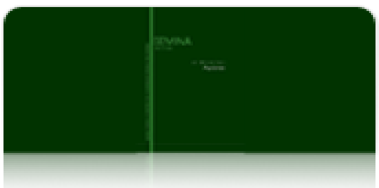

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Feeding behavior and physiological parameters of rearing goats fed diets containing detoxified castor cake

Comportamento alimentar e parâmetros fisiológicos de cabritas recriadas consumindo dietas contendo torta de mamona destoxificada

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Abstract

The objective of this study was to evaluate the influence of replacing soybean meal (SM) with castor bean cake (DCC), detoxified using two alkaline products, on the feeding behavior and physiological parameters of Saanen and Anglo-Nubian goat breeds with an initial body weight of 16.22 ± 0.67 kg. The treatments consisted of three diets that were isoproteic and isoenergetic: the first with a standard formulation based on corn and SM, the second with DCC detoxified using calcium hydroxide ($Ca(OH)_2$ DCC), and the third with DCC detoxified using sodium hydroxide (NaOH DCC). A completely randomized design with a 3 × 2 (diets and breeds) factorial arrangement and four replicates per combination was used. A dietary effect on the intake of dry matter (DM) and NDFap (P = 0.02 and 0.01) was observed, with lower values for goats fed NaOH DCC than the other diets. The diets influenced feeding and rumination times (P = 0.04 and 0.03). An interaction (P = 0.04 and 0.01) between the breeds and the SM-based diet was found for time variables (other activity and idle time). Increased feeding and neutral detergent fiber (NDF) rumination efficiencies were observed for goats fed SM and $Ca(OH)_2$ DCC (P = 0.03 and 0.01). Goats fed the NaOH DCC diet consumed large amounts of water, while Saanen goats urinated more times than did Anglo-Nubian goats. The diets had an effect on the heart rate and rectal temperature (P = 0.01 and 0.02), while the body surface temperature was influenced by the breed. Thus, $Ca(OH)_2$ or NaOH DCC has a great potential to replace SM in the feeding of dairy goats. When used as diet for goats in the growth phase, NaOH DCC causes a reduction of DM and NDF intakes. Neither DCC negatively affected the physiological parameters of goats.

Key words: Water. Anglo-Nubian. Calcium. Rumination. Sodium. Saanen.

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Resumo

Objetivou-se avaliar a influência da substituição do farelo de soja (FS) pela torta de mamona destoxificada (TMD) por dois produtos alcalinos sobre o comportamento alimentar e parâmetros fisiológicos de cabritas das raças Saanen e Anglo-nubiana, com peso corporal inicial de 16,22 ± 0,67 kg. Os tratamentos consistiram de três dietas, uma com formulação padrão à base de milho e FS e as demais foram formuladas com torta de mamona destoxificada por hidróxido de cálcio (TMD $Ca(OH)_2$) e outra por hidróxido de sódio (TMD NaOH), as quais foram isoproteicas e isoenergéticas. Utilizou-se um delineamento inteiramente casualizado, com arranjo fatorial 3 x 2 (dieta e raça) com quatro repetições por combinação. Houve efeito das dietas sobre o consumo de MS e FDNcp (P= 0,02 e 0,01), com menores valores para as cabras alimentadas com TMD NaOH. As dietas influenciaram os tempos de alimentação e ruminação (P= 0,04 e 0,03). Houve interação (P= 0,04 e 0,01) entre as raças e dieta à base de FS para as variáveis tempo com outras atividade e ócio. Observou-se maiores eficiências de alimentação e ruminação da FDN para as cabras que consumiram FS e TMD $Ca(OH)_2$ (P= 0,03 e 0,01). As cabras da dieta TMD NaOH consumiram maiores quantidades de água e as Saanen urinaram mais vezes que as Anglo-nubiana. Houve efeito das dietas sobre a frequência cardíaca e temperatura retal (P= 0,01 e 0,02), já a temperatura corporal foi influenciada pelas raças. A torta de mamona destoxificada pelo hidróxido de cálcio e/ou hidróxido de sódio tem grande potencial para substituir o farelo de soja na alimentação de cabras leiteiras. Quando usado na composição de dietas para caprinos em fase de crescimento, a torta de mamona destoxificada pelo hidróxido de sódio leva à redução do CMS, bem como da FDN. Ambas as tortas não alteram negativamente os parâmetros fisiológicos das cabras.
Palavras-chave: Água. Anglo-nubiana. Cálcio. Ruminação. Sódio. Saanen.

Introduction

Because of the increasing demand for food from animal and plant origin, there is a need for prospecting alternative ingredients to formulate ruminant diets, in order to not compete with noble ingredients that are also consumed directly in human diets.

One of the possibilities of feedstuffs alternative to those traditionally used in ruminant diets are by-products originating from the biodiesel industry, a prominent example of which are those derived from castor (SEVERINO et al., 2012). The limitation for using castor bean cake in animal feed is due to the presence of ricin in castor bean seeds, which is a toxic glycoprotein consisting of two subunits, A (36 kDa) and B (29 kDa), bound by disulfide bonds (ASLANI et al., 2007). The ingestion of castor seeds may cause intoxication in ruminants (WORBS et al., 2011).

Recent studies have shown the potential of using detoxified castor cake and castor bean meal instead of soybean meal in ruminant diets (POMPEU et al., 2012; FURTADO et al., 2012; GIOMBELLI et al., 2014; NICORY et al., 2015). However, few experiments have been carried out using dairy-purpose goats during the growth phase. This is mainly because, on dairy farms, goats that are not under production are viewed as a great source of expenditure, which has somehow not drawn the attention of researchers in performance evaluations during the growth phase. The use of the above-mentioned by-products can improve efficiency of the growth phase and positively influence the productive performance of future dairy goats.

We must also consider the interaction between animals of different breeds and their breeding environment. This is especially necessary for confined animals, since the implemented management represents a large part of the obtained results. Scientific research has advanced in the area of animal nutrition, especially regarding the study of animal behavior and physiological processes and how different factors affect them, particularly when there are changes in the supplied diets.

In this context, residues from the biodiesel industry, especially castor cake, can be used as an alternative food for ruminants in Brazilian semiarid regions, replacing soybean meal, which is a noble food used in human diets, thereby increasing production costs. In an effort to minimize the negative effects brought about by the low supply of soybean meal at certain times of the year, we proposed the use of castor cake detoxified using alkaline solutions as a possible substitute for soybean meal in diets for these animals. The objective of this study was to evaluate ingestive feeding behavior and physiological parameters of Saanen and Anglo-Nubian goat breeds in confinement.

Material and Methods

The study was conducted at the Technological Center for Goat Milk Production of Embrapa Goats and Sheep (3°44′57,42″ South and 40°20′43,50″ West), in the city of Sobral-CE, Brazil, from September 2015 to June 2016.

Twenty-four goats (12 Saanen and 12 Anglo-Nubian) with a body weight of 16.22 ± 0.67 kg were submitted to a confinement regime in individual, suspended stalls with a 5.06 m² slab floor, a 2.87 m² shaded area, equipped with drinkers, feeders, and salt licks. All procedures involving animals were carried out in accordance with the Ethics Committee on Animal Use regulations by the Brazilian Agricultural Research Corporation, National Goat Research Center, protocol number 005/2015.

The treatments consisted of three diets: the first was formulated with corn and soybean meal (SM) and the other two were formulated with castor cake detoxified using either calcium hydroxide ($Ca(OH)_2$ DCC) or sodium hydroxide (NaOH DCC), with both completely replacing soybean meal. Tifton 85 hay was used as forage. A completely randomized design with 3 × 2 (diets × breeds) factorial arrangement was used with four replicates per combination. In the pre-experimental conditions, goats were identified, treated against ecto- and endoparasites, and administered rabies vaccine.

The experimental diets were formulated based on the recommendations of the National Research Council-NRC (2007); the diets were isoproteic and isoenergetic with a forage: concentrate ratio of 43:57, 40:60, and 36:64 for the SM, $Ca(OH)_2$ DCC, and NaOH DCC diets, respectively. The chemical composition of the ingredients is shown in Table 1, and the proportion of the ingredients of the diets and their chemical composition based on the forage: concentrate ratio are shown in Table 2.

Two alkaline products, $Ca(OH)_2$ and NaOH in the proportions of 90 and 60 g kg^{-1} of cake, respectively, were used to detoxify the crude castor cake, while 2000 ml of water kg^{-1} of crude castor cake was used for the dilution and efficacy of the reagents. The cake was detoxified by adapting a semiautomatic mixer for homogenization of the detoxifying solution. A stationary cement mixer equipped with three-phase motor was used (Fischer® MOB 400 G2) to mix the solution.

Table 1. Chemical composition of the ingredients used for the preparation of the experimental diets.

Item (g kg DM^{-1})	Ingredients				
	Tifton 85 hay	Ground corn	Soybean meal	$Ca(OH)_2$ DCC	NaOH DCC
Dry matter (g kg^{-1} fresh matter)	872.52	889.24	870.21	904.22	904.82
Organic matter	911.34	965.92	956.90	867.77	855.63
Mineral matter[a]	88.75	34.11	43.10	132.32	144.42
Crude protein	104.12	79.50	443.30	315.41	309.01
Ether extract	14.52	36.83	28.84	52.10	47.53
Non-fiber carbohydrates	277.80	722.41	320.81	103.95	132.44
Neutral detergent fiber[b]	514.90	123.28	163.84	396.18	360.12
Acid detergent fiber	472.22	69.07	117.93	379.22	388.74
Hemicellulose	248.44	115.53	99.82	104.13	54.70
Cellulose	413.65	60.22	105.60	328.50	342.63
Lignin	60.62	8.80	12.21	50.73	46.15
Total digestible nutrients	546.83	848.75	822.52	620.54	627.93

[a] $Ca(OH)_2$ DCC: 0.90 g Na kg^{-1} DM and 2.25 g Ca kg^{-1} DM; NaOH DCC: 29.20 g Na kg^{-1} DM and 0.63 g Ca kg^{-1} DM. [b] Corrected for ash and protein.

Table 2. Proportion of ingredients and chemical composition of the experimental diets.

Ingredients	Diets		
	Soybean meal	DCC $Ca(OH)_2$	DCC NaOH
Item (g kg DM^{-1})	Proportion of ingredients		
Tifton 85 hay	427.31	394.97	363.29
Ground corn	460.83	481.95	504.65
Soybean meal	57.80	--------	--------
Detoxified castor cake	--------	83.31	82.95
Soy oil	45.03	39.94	39.25
Limestone	9.16	0.01	10.10
Mineral Premix[a]	*Ad libitum*	*Ad libitum*	*Ad libitum*
Chemical Composition (g kg^{-1} DM)			
Dry matter (g kg^{-1} fresh matter)	887.71	896.13	891.84
Organic matter	942.37	897.85	938.10
Mineral matter	57.74	102.26	61.98
Crude protein	112.01	112.91	112.32
Ether extract	62.02	63.40	65.43
Non-fiber carbohydrates	471.86	468.64	476.80
Neutral detergent fiber[b]	287.94	297.63	279.24
Acid detergent fiber	349.52	332.05	305.44
Hemicellulose	166.01	163.65	152.67
Cellulose	211.82	221.11	209.33
Lignin	30.86	32.68	30.32
Total digestible nutrients	664.98	658.58	663.61

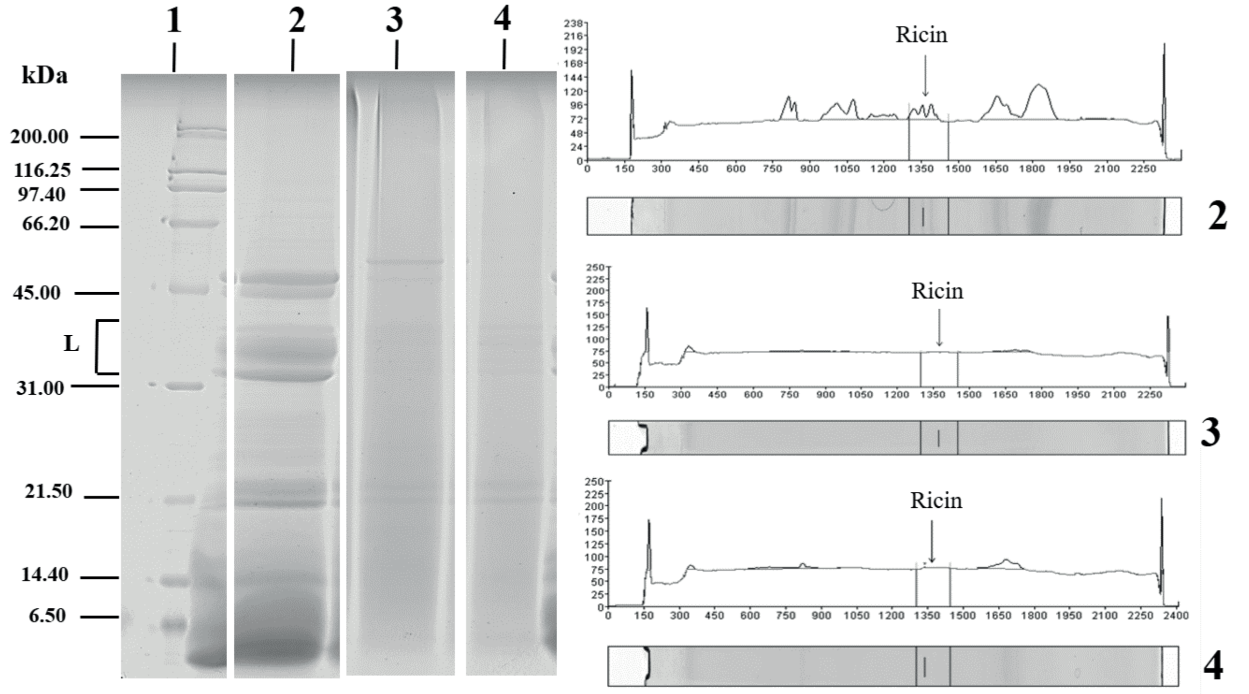
[a] Guaranteed levels (per kg, in active elements): calcium – 218.00 g; phosphorus – 71.00 g; sulfur – 20.00 g; iron – 1800.00 mg; iodine – 80.00 mg; manganese – 1300.00 mg; selenium – 15.00 mg; zinc – 3800.00 mg; molybdenum – 300.00 mg; maximum fluorine – 870.00 mg; phosphorus (P) solubility in citric acid 2% minimum - 95%.
[b] Corrected for ash and protein.

A vertical electrophoresis apparatus was used (model 2001, Amsterdam - Pharmacia, Uppsala, Sweden) to analyze the electrophoretic profile of the proteins from the castor bean cake and identify the ricin. SDS-PAGE was performed according to the methodology described by Laemmli and Favre (1973). Densitometry of the gels was performed using the Gel Analizer® application in order to confirm the disappearance of the bands, as shown in Figure 1.

On the day of the behavior assay, the feed was delivered at 08h00 and at 16h00 in sufficient quantity to allow a 10% of the supply as leftovers. Samples were taken from the supplied diet (both the forage and the concentrate), as well as from the leftovers the following day, which were then packed into plastic bags, properly identified, and stored in a freezer at -8 °C. Dry matter (DM; method number 934.01), organic matter (method number 942.05), crude protein (method number 954.01), and ethereal extract levels (method number 920.39) were subsequently determined from the samples (leftovers and supplied) according to AOAC (2003). For neutral detergent fiber (NDF) analyses, the samples were treated with thermostable alpha-amylase, without the use of sodium sulfite and corrected for residual ash (MERTENS, 2002).

To formulate the diets, the content of nitrogen compounds insoluble in neutral (NIDN) and acid detergents (NIDA) was estimated according to Licitra et al. (1996). Lignin content was obtained using the methodology described in Detmann et al. (2012), with FDA residue treated with 72% sulfuric acid. Non-fibrous carbohydrate (NFC) content was calculated by an adaptation of the method proposed by Hall (2003). Total carbohydrate (TC) content was obtained by the equation proposed by Sniffen et al. (1992). Total digestible nutrients (NDT) were calculated according to Weiss (1999).

Figure 1. Electrophoretic characterization of castor cake proteins treated with different chemical products. 1: Molecular weight marker (kDa); L: Lectins; 2: Crude castor cake; 3: Detoxified castor cake $Ca(OH)_2$; 4: Detoxified castor cake NaOH.



Feeding behavior observations were performed instantaneously at 10-minute intervals (feed intake, rumination, other activities, and idle) for 24 hours. Moreover, the frequency of water intake, urination and defecation were monitored in the interval between two observations. On the following day, collections were made during three two-hour periods (between 08h00 and 10h00; 14h00 and 16h00; and 18h00 and 20h00), to estimate the number of rumination chews per bolus (RCnb) and time elapsed with rumination chews per bolus (RCtb) using a digital timer. The methodology reported by Bürger et al. (2000) was used to determine feed efficiency (FE) and rumination efficiency (RE) as a function of DM (g DM h^{-1}) and NDF.

The physiological parameters of respiratory rate (RR), heart rate (HR), rectal temperature (RT), and body surface temperature (BST) were measured during three consecutive days at the following times: from 07h00 to 08h00, 12 to 13h00, and 18h00 to 19h00. RT was determined by introducing a digital clinical thermometer (Techline® TS-101PM; range, up to 42.9 °C) directly into the animal's rectum.

BST corresponded to the average temperatures obtained from five determined regions of the body: forehead (FST), neck (NST), rump (RST), back (BST), and womb (WST) surface temperatures using a non-contact digital infrared thermometer (ICEL-Manaus®– TD-950). RR and HR were obtained using a flexible stethoscope. Measurements were made at the laryngo-tracheal region for RR, counting the number of movements in 15 seconds; the value obtained was multiplied by four, with values expressed as movements $minute^{-1}$. Measurements were made for one minute between the third and fourth intercostal space close to the costochondral joint for HR, with values expressed as beats $minute^{-1}$.

Data were initially subjected to normality tests (Shapiro–Wilk) and homoscedasticity tests (Levene), and were also submitted to analysis of variance by the F test when the presuppositions were met, by using the following model:

$$Y_{ijk} = \mu + \propto_i + \beta_j + (\propto\beta)_{ij} + e_{ijk},$$

where Y_{ijk} is the dependent variable corresponding to the experimental observation; μ is the overall mean; αi is the fixed effect of the diets; β_j is the fixed effect of the breed; $(\alpha\beta)_{ij}$ is the interaction effect; and e_{ijk} is the random error, assuming an independent normal distribution. Interaction between breed and diet was only considered when significant at 5% probability. A comparison of means was carried out by Tukey test at 5% probability to evaluate the effects of breed and diet. Statistical analyses were performed using the GLM procedure of the SAS software version 9.3 (SAS INSTITUTE, 2005).

Results and Discussion

Diets affected DM and NDFap intakes ($P = 0.02$ and 0.01); however, no effect was noted for breed ($P > 0.05$). DM and NDFap intakes were higher for goats fed SM and $Ca(OH)_2$ DCC (Table 3). The diets influenced ($P = 0.03$) rumination and feeding time, with high feeding and rumination times for goats fed SM and $Ca(OH)_2$ DCC diets; no difference was noted between these diets. An interaction between breed and diet was observed ($P = 0.04$ and 0.01) for time variables (other activities and idle time). The same trend was observed when the animals were idle.

The low intake of DM and NDFap by goats fed NaOH DCC might be related to the sodium content in the detoxified DCC (Table 1). The amount of sodium in NaOH DCC (Table 1) was 32.40 times higher than that in $Ca(OH)_2$ DCC. According to Paulino et al. (2001), the inclusion of increased amounts of sodium in the diet of ruminants causes a self-regulating voluntary intake effect in the animals.

The rumination time in this study was close to the 403 minutes day^{-1} of rumination observed by Vieira et al. (2011) when SM was completely replaced with castor bean meal in sheep diet. The low rumination and feeding times that we observed are directly related to the low DM intake, since according to Queiroz et al. (2001), the time spent ruminating depends on the diet type and seems to show little variation among grain-rich diets, reaching a maximum of 600 minutes day^{-1} when fed diets rich in forage. Moreover, the food intake level also influences rumination time because a greater amount of food needs to be fragmented before being digested. Additionally, the low forage: concentrate ratio in the NaOH DCC diet (36:64) may have contributed to the short rumination time, as according to Giger-Reverdin et al. (2014), small concentrate particle sizes allow for high rates of food passage.

From another perspective, rumination time is directly related to NDFap intake, since according to Van Soest (1994), increased fiber intake promotes an increase in rumination time due to the greater need of processing fiber. Oliveira et al. (2016) evaluated the inclusion of castor bean meal detoxified using calcium oxide on the feeding behavior of lambs and found that the rumination time was above 500 minutes day^{-1}; they also showed a proportional increase in rumination time with the amount of bran in the diet. However, in their study, the NDFap content of the diets was above 47%, whereas in this study, the NDFap content of the diets was below 30%, which may have contributed to the low rumination time.

Table 3. Dry matter intake (DM), Neutral detergent fiber corrected for ash and protein (NDF_{ap}) and behavior al activities of goats fed detoxified castor cake.

Breed	Diets			Mean	MSE	P-value		
	SM	$Ca(OH)_2$ DCC	NaOH DCC			Diet	Breed	D x B
	DM (g day^{-1})							
Saanen	1120.90	1010.35	962.91	1031.38	36.1	0.02	0.34	0.92
Anglo-Nubian	1120.14	1032.28	980.27	1044.23				
Mean	1120.52a	1021.31a	971.59b					
	NDF_{ap} (g day^{-1})							
Saanen	365.61	360.90	308.51	345.00	1.98	0.01	0.48	0.43
Anglo-Nubian	379.30	352.55	298.21	343.35				
Mean	372.45a	356.72a	303.36b					
	Feeding (minutes day^{-1})							
Saanen	317.50	312.50	298.75	309.58	12.3	0.04	0.79	0.54
Anglo-Nubian	330.00	330.00	280.00	313.33				
Mean	323.75a	321.25a	289.37b					
	Rumination (minutes day^{-1})							
Saanen	402.50	422.50	327.50	384.16	10.13	0.03	0.57	0.71
Anglo-Nubian	405.00	420.00	347.50	390.83				
Mean	403.75a	421.25a	337.50b					
	Other activities (minutes day^{-1})							
Saanen	235.00Bb	355.00Aa	385.00Aa	325.00				
Anglo-Nubian	390.00Aa	315.00Aa	420.00Aa	375.00	27.5	0.18	0.13	0.04
Mean	312.50	350.00	387.50					

continue

continuation

Idle (minutes day^{-1})								
Saanen	485.00Aa	320.00Ab	458.75Aa	360.83	28.77	0.17	0.08	0.01
Anglo-Nubian	315.00Ba	375.00Aa	392.50Aa	421.25				
Mean	400.00	347.50	425.62					

MSE: Mean standard error
Averages followed by common lowercase letters in the lines and by uppercase letters in the columns do not differ from one another according to the Tukey test at 5% significance.

Throughout the experiment, Anglo-Nubian goats showed less adaptation to the confined environment, as they are less docile than are Saanen goats. Because the activities involved in feeding behavior are considered exclusive, long feeding times for goats fed SM reflected short times dedicated to other activities (idle and other activities). The increase in idle time is of fundamental importance for production animals, since idle animals show reduced energy expenditure (MISSIO et al., 2010). However, the DM intake should meet their nutritional requirements.

Gomes et al. (2017) evaluated the behavior in sheep fed diets containing castor oil cake (crude or detoxified using different alkaline products) and found that only diets with detoxified urea cake reduced the idle time of the animals. Palmieri et al. (2017) evaluated the effect of including detoxified castor bean meal in diets of growing goats and found no changes in feeding, rumination, or idle times; however, they found a reduction in DM intake and in RE of DM.

Low FE of NDF was observed for goats fed NaOH DCC diets, while the lowest NDF RE was found for goats fed SM, which did not differ from those in goats fed $Ca(OH)_2$ DCC (Table 4).

Table 4. Dry matter feed efficiency (FE_{DM}), neutral detergent fiber feed efficiency (FE_{NDF}), rumination efficiency of dry matter (RE_{DM}), rumination efficiency of neutral detergent fiber (RE_{NDF}), total chewing time (TCT) and number of ruminal bolus (NRB) of goats fed detoxified castor cake.

Breed	Diets				MSE	P-value		
	SM	$Ca(OH)_2$ DCC	NaOH DCC			Diet	Breed	D x B
	FE_{DM} (g DM h^{-1})			Mean				
Saanen	190.00	199.84	190.00	199.84	12.67	0.95	0.87	0.71
Anglo-Nubian	206.66	186.70	206.66	186.70				
Mean	198.33a	193.27a	198.33a					
FE_{NDF} (g NDF h^{-1})								
Saanen	73.83	70.13	54.27	66.07	4.69	0.03	0.93	0.72
Anglo-Nubian	79.24	64.86	55.41	66.50				
Mean	76.54a	67.50ab	54.84b					
RE_{DM} (g DM h^{-1})								
Saanen	154.07	153.95	161.32	156.45	9.41	0.53	0.69	0.88
Anglo-Nubian	153.61	155.55	173.39	160.85				
Mean	153.84a	154.75a	167.36a					

continue

continuation

	RE_{NDF} (g NDF h^{-1})							
Saanen	59.84	53.48	44.91	52.74	3.02	0.01	0.77	0.85
Anglo-Nubian	58.85	58.83	48.65	53.77				
Mean	59.34a	53.65ab	46.78b					
	TCT (h day^{-1})							
Saanen	12.33	11.64	12.10	12.02	0.41	0.732	0.177	0.475
Anglo-Nubian	11.50	11.77	10.79	11.35				
Mean	11.91a	11.70a	11.45a					
	NRB (nº day^{-1})							
Saanen	795.60	747.78	672.55	738.64	61.99	0.35	0.10	0.99
Anglo-Nubian	673.17	629.85	541.21	614.74				
Mean	734.39a	688.81a	606.88a					

MSE: Mean standard error
Averages followed by common lowercase letters in the lines and by uppercase letters in the columns do not differ from one another according to the Tukey test at 5% significance.

The different diets had an effect (P = 0.03) on the frequency of water intake and interaction (P = 0.02), and on the frequency of daily urination (Table 5). We found that Anglo-Nubian goats fed SM diet urinated less than Saanen goats fed the same diet.

Table 5. Water intake (WI), Urination (URI) and defecation (DEF) of goats fed detoxified castor cake.

Breed	Diets				MSE	P-value		
	SM	$Ca(OH)_2$ DCC	NaOH DCC			Diet	Breed	D x B
	Water intake (times day^{-1})			Mean				
Saanen	3.25	4.25	5.25	4.25A	0.69	0.03	0.26	0.18
Anglo-Nubian	2.75	1.25	6.00	3.33A				
Mean	3.00b	2.75b	5.62a					
	Urination (times day^{-1})							
Saanen	6.75Aa	5.50Aa	7.75Ba	6.66	0.77	0.47	0.27	0.02
Anglo-Nubian	5.50Aa	4.25Aa	2.25Ab	4.00				
Mean	6.12	4.87	5.00					
	Defecation (times day^{-1})							
Saanen	4.50	4.75	4.75	4.66A	0.76	0.58	0.64	0.59
Anglo-Nubian	5.00	4.00	6.25	5.08A				
Mean	4.75a	4.37a	5.50a					

MSE: Mean standard error
Averages followed by common lowercase letters in the lines and by uppercase letters in the columns do not differ from one another according to the Tukey test at 5% significance.

According to Neiva et al. (2004), the frequency of water intake directly correlates with DM intake. However, in this study, the inverse occurred, as goats fed NaOH DCC consumed low amounts of DM. This behavior can be explained by two factors. The first is related to the sodium content in NaOH DCC diets, i.e., the large amount of sodium in this diet (Table 1) reduced DM intake (Table 3). Large amounts of sodium in the diet alter the tonicity of the ruminal environment, creating an imbalance in the sodium level in the rumen compared to the other organs in the animal's body, leading to an increase in the frequency of water intake in order to dilute the sodium and render the medium isotonic (KOZLOSKI, 2011; MCKINLEY; JOHNSON, 2004).

The second factor is related to NDF intake and is a consequence of the former. Goats fed SM and $Ca(OH)_2$ DCC diets consumed large amounts of NDF, resulting in long rumination time (Table 3). This behavior stimulated increased saliva flow, thereby increasing DM dilution rate in the rumen. In contrast, goats fed NaOH DCC consumed low amounts of NDF, thereby low rumination times, which resulted in a low dilution rate, requiring high water intake frequency.

A factor that may have influenced the low urinary frequency in Anglo-Nubian animals is the dark fur coloration of these goats, which promotes increased absorption of heat from the environment, leading to increased thermal stress. In such animals, heat dissipation occurs through the conversion of water into vapor, by both sweat secreted by the skin glands and moisture of the respiratory tract (MORAND-FEHR; DUREAU, 2001), justifying the low urinary frequency.

Dietary effects on HR and RT (P = 0.01 and 0.02) were observed, whereas BST was influenced by the breed of the animals. The high RH for animals fed the SM diet should be related to the high DM intake and rumination time of the animals, since according to Kolb and Gürtler (1987), the ingestion of large amounts of food causes a considerable increase in HR, and rumination changes the HR by 3%. The animals fed this diet consumed large amounts of DM and presented high rumination times (Table 6). Despite the observed variation, all the animals presented HRs within the normal range, 70–90 beats per min^{-1} (KELLY, 1976).

The high feed intake and long rumination time (Table 3), along with the low frequency of water intake, probably increased the internal temperature of the goats fed SM and $Ca(OH)_2$ DCC diets, while goats fed NaOH DCC diet had low caloric increase because of low feed intake and high water intake, thus, dissipating metabolic heat. RT is a good indicator of the dietary effect on the energy produced by metabolism: an increase in the RT means that the animal is retaining heat, and if this heat is not dissipated, caloric stress can occur (CUNNINGHAM, 2014). Despite the minor observed variations, the goats in our study did not show stress from the diets, considering that according to Kelly (1976), the physiological reference for RT in goats at rest is 38.50 °C to 39.70 °C.

The BST of Anglo-Nubian goats was higher than that of Saanen goats, which is related to the color of their coats. Similar to the trend observed for the urinary frequency, the light coat color of Saanen goats reflects more heat, which, despite their stalls being covered/shaded, promotes greater reflection of heat from the environment. This is in contrast to the Anglo-Nubian goats, which in turn absorb greater amounts of heat due to their darker and spotted fur/coat. Silva et al. (2006) reported lower surface temperatures in Savana goats than in Anglo-Nubian, confirming that the light coat color of Savana goats facilitates heat reflection.

Table 6. Heart rate (HR), respiratory rate (RR), rectal temperature (RT) and body surface temperature (BST) of goats fed detoxified castor cake.

Breed	Diets				MSE	P-value		
	SM	$Ca(OH)_2$ DCC	NaOH DCC			Diet	Breed	D x B
	HR (beats min^{-1})			Mean				
Saanen	86.88	86.88	75.07	82.94A	1.78	0.01	0.15	0.63
Anglo-Nubian	93.27	83.33	75.55	84.05A				
Mean	90.08a	85.10b	75.31b					
	RR (mov min^{-1})							
Saanen	39.05	38.05	38.62	38.57A	0.52	0.24	0.79	0.83
Anglo-Nubian	39.66	39.02	37.63	38.77A				
Mean	39.36a	37.84a	38.83a					
	RT (ºC)							
Saanen	38.96	39.01	38.78	38.92A	0.03	0.02	0.35	0.36
Anglo-Nubian	39.09	38.95	38.85	38.97A				
Mean	39.03a	38.98a	38.82b					
	BST (ºC)							
Saanen	36.12	36.22	35.96	36.10B	0.17	0.99	0.02	0.58
Anglo-Nubian	36.52	36.39	36.65	36.52A				
Mean	36.32a	36.31a	36.30a					

MSE: Mean standard error

Averages followed by common lowercase letters in the lines and by uppercase letters in the columns do not differ from one another according to the Tukey test at 5% significance.

Conclusions

Castor cake detoxified using sodium hydroxide reduces the dry matter intake and feed efficiency of dairy goats. Physiological parameters are influenced by both diets and breed, without any negative changes that indicate animal stress or discomfort.

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