartida	Canindé	Saanen		Without tannin	With tannin		G	D	GxD
Dry matter (g/kg $BW^{0.75}$)	0.13	0.14	0.15	0.01	0.14	0.14	0.01	0.211	0.715	0.289
Crude protein (g/kg $BW^{0.75}$)	0.019^{B}	0.024^{A}	0.026^{A}	0.001	0.023	0.023	0.001	0.001	0.867	0.398
Neutral detergent fiber (g/kg $BW^{0.75}$)	0.055^{B}	0.069^{A}	0.068^{A}	0.003	0.063	0.064	0.002	0.009	0.839	0.599
Milk Production (g/kg $BW^{0.75}$)	0.026^{B}	0.026^{B}	0.071^{A}	0.012	0.037	0.048	0.008	0.002	0.278	0.688

$BW^{0.75}$= Metabolic body weight; SEM = Standard error of the mean; G = Genetic group effect; D = Diet effect; GxD = Interaction effect between genetic group and diet; Means followed by capital letters represent a significant difference between genetic groups; Significant at the 5% probability level.

3. Results

3.1. Intake and milk production per metabolic weight

There was neither effect of diet nor interaction between genetic group and diet on intake and milk production ($P > 0.05$) (Table 2). However, there was an effect of genetic group on intake of CP ($P = 0.001$) and NDF ($P = 0.009$), with higher mean values of intake for Saanen and Canindé goats. An effect of genetic group was also found for milk production ($P = 0.002$), in which Saanen goats had a higher production than Repartida and Canindé goats (Table 2).

3.2. Nitrogen balance

There was neither effect of diet nor interaction between genetic group and diet on nitrogen balance ($P > 0.05$). (Table 3). However, there was effect of genetic group on ingested N ($P = 0.001$), absorbed N ($P = 0.001$), excreted N in urine ($P = 0.016$) and excreted N in milk ($P = 0.004$), with higher mean values for Saanen goats in relation to Repartida and Canindé goats (Table 3). On the other hand, there was no effect of genetic group for excreted N in feces ($P = 0.732$), retained N ($P = 0.133$), absorbed N : ingested N ratio ($P = 0.134$) and retained N : ingested N ratio ($P = 0.653$) (Table 3).

3.3. Energy balance

There was neither effect of diet nor interaction between genetic group and diet on energy balance ($P > 0.05$). (Table 4). However, there was an effect of genetic group on ingested gross energy ($P = 0.003$), gross energy of milk produced ($P = 0.004$), gross energy lost in digestion gas ($P = 0.004$), digestible energy ($P = 0.009$) and metabolizable energy ($P = 0.009$), with higher values observed for Saanen goats compared to Repartida and Canindé goats (Table 4). Furthermore, there was an effect of genetic group on gross energy lost in urine ($P = 0.025$), in which Repartida and Saanen goats had greater losses compared to Canindé goats (Table 4). On the other hand, there was no effect of genetic group on gross energy lost in feces and absorbed: ingested gross energy ratio and retained : ingested gross energy ratio ($P > 0.05$) (Table 4).

3.4. Water balance

There was an interaction effect between genetic group and diet on absorbed water: total water intake ratio ($P = 0.010$) and retained water: total water intake ratio ($P = 0.010$) (Table 5). Saanen goats had a higher water intake via drinking fountain ($P < 0.001$), water intake via feed ($P = 0.001$), total water intake ($P < 0.001$), absorbed water ($P < 0.001$) and retained water ($P = 0.026$). As a result of the increased water intake, Saanen goats also showed a greater excretion of water via feces ($P = 0.027$) and via urine ($P = 0.015$) (Table 5). Tannin-added diet resulted in greater excretion of water via feces ($P = 0.003$) and higher retained water ($P = 0.013$) and retained water: TWI ratio ($P = 0.004$). In contrast, it resulted in a lower excretion of water via urine ($P = 0.040$) compared to the control diet (without tannin) (Table 5).

4. Discussion

The influence of tannin on DMI can vary widely and depend on factors such as the amount of tannin in the diet, animal species, biological characteristics of the tannin compound, effect of prolonged adaptation, ruminal fermentation and dietary characteristics (Adejoro et al., 2019; Hassan et al., 2020). The lack of effect of tannin on DMI in the present study is possibly related to the level of inclusion (5% DM) of the commercial tannin used, being considered an acceptable level, without negatively affecting voluntary intake. The results of the present study are in line with those observed in the literature (Aguerre et al., 2016; Pathak et al., 2017; Min and Solaiman, 2018), in which tannins are shown to be beneficial for ruminants at low concentrations because they protect plant proteins from ruminal degradation.

Table 3
Nitrogen balance of goats from different genetic groups receiving diets with and without tannin.

Variables	Genetic group			SEM	Diets		SEM	*P value*		
	Repartida	Canindé	Saanen		Without tannin	With tannin		G	D	GxD
Ingested N (g/day)	47.5^B	48.5^B	68.2^A	4.31	56.7	53.9	3.26	0.001	0.410	0.159
Feces N (g/day)	4.73	4.47	4.34	0.40	4.66	4.66	0.23	0.732	0.528	0.157
Absorbed N (g/day)	42.8^B	44.0^B	63.6^A	4.20	52.2	49.2	3.15	0.001	0.801	0.337
Urine N (g/day)	28.3^B	25.3^B	42.8^A	6.12	33.9	31.7	3.85	0.016	0.646	0.198
Retained N (g/day)	14.5^B	18.7^B	20.8^A	3.44	18.3	17.6	2.08	0.135	0.648	0.126
Milk K (g/day)	0.28^B	0.31^B	0.76^A	0.14	0.39	0.53	0.07	0.004	0.251	0.869
Absorbed N: Ingested N (%)	0.90	0.91	0.93	0.01	0.92	0.91	0.01	0.134	0.419	0.325
Retained N: Ingested N (%)	0.31	0.31	0.32	0.06	0.34	0.32	0.04	0.653	0.794	0.510

SEM = Standard error of the mean; G = Genetic group effect; D = Diet effect; GxD = Interaction effect between genetic group and diet; Means followed by capital letters represent a significant difference between genetic groups; Significant at the 5% probability level.

Table 4
Energy balance of goats from different genetic groups receiving diets with and without tannin.

Variables	Genetic group			SEM	Diets		SEM	*P value*		
	Repartida	Canindé	Saanen		Without tannin	With tannin		G	D	GxD
Ingested (Mcal/kg $BW^{0.75}$)	43.5^{B}	40.2^{B}	58.8^{A}	3.98	48.6	47.6	3.24	0.003	0.811	0.284
Feces (Mcal/kg $BW^{0.75}$)	13.1	12.3	16.8	2.02	14.2	14.2	1.11	0.090	0.985	0.058
Urine (Mcal/kg $BW^{0.75}$)	2.78^{A}	1.47^{B}	2.58^{A}	0.38	2.23	2.48	0.23	0.025	0.489	0.080
Milk (Mcal/kg $BW^{0.75}$)	4.47^{B}	5.06^{B}	13.6^{A}	2.07	6.81	9.06	1.26	0.004	0.193	0.751
Gases (Mcal/kg $BW^{0.75}$)	2.16^{B}	1.95^{B}	3.07^{A}	0.21	2.50	2.36	0.20	0.004	0.580	0.466
Digestible Energy (Mcal/kg $BW^{0.75}$)	30.4^{B}	27.8^{B}	42.0^{A}	3.29	34.4	33.5	2.53	0.009	0.794	0.783
Metabolizable Energy (Mcal/kg $BW^{0.75}$)	25.5^{B}	24.4^{B}	36.4^{A}	2.78	29.7	28.6	2.17	0.009	0.739	0.851
Absorbed : Ingested (%)	0.70	0.68	0.71	0.03	0.70	0.70	0.02	0.761	0.979	0.289
Retained : Ingested (%)	0.58	0.60	0.62	0.03	0.60	0.60	0.02	0.635	0.815	0.125

$BW^{0.75}$ = Metabolic body weight; SEM = Standard error of the mean; G = Genetic group effect; D = Diet effect; GxD = Interaction effect between genetic group and diet; Means followed by capital letters represent a significant difference between genetic groups; Significant at the 5% probability level.

Table 5
Water balance of goats from different genetic groups receiving diets with and without tannin.

Variables	Genetic group			SEM	Diets		SEM	*P value*		
	Repartida	Canindé	Saanen		Without tannin	With tannin		G	D	GxD
WID (L/day)	1.27^{B}	1.20^{B}	2.68^{A}	0.26	1.82	1.71	0.19	<0.001	0.608	0.634
WIF (L/day)	1.91^{B}	1.90^{B}	2.96^{A}	0.22	2.36	2.22	0.17	0.001	0.417	0.205
TWI (L/day)	3.18^{B}	3.11^{B}	5.63^{A}	0.45	4.07	4.04	0.36	<0.001	0.935	0.553
WEF (L/day)	0.43^{B}	0.38^{C}	0.52^{A}	0.06	0.37^{b}	0.56^{a}	0.02	0.027	0.003	0.077
WEU (L/day)	1.86^{C}	2.26^{B}	3.46^{A}	0.64	3.02^{a}	2.08^{b}	0.27	0.015	0.040	0.782
Absorbed water (L/day)	2.75^{B}	2.73^{B}	5.12^{A}	0.44	3.68	3.52	0.34	<0.001	0.644	0.596
Retained water (L/day)	0.87^{B}	0.47^{C}	1.66^{A}	0.03	0.38^{b}	0.51^{a}	0.02	0.026	0.013	0.067
Absorbed water: TWI (%)	0.85^{B}	0.86^{B}	0.93^{A}	0.014	0.91^{a}	0.85^{b}	0.01	0.002	0.003	0.010
Retained water: TWI (%)	0.13^{A}	0.12^{A}	0.09^{B}	0.02	0.10^{b}	0.13^{a}	0.07	0.001	0.004	0.010

SEM = Standard error of the mean; WID = Water intake via drinking fountain; WIF = Water intake via feed; TWI = Total water intake; WEF = Water excretion via feces; WEU = Water excretion via urine; G = Genetic group effect; D = Diet effect; GxD = Interaction effect between genetic group and diet; Means followed by capital letters represent a significant difference between genetic groups; Means followed by lowercase letters represent a significant difference between diets; Significant at the 5 % probability level.

Lactating goats need diets with adequate protein levels to meet the maintenance and production requirements, with a direct impact on the persistence of lactation and the amount of milk produced (Câmara et al., 2015). Although the Repartida goat had a lower intake of CP in relation to the Canindé and Saanen goat, its crude protein requirements were met by the diets, according to what was established by the NRC (2007). Therefore, the effect of the genotype did not affect the protein intake of the goats. The results found were superior to the findings by Paiva et al. (2017), who found mean values of 15.87 g/kg $BW^{0.75}$ for native dairy goats confined in a semiarid environment. When a feed has high energy and low fiber content, what regulates the DMI is the energy requirement itself. Thus, the animal will consume the energy necessary for its requirement, controlling its intake (Mertens, 1996). As there was no limitation to DMI, considering also that experimental diets were formulated to contain similar levels of energy and fiber, the lower intake of NDF found for Repartida goat could be related to a possible greater selection of the concentrate by this genetic group. This result is in agreement with the findings of Soares et al. (2017), who analyzed the effect of the genotype on the productive performance of goats receiving a diet based on maniçoba silage and concentrate, and found that Repartida goats had a lower NDF intake (0.015 kg / day) in relation to the other evaluated breeds. The use of moderate levels of tannins in the ruminant diet has been reported to improve ruminal metabolism, decreasing protein degradation and rumen methane production, mainly by affecting ruminen microorganisms (Min and Solaiman, 2018), changing nitrogen and energy balances (Stewart et al., 2019; Aguerre et al., 2020; Norris et al., 2020). Thus, in our study, it was expected that changes in the nitrogen and energy balance could be observed due to the inclusion of tannin in the diet, which did not happen. This result could be due to the adaptation mechanisms to the dietary tannin developed by the goats, since animals had 25 days of adaptation to the diets before the measurements and sample collections. Ben Salem et al. (2005) observed a significant effect of interaction between diet with tannin and adaptation time of lambs before samples collection for variables of nitrogen intake and fecal and urinary nitrogen. In addition, they observed a tendency for this interaction in the nitrogen retained variable. According to Mlambo et al. (2007), the ruminal fluid of adapted animals is better able to ferment feed with tannins and this would possibly be due to microbial adaptations, similar to synthesis of phenolic- or tannin-degrading enzymes, excretions of tannin-binding polysaccharides and changes in microbial populations.

The highest mean value of ingested N for Saanen goats could be related to their higher metabolic needs and milk production, which could also explain their greater excretion of N in urine and milk. However, Saanen goats demonstrated better use of N, as they also showed higher values of absorbed and retained N, which may have contributed to their higher milk production. Furthermore, it is worth emphasizing that even with the higher N intake verified for Saanen goats, there was no effect of genetic group on absorbed N :

ingested N and retained N : ingested N ratios, showing that native animals (Repartida and Canindé goats) are able to adapt to diets, without reducing nutrient availability.

As the increase in milk production is a highly energy-dependent metabolic process (Goetsch, 2019), Saanen goats showed greater energy demand (Table 4), allowing an increase in the gross energy intake. Higher mean values for digestible energy and metabolizable energy observed for this genetic group may indicate greater energy available for milk production (Table 2). Although, Saanen goats make better use of gross energy compared to Repartida and Canindé, the higher intake of gross energy may have contributed to their higher gross energy excretion value. Nevertheless, when considering the retained to ingested energy ratio, it is important to emphasize that the native breeds were equal to the Saanen breed.

An important factor in determining the amount of water ingested is the breed of the animal. In general, native or adapted breeds from dry land regions with water scarcity have lower intake and greater water use efficiency when compared to breeds from temperate regions (Akinmoladun et al., 2019; Joy et al., 2020). Higher water intake (via drinking fountain, via feed and total water intake) by Saanen goats is probably due to their higher productive requirements and energy expenditure, needing to increase water intake. This is evidenced by their greater values of absorbed and retained water, as well as by their higher absorbed water to total water ratio. However, Repartida and Canindé goats showed greater retained water: total water intake ratio and lower amounts of excreted water, when compared to Saanen goats. These differences are related to the physiological and behavioral adaptations that maximize water use and minimize losses (Joy et al., 2020). Thus, the Repartida and Canindé goats demonstrated, as expected, a greater capacity in the use of water in their metabolism, due to their greater adaptability to the water retractions characteristic of the Brazilian semiarid region. When considering the effect of tannin in the diet on the increase in water excretion via urine, Kronberg and Schauer (2013) mention that when ingesting tannin, of natural or commercial origin, there is an increase in water intake by animals, due to the effect of tannins on salivary glycoproteins, precipitating them and causing loss of lubricating power, inducing water intake. However, in the present study, there was no effect of tannin inclusion in the diet on water intake. Furthermore, the addition of tannin in the diet reduced urinary excretion of water by 31 %. The difference between our results and those reported by Kronberg and Schauer (2013) may be due to the different animal species used in the studies, because while the authors worked with sheep and cattle, we work in this study with goats. Although the amount of tannin used in our study was greater than that used in the study by Kronberg and Schauer (2013; 5 vs 2% dry matter basis), it is proposed that goats are more tolerant to tannin diets than cows and sheep, possibly due to differences in feeding behavior between these species and due to the higher production of tannin-binding salivary proteins by goats (Lamy et al., 2011).

Schmitt et al. (2020) suggest that the goat species has physiological and behavioral mechanisms capable of neutralizing, through saliva, the effect of feed tannins. Thus, during feeding, goats secrete a greater amount of saliva, containing proline-rich salivary proteins (PRP), which bind to tannin avoiding its complexation with dietary protein. This can increase in the ruminal degradability of feed protein, increased microbial protein synthesis and nitrogen supply to the small intestine, with a consequent increase in the absorption of amino acids for production (Mlambo et al., 2015; Min and Solaiman, 2018).

The ingestion of feeds with a high tannin content increases the activity of the salivary gland, increasing the production of saliva and thus reducing the perception of the astringency of the feed ingested (Lamy et al., 2011; Ventura-Cordero et al., 2017). Consequently, a greater supply of liquids would be needed to stimulate the production of saliva (Kronberg and Schauer, 2013). Although we did not observe an increase in water intake in response to the tannin diet, there were 34 % increases in retained water and retained water: TWI ratio in response to the tannin. This greater water retention was mainly due to a reduction in the excretion of urinary water, and it could contribute to support a greater salivary secretion in response to the inclusion of tannin in the diet. Further studies are needed to understand the mechanisms related to increased water retention in goats consuming diets with tannins.

5. Conclusion

In the experimental conditions, the inclusion of 5% tannin in the diet for Repartida, Canindé and Saanen dairy goats do not affect the intake of dry matter and nutrients and milk production. Nevertheless, it increases the efficiency of water use by animals. The genetic group is the major cause of influence on the intake of nutrients, and nitrogen, energy and water balances, in which Repartida and Canindé goats were more efficient in the use of water. Further, studies with different levels of tannin should be carried out to assess the possible effect of tannins on intake, and nitrogen, energy and water balances of lactating goats adapted to the semiarid region.

Author contributions

Ana Paula Ribeiro da Silva – Data curation; Formal analysis; Investigation; Methodology; Roles/Writing - original draft; **Aline Silva de Sant'ana -** Formal analysis; Methodology; **Sheyla Priscila Oliveira do Nascimento -** Formal analysis; Investigation; Methodology; **Steyce Neves Barbosa -** Formal analysis; Investigation; Methodology; **Ana Laura Alencar Miranda -** Formal analysis; Investigation; Methodology; **Fabrina de Sousa Luna** - Formal analysis; Investigation; Methodology; **Glayciane Costa Gois -** Roles/ Writing - original draft; Writing - review & editing; **Salete Alves de Moraes** - Project administration; Resources; Visualization; **Rafael Torres de Souza Rodrigues -** Project administration; Resources; Visualization; **Daniel Ribeiro Menezes –** Conceptualization; Project administration; Resources; Supervision; Validation; Visualization; Writing - review & editing.

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Declaration of Competing Interest

The authors report no declarations of interest.

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