Revista Brasileira de Zootecnia

Detoxified castor in the diets of dairy goats: II. Lactation curves, composition, and fatty acid profile of milk

Ricardo Alves de Araújo[1]* (iD), Roberto Cláudio Fernandes Franco Pompeu[2] (iD), Magno José Duarte Cândido[3] (iD), Marcos Cláudio Pinheiro Rogério[2] (iD), Ronaldo Carlos Lucas[3] (iD), Samuel Rocha Maranhão[3] (iD), Clemente Fernandes dos Santos Neto[3] (iD), José Neuman Miranda Neiva[4] (iD)

[1] Universidade Estadual do Maranhão, Itapecuru-Mirim, MA, Brasil.
[2] Embrapa Caprinos e Ovinos, Sobral, CE, Brasil.
[3] Universidade Federal do Ceará, Fortaleza, CE, Brasil.
[4] Universidade Federal do Tocantins, Araguaína, TO, Brasil.

Corresponding author:
ricardo_zoo@hotmail.com

How to cite: Araújo, R. A.; Pompeu, R. C. F. F.; Cândido, M. J. D.; Rogério, M. C. P.; Lucas, R. C.; Maranhão, S. R.; Santos Neto, C. F. and Neiva, J. N. M. 2020. Detoxified castor in the diets of dairy goats: II. Lactation curves, composition, and fatty acid profile of milk. Revista Brasileira de Zootecnia 49:e20190140. https://doi.org/10.37496/rbz4920190140

ABSTRACT - We aimed to evaluate the lactation curves, composition, and fatty acid profile of milk of lactating goats fed diets containing detoxified castor cake (DCC) by alkaline solutions during 150 days of lactation. Twenty-four Saanen and Anglo Nubian goats, approximately 17 months old (first lactation) and 43±2.97 kg body weight, were distributed in a completely randomized block design with eight replicates. Treatments consisted of three diets, one containing soybean meal (SM) and two others containing DCC, with calcium hydroxide [$Ca(OH)_2$] and sodium hydroxide (NaOH). The lactation curves showed greater persistence of lactation in Saanen goats. There were significant effects of diets on the profile of some fatty acids present in the milk. We observed that the NaOH DCC diet led to an increase in desirable fatty acid content. Both $Ca(OH)_2$ and NaOH DCC diets led to decreased milk production during the lactation period; however, the NaOH DCC diet led to high productive efficiency. Furthermore, NaOH DCC did not negatively affect the desirable fatty acid content, unlike $Ca(OH)_2$ DCC. Diets formulated with detoxified castor decrease the production of milk from goats during lactation phase. It should be emphasized that milk produced by goats fed DCC diets does not contain unwanted waste.

Keywords: Anglo Nubian, persistence, ricin, Saanen

Introduction

Goats farmed for high levels of milk production require diets with an adequate nutritional balance, especially those with high genetic potential, such as the Saanen and Anglo Nubian breeds. These animals are generally concentrated in low-income countries, with food deficits, where its products are an important food source (Pulina et al., 2018). It is therefore necessary to investigate alternative feeds that reduce the production costs (Romero-Huelva et al., 2017), while maintaining the nutritional quality of diets and of the milk produced (Goetsch, 2016).

In Brazil, in recent years, there has been a marked increase in animal byproducts with potential to be used in animal feeds, especially those from the biodiesel production chains (Moreira et al., 2014; Araújo et al., 2018). Among these products, we highlight castor bean cake due to its high protein content, but its utility as an animal feed may be compromised by the presence of antinutritional compounds, especially ricin (Dang and Van Damme, 2015). Ricin is a highly toxic protein, whose different methods for detoxification are currently being studied, aiming at its safe use in diets for ruminants (Borja et al.,

2017). Inefficient detoxification, however, can generate undesirable waste products from these animals (Alves et al., 2017).

In this context, the use of the detoxified castor in diets of dairy goats presents a gap to be studied, because, although goat milk is considered a food of high nutritional value, its properties can be changed, both negatively and advantageous, as the inclusion of fatty acids are desirable or not (Cattaneo et al., 2006).

Therefore, formulating changes in the nutritional quality of goat milk, with an emphasis on regional products, presents an alternative with great potential to contribute to the production of goat milk, considering the possibility of using animal byproducts from the biodiesel chain in diets for ruminants, giving efficient allocation to these products, and incorporating them in the productive chain of dairy goats. Thus, the hypothesis of this study is that there is a possibility of substitution of soybean meal by castor detoxified by alkaline solutions at the lactation stage of Saanen and Anglo Nubian goats, which can improve the nutritional efficiency, without modifying milk production and quality.

Based on the above, we aimed to evaluate the influence of castor detoxified by alkaline solutions on the lactation curves, milk yield and composition, and fatty acid profile of milk of lactating goats.

Material and Methods

All animal procedures were conducted in accordance with the regulations of the Ethics Committee on the Use of Animals (case no. 005/2015). The chemical analyses were performed in Sobral, CE, Brazil (3°44'57.42" S, 40°20'43.50" W). The chemical composition of milk and somatic cell counts were analyzed in Piracicaba, SP, Brazil. The experiment with the goats was conducted in Sobral.

Twenty-four goats with 43±2.97 kg body weight and body condition scores of 2.5±0.5 were used. Treatments consisted of three diets: the first was formulated with corn and soybean meal (SM) and the other two with detoxified castor cake (DCC) using calcium hydroxide ($Ca(OH)_2$ DCC) or sodium hydroxide (NaOH DCC), as a total substitution of SM. Tifton 85 hay, chopped to 4 cm, was used as a forage source.

Goats were distributed in a randomized block design (breed factor), with eight replicates per diet. At the end of the survey, there was a preliminary analysis of the data, in which we evaluated a possible interaction between breeds and diets, which did not happen. Therefore, we chose to use the randomized blocks to assess the effect of the breeds, considering that only milk production was affected by this factor. The diets, however, influenced some of the variables analyzed. In this way, all the remaining variables had eight repetitions, because the effect of breeds was null.

The goats were confined and housed in individual masonry stalls with suspended wooden floors and a total area of 5.06 m². Each stall contained a 2.87-m² solarium, constructed with wooden slats, which assured visual, auditory, olfactory, and tactile contact with the other animals of the adjacent bays. The solarium area was composed of wooden grids equipped with feeders, drinkers, and saltshakers. During the pre-experimental period, the goats were identified, treated against ecto- and endoparasites, and vaccinated against rabies (Dectomax® and Ourovac®, respectively). Then, they were distributed among treatments, and a 15-day adaptation period to the diets was allowed.

The experimental diets were formulated based on the isonitrogenous and isoenergetic diet recommendations of the NRC (2007) for goats with 45 kg body weight and daily milk production of 1.5 L. The chemical compositions of the ingredients used in the diet preparation are described in Table 1, and the proportions of ingredients and chemical composition of the diets are shown in Table 2. Detoxification with calcium hydroxide significantly elevated the calcium levels in the $Ca(OH)_2$ DCC diet. Upon addition of 90 g $Ca(OH)_2$, each kilogram of castor meal received 22.25 g of calcium (Table 1). This addition represents 40% of the calcium present in the mineral supplement and could cause an imbalance in the dietary calcium:phosphorus ratio. Owing to this variation, the forage:concentrate

Table 1 - Chemical composition of the ingredients used in the experimental diets

Item (g/kg dry matter)	Ingredient				
	Tifton 85 hay	Ground corn	Soybean meal	Ca(OH)$_2$ DCC[1]	NaOH DCC[2]
Dry matter (g/kg fresh matter)	872.50	889.20	870.20	904.20	904.80
Organic matter	911.30	965.90	956.90	867.70	855.60
Mineral matter	88.70	34.10	43.10	132.30	144.40
Crude protein	104.10	79.50	443.30	315.40	309.00
Neutral detergent insoluble protein	26.98	30.23	131.75	100.27	102.74
Acid detergent insoluble nitrogen	12.26	20.92	40.03	48.79	49.35
Ether extract	14.50	36.80	28.80	52.10	47.50
Total carbohydrates	792.80	845.70	484.70	500.10	492.60
Non-fiber carbohydrates	277.80	722.40	320.80	103.90	132.40
Neutral detergent fiber (NDF)	722.70	184.60	217.80	483.40	443.50
NDF corrected for ash and protein	514.90	123.20	163.80	396.10	360.10
Acid detergent fiber	472.20	69.00	117.90	379.20	388.70
Lignin	60.60	8.80	12.20	50.70	46.10
Total digestible nutrients	546.80	848.00	822.50	620.50	627.90

[1] Ca(OH)$_2$ castor cake: 0.9 g Na/kg DM and 22.25 g Ca/kg DM.
[2] NaOH castor cake: 29.2 g Na/kg DM and 0.63 g Ca/kg DM.

Table 2 - Ingredient proportions and chemical compositions of the experimental diets

Item	Diet		
	Soybean meal	Ca(OH)$_2$ DCC	NaOH DCC
Ingredient (g/kg dry matter)			
Tifton 85 hay	525.40	485.80	474.30
Ground corn	414.20	424.60	437.40
Soybean meal	58.70	-	-
Detoxified castor cake	-	89.60	85.70
Limestone	1.70	-	2.60
Mineral mixture[1]	*ad libitum*	*ad libitum*	*ad libitum*
Chemical composition (g/kg dry matter)			
Dry matter (g/kg fresh matter)	883.03	890.84	885.76
Organic matter	939.17	933.06	930.90
Mineral matter	62.49	66.94	71.43
Crude protein	113.94	110.13	112.12
Neutral detergent insoluble protein	12.54	13.58	13.89
Acid detergent insoluble nitrogen	3.17	3.65	3.54
Ether extract	26.46	29.22	29.82
Total carbohydrates	759.80	766.30	756.60
Non-fiber carbohydrates	471.80	468.70	477.40
Neutral detergent fiber (NDF)	416.78	424.98	404.54
NDF corrected for ash and protein	287.97	297.65	279.21
Acid detergent fiber	352.80	356.60	337.19
Lignin	30.86	32.62	30.32
Total digestible nutrients	674.90	678.80	678.70

[1] Guaranteed level (per kg, inactive elements): calcium, 218 g; phosphorus, 71 g; sulfur, 20 g; manganese, 1,300 mg; potassium, 28.20 mg; cobalt, 30 mg; selenium, 15.30 mg; zinc, 1,700 mg; copper, 710 mg.

4

Detoxified castor in the diets of dairy goats: II. Lactation curves, composition, and fatty acid profile of milk
Araújo et al.

ratio differed across the treatments. Moreover, DCC should be included as a protein ingredient at a maximum proportion of 8% of dietary dry matter (Pompeu et al., 2012).

Samples of experimental diets for determination of the fatty acid composition (Table 3) were collected throughout the experiment and stored in plastic bags previously identified and frozen at −78 °C. Prior to analysis, the samples were thawed at room temperature, dried in an oven at 65 °C for 72 h, and processed in Wiley mills with 1-mm sieves.

For the analysis of milk composition and quality, samples were collected every 30 d, from the seventh day of lactation. They were put in plastic bottles containing preservative Bronopol (2-bromo-2-nitropropane-1,3-diol) and analyzed later. For the determination of long-chain fatty acid profiles, milk samples were collected in the morning and afternoon every 30 d and immediately frozen in 50-mL Falcon® type tubes. At the end of the collection period, composite samples were prepared representing the milk proportion.

Milk production was corrected to 3.5% fat (MPF) using the formula: MPF = [(0.432 + 0.1625 × % of milk fat) × kg of milk], as proposed by Sklan et al. (1992). The energy value (EV) of milk was estimated in accordance with the equation proposed by Baldi et al. (1992): EV = 203.8 + (8.36 × % fat) + (6.29 × % protein). We used the model of Nelder (1966) for analysis of the parameters of the lactation curve, according to the equation: $\hat{Y}t = t / (a + bt + ct^2)$, in which Y is the milk production, a represents the growth rate of the curve to the peak of production, b is the average slope of the lactation curve, c is the slope in the phase of decline, and t is the time of lactation in weeks. From the model parameters, the time to reach peak (TP) and milk production at peak (PP) were analyzed. For the TP estimation, we used the formula TP = $\sqrt{a/c}$, and for PP, the formula $1/2 \sqrt{ac + b}$.

Castor cakes used in this study were obtained after collecting oil, by mechanically pressing castor bean seeds at temperatures between 90 and 100 °C. After mixing the cakes with reagents and water for 3 h (mixing for 10 min and resting for 30 min, alternately), the cakes were placed outdoors on a plastic canvas for 48 h and constantly rolled with a squeegee adapted for homogeneous drying. After drying, the cakes were chopped using a forage machine to reduce the material size and to facilitate its homogenization with the other ingredients.

Table 3 - Composition of fatty acids of the experimental diets (%)

Fatty acids	Name	Diet (%)		
		Soybean meal	Ca(OH)$_2$ DCC	NaOH DCC
C8:0	Caprylic	-	0.95	0.40
C11:0	Undecanoic	-	0.03	-
C13:0	Tridecanoic	4.66	4.78	4.92
C14:0	Myristic	0.02	0.02	0.02
C15:1 cis10	Cis,10, Pentadecanoic	0.73	0.75	0.78
C16:0	Palmitic	7.14	5.78	6.16
C16:1 cis9	Cis, 9, Palmitoleic	13.52	13.86	14.28
C16:1	Palmitoleic	20.17	20.67	21.29
C17:0	Heptadecanoic	0.31	0.32	0.32
C17:1 cis10	Cis-10- heptadecanoic	1.40	1.00	0.98
C18:0	Stearic	19.43	17.11	17.18
C18:1n9c	Oleic	29.48	25.12	25.56
C18:1 trans9	Elaidic	1.47	1.46	1.48
C18:1 cis 9, 12-OH	Hidroxy ricinoleic	-	4.21	8.23
C18:2n6c	Linoleic	2.92	2.20	2.34
C18:3n3	Linolenic	0.21	0.14	0.15
C18:3n6	γ-linolenic	2.43	2.31	2.22

5

Detoxified castor in the diets of dairy goats: II. Lactation curves, composition, and fatty acid profile of milk
Araújo et al.

The concentrations of alkaline products (calcium hydroxide and sodium hydroxide) used for 100% detoxification of ricin in crude castor cakes were 90 g Ca(OH)$_2$ and 60 g NaOH per kilogram, respectively, which were diluted in 2 L of water using a stationary mixer (Fischer® MOB 400 G2) equipped with a three-phase motor. No hemagglutinating activity was observed at those concentrations, i.e., ricinus agglutinin was no longer active; therefore, these two concentrations were used to formulate the diets.

The analysis of yield of cheese (YC) was performed with the addition of an enzyme coagulant (HalaMix®) to milk for 1 h at room temperature of 25 °C in 5-mL Eppendorf® tubes. After coagulation, this material was centrifuged for 3,293 × g for 15 min, and the liquid fraction was drained in 45 min, following the protocol proposed by Othmane et al. (2002), with adjustments. The YC was defined as the weight of the residue obtained after centrifugation of the drainage, expressed in kg/100 L of milk. Milk acidity was verified by the Dornic method, and the density was determined through the Thermo-lactodensimeter of Quevenne; the values obtained were corrected to 15 °C.

The composition analysis was carried out by infrared spectrophotometry in a B2300 Combi (Bentley®), to quantify the levels of protein, fat, lactose, total solids, urea nitrogen, and casein. The somatic cell count was performed using a Somacount 500 electronic counter.

Samples intended for the analysis of long-chain fatty acids profile were thawed in a water bath at 40 °C and centrifuged, logged, and then the fat was extracted, according to the methodology described by Bligh and Dyer (1959). Nitrogen was used to completely evaporate the chloroform, resulting in purified fat. The fatty acids were transmethylated according to the method described by Molkentin and Precht (2000), with modifications.

The esters formed were separated using a gas chromatograph (Shimadzu® GC 2010) equipped with a flame detector and silica capillary column (Supelco SP-TM-2560, 100 × 0.25 mm i.d.). Both injector and detector were kept at 250 °C. Nitrogen gas drag was used, and the nozzle pressure was kept constant at 243.7 kPA. A reference standard (Supelco 37 Component FAME mix), to which the CLA (conjugated linoleic acid methyl ester, Sigma-Aldrich) was added, was used to determine recoveries and correction factors for the fatty acid determination. The fatty acids were identified and quantified by comparison of retention times and areas of their peaks and their respective standards. The Atherogenicity index was calculated by the formula: [C12 + (4 × C14) + C16] /sum of unsaturated fatty acids), as per Chilliard et al. (2003).

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

$$Y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij},$$

in which Y_{ij} is the dependent variable corresponding to the experimental observation, μ is the overall mean, α_i is the fixed effect of the diets, β_j is the fixed effect of the breed, and ε_{ij} is the random error, assuming an independent normal distribution. A comparison of means was performed by Tukey's test at 5% probability to evaluate the effects of breed and diet. Statistical analysis was performed using the PROC MIXED procedure of SAS software (Statistical Analysis System, version 9.4).

In the adjustment of lactation curves, the parameters of non-linear regressions were estimated by NLIN procedure, using the modified Gauss-Newton method. For this method to be iterative, it requires initial values to start the process of minimizing the sum of squares of the error. In this way, we used initial guesses for each parameter, until they reached a sufficient interval for the program calculation.

Results

We observed that the Anglo Nubian goats fed SM and Ca(OH)$_2$ DCC diets required more time to reach the peak of production (46.90 days), followed by the Saanen goats fed the same diets (45.50 d). The goats that received the NaOH DCC diet reached the peak of production earlier, 42.70 d for the Anglo Nubian and 44.80 d for the Saanen goats (Figure 1).

The peak of production was higher for the Saanen goats fed Ca(OH)$_2$ DCC (2.51 kg/day), 10 g more than the Anglo Nubians fed SM. The lowest peak of production happened for the Anglo Nubian goats fed NaOH DCC (2.42 kg/day). It is observed that the model adjusted satisfactorily to all lactation curves according to the coefficient of determination (R^2). The slope of the curve for the Anglo Nubian goats fed NaOH DCC (E) was larger than the others (0.258) and the lowest tilt was observed for the Saanen
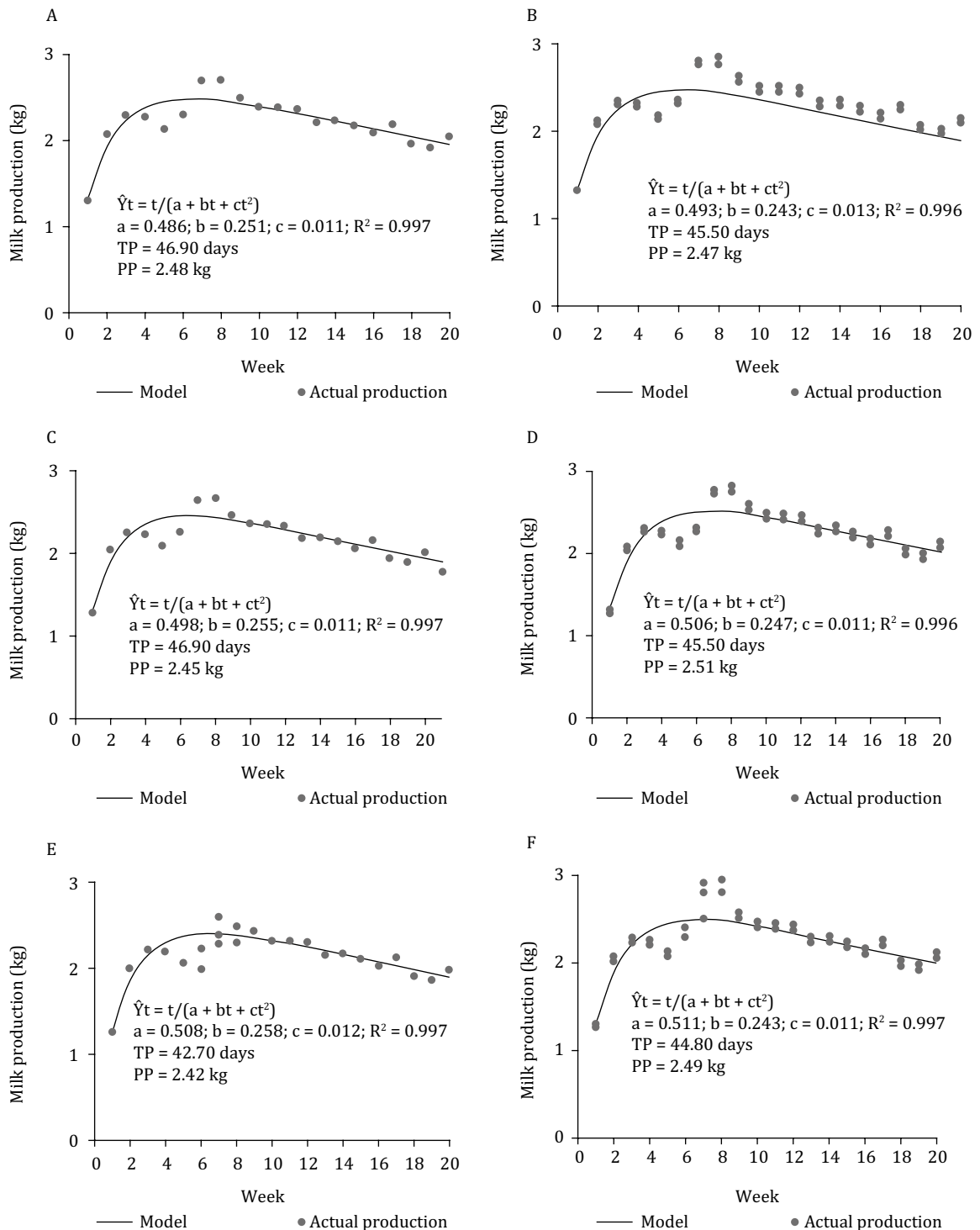
A

$\hat{Y}t = t/(a + bt + ct^2)$
a = 0.486; b = 0.251; c = 0.011; R^2 = 0.997
TP = 46.90 days
PP = 2.48 kg

— Model   • Actual production

B

$\hat{Y}t = t/(a + bt + ct^2)$
a = 0.493; b = 0.243; c = 0.013; R^2 = 0.996
TP = 45.50 days
PP = 2.47 kg

— Model   • Actual production

C

$\hat{Y}t = t/(a + bt + ct^2)$
a = 0.498; b = 0.255; c = 0.011; R^2 = 0.997
TP = 46.90 days
PP = 2.45 kg

— Model   • Actual production

D

$\hat{Y}t = t/(a + bt + ct^2)$
a = 0.506; b = 0.247; c = 0.011; R^2 = 0.996
TP = 45.50 days
PP = 2.51 kg

— Model   • Actual production

E

$\hat{Y}t = t/(a + bt + ct^2)$
a = 0.508; b = 0.258; c = 0.012; R^2 = 0.997
TP = 42.70 days
PP = 2.42 kg

— Model   • Actual production

F

$\hat{Y}t = t/(a + bt + ct^2)$
a = 0.511; b = 0.243; c = 0.011; R^2 = 0.997
TP = 44.80 days
PP = 2.49 kg

— Model   • Actual production

Figure 1 - Lactation curves estimated by the Nelder model for Anglo Nubian (A) and Saanen (B) goats fed diets containing soybean meal (SM); Anglo Nubian (C) and Saanen (D) fed diets containing detoxified castor by calcium hydroxide [Ca(OH)$_2$ TMD]; Anglo Nubian (E) and Saanen (F) fed diets containing detoxified castor by sodium hydroxide [NaOH TMD].

7

Detoxified castor in the diets of dairy goats: II. Lactation curves, composition, and fatty acid profile of milk
Araújo et al.

goats fed SM (B), with a slope of 0.243. In general, it was observed that the Saanen goats, regardless of the diets, showed a lower slope of the curve (0.246), and the Anglo Nubian goats showed an inclination of 0.255.

There was a significant effect (P<0.05) of diets on milk fat content and YC, but no significant effect was observed (P>0.05) on the other parameters or effects of the breeds (Table 4). The goats fed SM produced a fattier milk (35.12 g/kg of milk); the goats fed DCC produced a lower-fat milk, 31.82 and 32.51 g/kg for the diets containing Ca(OH)$_2$ DCC and NaOH DCC, respectively. The same trend occurred for YC, in which goats fed SM yielded 22.80 kg of cheese for each 100 kg of milk. The milk from goats fed DCC produced less cheese, i.e., for each 100 kg of milk 20.75 and 21.62 kg of cheese were produced for diets containing Ca(OH)$_2$ DCC and NaOH DCC, respectively, which did not differ among themselves.

When the values are expressed in g/day, it is observed that the diets markedly influenced milk composition. We observed a significant effect (P<0.05) of diets on the levels of fat, protein, lactose, and degreased dry extract, but there was no significant effect (P>0.05) on the content of total solids (Table 4). Generally, all the above components were higher in milk from goats fed the SM diet. The composition of milk of goats fed DCC diets did not differ among themselves.

There were significant effects (P<0.05) of diets on the profile of some fatty acids present in milk (Table 5). In relation to short-chain fatty acids (C4–C13), it was observed that C10:0 and C12:0 were higher in the milk of goats fed diets with SM or Ca(OH)$_2$ DCC. The medium-chain fatty acids (C14:C16), which were significantly influenced by the diets, were C:14, C14:1, and C:16 (myristic, myristoleic, and palmitic, respectively), and for the long chain fatty acids (>C16), only C18:1n 9c and C18:2n 6c (oleic and linoleic acid, respectively) were significantly influenced. In this case, we observed that myristic acid was higher in the milk of goats fed Ca(OH)$_2$ DCC (3.66 g/100 g of fatty acids); palmitic acid was also higher in milk from this diet, but did not differ from that of the milk of goats fed SM. Myristoleic acid

Table 4 - Physicochemical composition of milk from goats fed diets containing detoxified castor by different alkali in substitution to soybean meal

Production (g/kg)	Diet			SEM	P-value	
	Soybean meal	Ca(OH)$_2$ DCC	NaOH DCC		Diet	Breed
Fat	35.12a	31.82b	32.51b	0.32	<0.05	0.41
Protein	31.03	28.51	29.63	0.10	0.36	0.65
Lactose	45.52	45.21	45.12	0.27	0.92	0.08
Total solids	111.02	110.21	115.50	0.48	0.67	0.35
Casein	24.22	21.16	22.47	0.13	0.32	0.54
Dry extract degreased	8.53	8.26	8.34	0.13	0.42	0.40
Yield of cheese (kg)	22.80a	20.75b	21.62b	0.91	<0.05	0.67
Acidity (°D)	15.60	15.25	15.87	0.64	0.78	0.70
Somatic cell count (cell/mL × 1000)	352.40	367.00	352.40	134.44	0.66	0.40
Milk urea nitrogen (mg/dL)	13.98	14.92	17.75	1.66	0.340	0.25
Energy value (Mcal/kg)	2.56	2.52	2.53	0.02	0.36	0.38
Density (kg/m³)	1.030	1.029	1.030	0.10	0.98	0.78
Composition (g/day)						
Fat	88.70a	80.33b	81.10b	3.61	<0.05	0.39
Protein	68.51a	62.29b	63.99b	1.86	<0.05	0.62
Lactose	100.64a	98.64b	97.49b	1.37	<0.05	0.10
Total solids	245.48	240.23	249.58	8.40	0.05	0.38
Dry extract degreased	188.55a	180.06b	180.25b	3.02	<0.05	0.60

SEM - standard error of the mean.
a-b - Means within a row with different letters are different by Tukey's test at 5% significance.

8

Detoxified castor in the diets of dairy goats: II. Lactation curves, composition, and fatty acid profile of milk
Araújo et al.

was lower in the milk from goats fed NaOH DCC (0.36 g/100 g of fatty acids) and oleic and linoleic acids in the milk of goats fed the Ca(OH)$_2$ DCC diet.

The concentrations of saturated (SFA), monounsaturated (MUFA), and polyunsaturated (PUFA) fatty acids, the PUFA:SFA ratio, desirable fatty acids, omega-6 fatty acids, and the atherogenicity index were significantly influenced (P<0.05) by the diets (Table 6).

Table 5 - Fatty acid profile (g/100 g of fatty acids) of milk from goats fed diets containing detoxified castor by different alkali in substitution to soybean meal

Fatty acid	Name	Diet			SEM	P-value	
		Soybean meal	Ca(OH)$_2$ DCC	NaOH DCC		Diet	Breed
C6:0	Caproic	1.95	1.95	1.87	0.07	0.75	0.30
C8:0	Caprylic	1.78	2.17	1.58	0.14	0.15	0.25
C10:0	Capric	6.57a	6.88a	5.63b	0.51	<0.05	0.05
C11:0	Undecanoic	0.23	0.25	0.20	0.03	0.60	0.61
C12:0	Lauric	3.42a	3.66a	3.13b	0.21	<0.05	0.36
C13:0	Tridecanoic	0.13	0.13	0.13	0.02	0.96	0.69
C14:0	Myristic	7.62b	8.97a	7.90b	0.39	<0.05	0.50
C14:1	Myristoleic	0.55a	0.46b	0.36c	0.06	<0.05	0.43
C15:0	Pentadecanoic	0.83	0.70	0.82	0.10	0.67	0.446
C16:0	Palmitic	25.56a	25.59a	23.31b	0.75	<0.05	0.10
C16:1	Palmitoleic	0.40	0.63	0.48	0.06	0.13	0.12
C17:0	Heptadecanoic	0.71	0.70	0.75	0.08	0.88	0.07
C18:0	Stearic	15.82	14.89	16.18	0.65	0.39	0.17
C18:1n 9t	Elaidic	0.65	0.68	0.62	0.14	0.96	0.39
C18:1n 9c	Oleic	30.30b	28.80b	33.13a	1.58	<0.05	0.15
C18:2n 6c	Linoleic	3.27a	2.62b	3.01a	0.15	<0.05	0.88
C18:3n3	Linolenic	0.22	0.26	0.20	0.03	0.40	0.64
C18:3n6	γ-linolenic	0.23	0.23	0.22	0.02	0.97	0.72
Cis-9, trans-11,18:2	Conjugated linoleic	0.46	0.43	0.47	0.05	0.85	0.96

SEM - standard error of the mean.
a-c - Means within a row with different letters are different by Tukey's test at 5% significance

Table 6 - Summations and relations of the principal fatty acids present in the fat of milk of goats fed with diets containing detoxified castor by different alkali in substitution to soybean meal

Fatty acid	Diet			SEM	P-value	
	Soybean meal	Ca(OH)$_2$ DCC	NaOH DCC		Diet	Breed
Saturated fatty acids (SFA)	63.43a	65.47a	61.46b	1.68	<0.05	0.18
Monounsaturated fatty acids	32.27a	30.89b	34.51a	1.25	<0.05	0.07
Polyunsaturated fatty acids (PUFA)	4.28a	3.63b	4.02a	0.15	<0.05	0.23
PUFA: SFA	0.51a	0.46b	0.55a	0.03	<0.05	0.07
Desirable fatty acids[1]	48.10a	45.79b	50.69a	1.34	<0.05	0.07
Omega-3 fatty acids[2]	0.22	0.26	0.20	0.03	0.13	0.25
Omega-6 fatty acids[3]	3.51a	3.23a	2.85b	0.16	<0.05	0.84
Atherogenicity index	1.74b	2.07a	1.66b	0.12	<0.05	0.08

SEM - standard error of the mean.
a-b - Means within a row with different letters are different by Tukey's test at 5% significance.
[1] Desirable fatty acids + C18:0.
[2] Σ (C18:1 cis15, C18:2 trans11cis15, C18:3 n3, C22:6 n3).
[3] Σ (C18:2n6c, C18:3n6).

9

Detoxified castor in the diets of dairy goats: II. Lactation curves, composition, and fatty acid profile of milk
Araújo et al.

It was observed that DCC reduced the content of SFA when compared with the other diets; in addition, MUFA and PUFA were reduced when goats were fed $Ca(OH)_2$ DCC. This reduction in the saturation of fatty acids provided the lowest PUFA:SFA ratio in goats that were fed this diet, which in turn decreased the concentration of desirable fatty acids (45.79 g/100 g of fatty acids), among which we can highlight the total CLA (0.54 g/100 g of fatty acids) and, consequently, the increase in the atherogenicity index (2.07). Omega-6 fatty acids were lower in the milk of goats fed NaOH DCC.

Discussion

The effects of different breeds on milk production in terms of daily and total production throughout the lactation period were expected, considering that Saanen goats, under environmental and nutritional conditions equal to those of Anglo Nubian goats, produce greater quantities of milk (Lôbo et al., 2017). The data related to the lactation curves (Figure 1) corroborate this result. In summary, the differences between the different breeds implies greater persistency of lactation in Saanen goats. With regard to the effects of the diets, although goats fed DCC produced less milk, their growth rate until the peak of production was higher, indicating rapid growth and, therefore, less time to reach this peak, but with lower milk production.

In relation to lower milk yield corrected for 3.5% fat (MYCF) of goats fed DCC diets, several factors may have contributed in a direct way, among which the lower lactose content of milk is important. The latter is associated with the adjustment of the milk volume due to the osmotic pressure in the alveoli of the mammary glands. Besides, higher amounts of lactose lead to increased milk production (Torres et al., 2016). This variable, however, should not be analyzed in isolation, as despite the greater FEMP, the compositions of the milk from goats fed both diets containing DCC were inferior to the constituents of milk produced by goats fed SM. Among these, we highlight the milk solids (g/day) and YC with the replacement of SM by DCC. Thus, it is observed that the DCC used in feed for lactating goats can affect the yield of milk derivatives. This result is of paramount importance, considering that cheese and other milk products derived from goat milk are common products for market (Clark and García, 2017).

The acidity of the milk showed a mean value of 15.57 (°Dornic). The results presented are within the limits in the Normative Instruction no. 37 of Brazilian legislation (Brasil, 2000), which varies from 13 to 18 °D. When the titratable acidity of the milk has a content of more than 18 °D, it is a sign of high levels of bacterial contamination, bearing in mind that lactose is fermented by lactic acid bacteria forming mainly lactic acid, which is responsible for the increase in the acidity of the milk and, consequently, reduction of lactose, which can reduce the quality of milk for marketing.

The sanitization performed on the hooves of goats was effective and contributed to minimizing the microbial contamination of milk, which was confirmed by low somatic cell counts. The diets also did not influence the milk density. This parameter is used to check information about the quantity of fat in milk and for fraud detection, such as the use of water in milk. The higher the levels of fat and water in milk composition, the lower the density. The milk of goats fed SM could have presented a lower density, since fat content was higher (35.12 g/kg), but as the amount of total solids did not differ between the milk produced, the density was equal.

Notably, ricinoleic acid present in DCC diets (Table 3) was observed in the milk of goats; this can be beneficial, considering that the metabolism of this acid in the rumen is slow (Alves et al., 2017). The levels of capric acid were lower in the milk of goats fed NaOH DCC. This fatty acid, as well as the caproic and caprylic acids, is responsible for the flavor and characteristic odor of goat milk, which is considered unpalatable by a good portion of the population not accustomed to it (García et al., 2014). Thus, it can be indirectly inferred that feeding goats the NaOH DCC diet, which comprises lower content of these fatty acids, may render the milk more palatable and, therefore, increase sales potential, but only one sensory analysis and/or acceptability could confirm such information. Palmitic acid can be an indicator of this assertion, because, according to Chilliard et al. (2003), there is a strong negative correlation between the activity of lipolytic enzymes, responsible for oxidation and the off-flavor of milk, and the palmitic acid concentration. Thus, the low levels of palmitic acid identified in the milk of goats fed the

10

Detoxified castor in the diets of dairy goats: II. Lactation curves, composition, and fatty acid profile of milk
Araújo et al.

NaOH DCC diet may indicate high levels of lipases activity and, consequently, the higher possibility of oxidation and off-flavor, which indicates lower shelf life.

The level of myristoleic acid was lower in the milk of goats fed NaOH DCC. The level of monounsaturated myristoleic acid was low in milk, and was produced by goats fed the standard diet. In addition, the levels of MUFA for this milk from goats fed the standard diet were higher. Similarly, the levels of linoleic and oleic acids were higher. The reduction in the amounts of linoleic and linolenic acids in the milk of goats fed $Ca(OH)_2$ DCC is undesirable, because, although the diets did not influence the amount of conjugated linoleic acids, these are important precursors for CLA production (Tsiplakou and Zervas, 2008). It is possible that this occurred due to the greater amount of SFA in the diet (Table 3) compared with the others, providing more substrates for the ruminal microorganisms, and therefore a more conducive environment for bacterial biohydrogen of the unsaturated fatty acids. This reduction was also observed in the amounts of PUFA, which were lower in the milk of goats fed the $Ca(OH)_2$ DCC diet, influencing even the smallest PUFA:SFA ratio and the amount of desirable fatty acids. According to Schmidely et al. (2005), the increase in the PUFA:SFA ratio may be favorable to reduce the plasma cholesterol levels, which proves to be a negative point to the milk of goats fed the $Ca(OH)_2$ DCC diet. In addition, the atherogenicity index (AI) was greater in this milk. This index has a negative correlation with milk quality, because the lower the AI, the greater its quality, reducing the risk of cardiovascular diseases in people who consume this type of product (Ulbricht and Southgate, 1991).

Despite the greater amount of PUFA in milk of goats fed the standard and the NaOH DCC diets, the acids belonging to the omega-6 family decreased in the milk of goats fed NaOH DCC diet, which is undesirable, since these acids are of great importance to human health in terms of nutritional functions and possessing anti-inflammatory properties (Cattaneo et al., 2006). As these acids cannot be synthesized by ruminants (Cook and McMaster, 2002), it can be concluded that the diet containing NaOH DCC produced smaller quantities of acids belonging to this family.

Conclusions

The alkaline chemical treatments in the detoxification process directly affect the quality of goat milk. Diets formulated with detoxified castor decrease the production of milk of goats during lactation. Thus, it is recommended that the milk industry utilize diets containing detoxified castor with NaOH, because it increases the product value. However, feeding animals diets formulated with detoxified castor with $Ca(OH)_2$ leads to similar production values as diets based on soybean, but with lower nutritional levels.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Data curation: R.A. Araújo. Formal analysis: R.A. Araújo. Investigation: R.A. Araújo, R.C.F.F. Pompeu, M.J.D. Cândido, M.C.P. Rogério, R.C. Lucas, S.R. Maranhão, C.F. Santos Neto and J.N.M. Neiva. Methodology: R.A. Araújo, R.C.F.F. Pompeu, M.C.P. Rogério and J.N.M. Neiva. Project administration: R.A. Araújo and R.C.F.F. Pompeu.

Acknowlegments

References

Alves, S. P.; Araujo, C. M.; Queiroga, R. C.; Madruga, M. S.; Parente, M. O. M.; Medeiros, A. N. and Bessa, R. J. B. 2017. New insights on the metabolism of ricinoleic acid in ruminants. Journal of Dairy Science 100:8018-8032. https://doi.org/10.3168/jds.2017-13117

Araújo, R. A.; Neiva, J. N. M.; Pompeu, R. C. F. F.; Cândido, M. J. D.; Rogério, M. C. P.; Lucas, R. C.; Maranhão, S. R.; Fontinele, R. G. and Egito, A. S. 2018. Feeding behavior and physiological parameters of rearing goats fed diets containing detoxified castor cake. Semina: Ciências Agrárias 39:2247-2260. https://doi.org/10.5433/1679-0359.2018v39n5p2247

Baldi, A.; Cheli, F.; Corino, C.; Dell'Orto, V. and Polidori, F. 1992. Effects of feeding calcium salts of long chain fatty acids on milk yield, milk composition and plasma parameters of lactating goats. Small Ruminant Research 6:303-310. https://doi.org/10.1016/0921-4488(91)90137-F

Bligh, E. G. and Dyer, W. J. 1959. A rapid method of total lipid extraction and purification. Canadian Journal of Biochemistry and Physiology 37:911-917. https://doi.org/10.1139/o59-099

Borja, M. S.; Oliveira, R. L.; Silva, T. M.; Bezerra, L. R.; Nascimento Júnior, N. G. and Borja, A. D. P. 2017. Effectiveness of calcium oxide and autoclaving for the detoxification of castor seed meal in finishing diets for lambs. Animal Feed Science and Technology 231:76-88. https://doi.org/10.1016/j.anifeedsci.2017.07.001

Brasil. 2000. Ministério da Agricultura, Pecuária e Abastecimento. Departamento de Defesa da Agricultura. Instrução Normativa nº 37, de 31 de outubro de 2000. Aprova o regulamento técnico de produção, identidade e qualidade de leite de cabra. Diário Oficial da União, Brasilia, DF, 8 nov. 2000. Secão 1, p.23.

Cattaneo, D.; Dell'Orto, V.; Varisco, G.; Agazzi, A. and Savoini, G. 2006. Enrichment in *n*-3 fatty acids of goat's colostrum and milk by maternal fish oil supplementation. Small Ruminant Research 64:22-29. https://doi.org/10.1016/j.smallrumres.2005.03.013

Chilliard, Y.; Ferlay, A.; Rouel, J. and Lamberet, G. 2003. A review of nutritional and physiological factors affecting goat milk lipid synthesis and lipolysis. Journal of Dairy Science 86:1751-1770. https://doi.org/10.3168/jds.S0022-0302(03)73761-8

Clark, S. and García, M. B. M. 2017. A 100-year review: Advances in goat milk research. Journal of Dairy Science 100:10026-10044. https://doi.org/10.3168/jds.2017-13287

Cook, H. W. and McMaster, C. R. 2002. Fatty acid desaturation and chain elongation in eukaryotes. p.181-204. In: Biochemistry of lipids, lipoproteins and membranes. 4th ed. Vance, D. E. and Vance, J. E., eds. Elsevier, Amsterdam.

Dang, L. and Van Damme, E. J. M. 2015. Toxic proteins in plants. Phytochemistry 117:51-64. https://doi.org/10.1016/j.phytochem.2015.05.020

García, V.; Rovira, S.; Boutoial, K. and López, M. B. 2014. Improvements in goat milk quality: A review. Small Ruminant Research 121:51-57. https://doi.org/10.1016/j.smallrumres.2013.12.034

Goetsch, A. L. 2016. Invited review: Current areas of research of feeding practices for lactating goats. The Professional Animal Scientist 32:725-735. https://doi.org/10.15232/pas.2016-01541

Lôbo, A. M. B. O.; Lôbo, R. N. B.; Facó, O.; Souza, V.; Alves, A. A. C.; Costa, A. C. and Albuquerque, M. A. M. 2017. Characterization of milk production and composition of four exotic goat breeds in Brazil. Small Ruminant Research 153:9-16. https://doi.org/10.1016/j.smallrumres.2017.05.005

Molkentin, J. and Precht, D. 2000. Validation of a gas-chromatographic method for the determination of milk fat contents in mixed fats by butyric acid analysis. European Journal Lipid Science and Technology 102:194-201.

Moreira, M. N.; Silva, A. M. A.; Carneiro, H.; Bezerra, L. R.; Morais, R. K. O. and Medeiros, F. F. 2014. *In vitro* degradability and total gas production of biodiesel chain byproducts used as a replacement for cane sugar feed. Acta Scientiarum. Animal Sciences 36:399-403. https://doi.org/10.4025/actascianimsci.v36i4.23950

NRC - National Research Council. 2007. Nutrient requirements of small ruminants. National Academy Press, Washington, DC.

Nelder, J. A. 1966. Inverse polynomials, a useful group of multi-factor response functions. Biometrics 22:128-141. https://doi.org/10.2307/2528220

Othmane, M. H.; De La Fuente, L. F.; Carriedo, J. A. and San Primitivo, F. 2002. Heritability and genetic correlations of test day milk yield and composition, individual laboratory cheese yield, and somatic cell count for dairy ewes. Journal of Dairy Science 85:2692-2698. https://doi.org/10.3168/jds.S0022-0302(02)74355-5

Pulina, G.; Milán, M. J.; Lavín, M. P.; Theodoridis, A.; Morin, E.; Capote, J.; Thomas, D. L.; Francesconi, A. H. D. and Caja, G. 2018. Invited review: Current production trends, farm structures, and economics of the dairy sheep and goat sectors. Journal of Dairy Science 101:6715-6729. https://doi.org/10.3168/jds.2017-14015

Pompeu, R. C. F. F.; Cândido, M. J. D.; Pereira, E. S.; Bomfim, M. A. D.; Carneiro, M. S. S.; Rogério, M. C. P.; Sombra, W. A. and Lopes, M. N. 2012. Desempenho produtivo e características de carcaça de ovinos em confinamento alimentados com rações contendo torta de mamona destoxificada em substituição ao farelo de soja. Revista Brasileira de Zootecnia 41:726-733. https://doi.org/10.1590/S1516-35982012000300036

12

Detoxified castor in the diets of dairy goats: II. Lactation curves, composition, and fatty acid profile of milk
Araújo et al.

Romero-Huelva, M.; Ramírez-Fenosa, M. A.; Planelles-González, R.; García-Casado, P. and Molina-Alcaide, P. 2017. Can by-products replace conventional ingredientes in concentrate of dairy goat diet? Journal of Dairy Science 100:4500-4512. https://doi.org/10.3168/jds.2016-11766

Schmidely, P.; Morand-Fehr, P. and Sauvant, D. 2005. Influence of extruded soybeans with or without bicarbonate on milk performance and fatty acid composition of goat milk. Journal of Dairy Science 88:757-765. https://doi.org/10.3168/jds.S0022-0302(05)72739-9

Sklan, D.; Ashkennazi, R.; Braun, A.; Devorin, A. and Tabori, K. 1992. Fatty acids, calcium soaps of fatty acids, and cottonseeds fed to high yielding cows. Journal of Dairy Science 75:2463-2472. https://doi.org/10.3168/jds.S0022-0302(92)78008-4

Torres, A.; Castro, N.; Suárez-Trujillo, A.; Argüello, A. and Capote, J. 2016. Interrelationships among the length of milk stasis, tight junction permeability to lactose and monovalent cations, rate of milk secretion and composition in dairy goats traditionally milked once a day. Small Ruminant Research 137:85-90. https://doi.org/10.1016/j.smallrumres.2016.03.022

Tsiplakou, E. and Zervas, G. 2008. The effect of dietary inclusion of olive tree leaves and grape marc on the content of conjugated linoleic acid and vaccenic acid in the milk of dairy sheep and goats. Journal of Dairy Research 75:270-278. https://doi.org/10.1017/S0022029908003270

Ulbricht, T. L. V. and Southgate, D. A. T. 1991. Coronary heart disease: seven dietary factors. Lancet 338:985-992. https://doi.org/10.1016/0140-6736(91)91846-M