



# Feeding behavior of sheep in feedlot and fed with diets containing detoxified castor cake in substitution to the soybean meal

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**ABSTRACT.** To evaluate the ingestive behavior of sheep confined and fed with substitution levels of soybean meal (SM) by detoxified castor cake (DCC). We adopted a completely randomized design, with four levels of substitution (0; 33; 67 and 100%) with five replicates (sheep). We estimated the percentages of total times of intake of feed, time of rumination, in 'other activities', in idle agreed and in idle sleeping, dividing the day into eight periods (5h00 to 8h00; 8h01 to 11h00; 11h01 to 14h00; 14h01 to 17h00; 17h01 to 20h00; 20h01 to 23h00; 23h01 to 2h00 and 2h01 to 5h00). No interaction was observed between levels of substitution of the SM by DCC and period of the day to go. However, the isolated effect period of the day, there is more time to go from 8h00 to 11h00. The time rumination was not influenced by the levels of substitution of the SM by DCC. As for the variable other activities, the level of 67% DCC was superior to that of 100%. Regarding the variables idle agreed and idle sleeping, were not observed effects of substitution levels of SM by DCC. The DCC provides no changes in the behavior of the sheep, but the period of the day exerts influence on the behavioral pattern of such animals.

**Keywords:** Biodiesel byproducts; rumination chews; idleness; *Ricinus communis*.

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## Introduction

In the Northeast region of Brazil, the rational creation of sheep represents an activity of great socioeconomic importance for the exploitation of meat and skin. Although it has very expressive herds, its productivity indexes still leave to be desired (Furtado et al., 2020). Thus, confinement emerges as a strategy to minimize the impact of forage scarcity on pastures, leading to decreased age at slaughter, improvement in carcass quality and increased meat supply in the off-season.

However, one of the obstacles to the creation of ruminants in intensive systems is food, which is often one of the factors that most influence the production system, making food sources of good nutritional value and low cost necessary (Cirne et al., 2014; Araújo et al., 2020). Therefore, in recent years, several studies have been carried out in the search for alternative foods that can partially or totally replace traditional foods without harming the productive performance of animals (Gilaverte et al., 2011; Silva et al., 2011).

The use of by-products of the biodiesel industry in sheep confinement can be an interesting alternative for cost reduction, besides enabling the reduction of potential environmental problems caused by their deposition in the environment (Pompeu et al., 2012; Grandis et al., 2015). Castor bean (*Ricinus communis* L.), for example, is one of the most used oilseeds in biodiesel production in the Northeast, especially because it presents drought tolerance and has a minimum rainfall requirement of 400 to 500 mm. From the extraction of oil, which has several industrial applications, the shell, bran and castor cake (Bomfim, Silva, & Santos, 2009) are generated as by-products.

Due to the high yield in the oil industrialization process and its high protein content, castor bean cake can be an alternative source of protein in the feeding of small ruminants, replacing other food sources intended

for human consumption, such as soybeans. However, before using it, it is necessary that the cake be subjected to detoxification, due to the presence of toxic compounds such as ricin and *Ricinus communis agglutinin* (RCA) (Dubois, Piccirilli, Magne, & He, 2013). In view of the above, this study was conducted with the objective of evaluating the influence of four levels of soybean meal substitution by detoxified castor bean cake on the ingestive behavior of mixed-breed sheep of Morada Nova.

## Material and methods

The study was conducted at the Núcleo de Ensino e Estudos em Forragicultura-NEEF/DZ/CCA/UFC, in Fortaleza, Ceará. The municipality of Fortaleza is located in the coastal area at 15.49 m altitude, 30°43'02" south latitude, and 38°32'35" of west longitude.

Four replacement levels were evaluated (0; 33; 67 and 100%) soybean meal by detoxified castor bean cake, in lamb feed, with tifton grass 85 hay as bulky. A completely randomized design was adopted, in an arrangement of subdivided plots, with the levels of replacement of soybean meal by detoxified castor bean cake allocated in the plots, and the periods of the day in the subplots, with five replications (lambs). Castor cake was obtained from the mechanical extraction (pressing) of seed oil, using temperatures between 90 and 100°C. The detoxification process was carried out at Embrapa Agroindústria Tropical, through the autoclaving method (autoclave Sercon, model HAE23), with pressure of 1.23 kgf cm<sup>-2</sup> or 15 psi at 123°C, for 60 minutes, according to Anandan, Kumar, Ghosh and Ramachandra (2005).

The experimental animals were acquired from the herd itself of the Núcleo de Ensino e Estudos em Forragicultura-NEEF. These are cross-breed sheep (1/2 Morada Nova var. vermelha x 1/2 without defined racial pattern), males, whole, with initial body weight of 18.7 ± 1.62 kg and age of 6.5 months. Before the beginning of the experiment, the animals were wormed and received supplementation of vitamins A, D and E (injectable), subcutaneously, being housed in individual stalls of approximately 1.0 m<sup>2</sup>, provided with feeders and drinking fountains, in a covered area.

The experimental diets were formulated based on the recommendations of the National Research Council (NRC, 2007), being isoprotein and isoenergetic, adopting a bulky:concentrate ratio of 50:50. The hay of tifton 85 grass, produced with a cutting age of approximately 50 days, was acquired from Fazenda Laranjeira, in the municipality of Pentecoste, Ceará. The centesimal composition of the ingredients and the bromatological composition of the experimental diets are presented in Tables 1 and 2, respectively.

**Table 1.** Centesimal composition of the ingredients and the total feed containing different levels of soybean meal replacement by detoxified castor cake.

Ingredient	Replacement level			
	0% DCC <sup>1</sup>	33% DCC	67% DCC	100% DCC
Hay of tifton 85	50.14	50.37	50.55	50.45
Ground corn	33.58	32.49	31.72	30.59
Soybean meal	14.23	10.33	5.31	-
Detoxified castor cake	-	5.09	10.78	16.83
Urea	0.23	0.32	0.50	0.68
Ammonium sulfate	0.10	0.15	0.23	0.31
Common salt	0.50	0.50	0.51	0.50
Limestone	0.53	0.27	-	-
Dicalcium phosphate	0.29	0.08	-	0.24
Mineral salt (Ovifós) <sup>2</sup>	0.40	0.40	0.40	0.40

<sup>1</sup>DCC: detoxified castor cake. <sup>2</sup>Composition: phosphorus, 65.00 g; calcium, 160.00 g; sulphur, 15.00 g; magnesium, 6.50 g; sodium, 150.00 g; cobalt, 0.125 g; zinc, 4.50 g; iron, 1.70 g; manganese, 4.50 g; iode, 0.06 g; selenium, 0.03 g; fluoride, 0.95 g.

The experimental ration was provided daily in two meals, at 8h00 (50% of the total offered per day) and the remaining 50% at 16h00, collecting the remaining leftovers the next day, which were weighed, keeping them around 15%.

The animals were confined in individual wooden stalls, provided with feeders and drinking fountains weekly throughout the experimental period, which consisted of 14 days of adaptation and data collection, ending with the animals reaching slaughter body weight of approximately 30 kg. After 45 days of confinement, with the intensification of the effect of the treatments on sheep, the behavior test was conducted, over 24 hours, being evaluated simultaneously, with artificial lighting at night. Two observers took turns in each treatment, in four-hour shifts, strategically positioned so as not to interfere in the behavior of the animals.

**Table 2.** Chemical composition of experimental ingredients and diets.

Item	Ingredient				Total feed (% DM) <sup>1</sup>				
		Hay of tifton	Ground corn	Soybean meal	Castor cake	0% DCC	33% DCC	67% DCC	100% DCC
DM %FM		91.43	89.76	88.88	90.61	89.28	89.91	90.58	90.75
OM %FM		85.35	87.91	82.59	84.53	84.71	85.29	85.93	86.09
CP %DM		5.99	10.03	48.06	30.19	13.86	13.68	13.42	13.08
NDF %DM		82.11	16.17	13.28	47.99	48.49	50.43	52.51	54.45
NDFap %DM		79.81	13.66	12.03	45.26	46.32	48.18	50.19	52.06
ADF %DM		43.00	3.87	9.73	40.23	24.24	25.97	27.82	29.65
EE %DM		1.32	5.91	1.80	6.10	2.90	3.08	3.30	3.50
CELL <sup>2</sup> %DM		32.64	2.72	4.71	33.32	17.95	19.51	21.20	22.91
HCEL <sup>3</sup> %DM		36.81	9.79	2.30	5.03	22.07	22.22	22.38	22.41
LIG <sup>4</sup> %DM		6.64	0.61	1.14	3.42	3.70	3.83	3.98	4.11
NIDN %TN		69.88	11.19	5.00	15.73	39.51	40.15	40.84	41.32
NIDA %TN		36.59	2.69	3.65	13.34	19.77	20.36	20.98	21.53
TC <sup>5</sup> %DM		86.61	82.21	43.85	57.63	77.27	77.80	78.40	78.54
FCn <sup>6</sup> %DM		6.80	68.55	31.82	12.37	30.96	29.61	28.20	26.48
TDN %DM		50.46	89.34	80.15	71.53	66.70	66.36	65.81	64.82

<sup>1</sup>Percentage of detoxified castor cake in concentrated feed, based on DM. <sup>2</sup>Cellulose. <sup>3</sup>Hemicellulose. <sup>4</sup>Lignin. <sup>5</sup>Total carbohydrates. <sup>6</sup>Non fibrous carbohydrates.

The evaluation was performed instantly, with intervals of 10 minutes (intake of feed, rumination, other activities, idleness or sleeping, during the 24 hours). In addition, in the interval between two observations, the frequency of defecation, urination and water intake was recorded. The next day, collections were made during three periods of two hours (8 to 10; 14 to 16 and 18 to 20) to estimate the number of mericic mastications per ruminal bolus and the time spent of mericic mastications by ruminal bolus, using a digital chronometer. The amounts of dry matter and neutral detergent fiber consumed were calculated by the difference between the amount of food supplied and the leftovers.

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<sup>-1</sup>) and NDF. In tabulating the data of the continuous variables (intake of feed, rumination, other activities, idleness awake or sleeping) and punctual (water intake, urination and defecation), we opted to divide the day at intervals of three hours, starting at 5 am, when invariably the animals started the activities of the day. Thus, eight evaluation periods were obtained (5h00 to 8h00; 8h01 to 11h00; 11h01 to 14h00; 14h01 to 17h00; 17h01 to 20h00; 20h01 to 23h00; 23h01 to 2h00 e 2h01 to 5h00).

The data were submitted to variance analysis and regression analysis. Initially, they were submitted to the normality (Shapiro – Wilk) and homoscedasticity (Levene) tests, and then submitted to variance analysis by the F test, when the assumptions were met, using the following model:  $Y_i = \mu + \alpha_i + e_i$ . Where  $Y_i$  is the dependent variable corresponding to the experimental observation;  $\mu$  is the general average;  $\alpha_i$  is the fixed effect of diets; and  $e_i$  is the random error, assuming an independent normal distribution. The comparison of means was performed by the Tukey test, with 5% probability, to evaluate the effects of substitution levels in the diet. Statistical analyses were performed using the GLM procedure of the Software SAS version 9.4 (Statistical Analysis System [SAS Institute Inc.], 2003).

## Results and discussion

Interaction ( $p < 0.05$ ) was observed between soybean meal replacement levels by DCC and periods of the day for all continuous activities of ingestive behavior (Table 3). Thus, the factors were analyzed in the conditioned effect. Among the substitution levels, only in the period from 8h00 to 11h00, a greater time spent with the intake of feed was observed, when 100% of the SM was replaced by DCC, compared to 0 and 33% replacement. Regarding the period of the day, it was observed that at the 0% level of substitution, the feed intake was more distributed between the hours, being performed more consistently in the periods of 8h00 to 11h00, 14h00 to 17h00, 17h00 to 20h00 and 20h00 to 23h00. As the levels of substitution of the SM by DCC increased, the period of time dedicated to the intake of feed was concentrated from 8h00 to 11h00, 14h00 to 17h00 and 17h00 to 20h00, with less time spent in this activity between 2h00 and 8h00, due to the predominance of other activities, especially rumination.

**Table 3.** Continuous activities of sheep confined and fed detoxified castor cake in place of soybean meal.

Level (%)	Periods								Mean
	5h00 – 8h00	8h01 – 11h00	11h01 – 14h00	14h01 – 17h00	17h01 – 20h00	20h01 – 23h00	23h01 – 2h00	2h01 – 5h00	
	Feed intake (% of time)								
0	4.44 b	28.89 Ba	6.67 b	24.44 a	22.22 a	26.67 a	8.89 b	10.00 b	16.53
33	5.56 cd	32.22 Ba	11.11 cd	26.67 a	24.44 ab	16.67 bc	14.45 bcd	3.34 d	16.81
67	7.78 b	34.44ABa	15.56 b	28.89 a	27.78 a	15.56 b	11.11 b	6.67 b	18.47
100	1.11 e	44.45 Aa	13.33 cd	32.22 b	22.22 bc	18.89 c	4.45 de	1.11 e	17.22
Mean	4.72	35	11.67	28.06	24.17	19.45	9.72	5.28	
	Rumination (% of time)								
0	40.00 abc	33.33 abc	26.67 c	32.22 Aabc	26.66 c	31.11 Aabc	41.11 ab	43.33 Ba	34.3
33	50.00 ab	34.44 cd	28.89 cde	17.78 Be	22.23 de	37.78 Abc	35.56 cd	60.00Aa	35.83
67	46.67 a	28.89 c	28.89 c	20.00 ABc	17.78 c	31.11 Abc	43.33 ab	48.89 ABa	33.19
100	43.33 ab	27.78 cd	35.56 bc	22.22 ABcd	28.89 cd	17.78 Bd	35.56 bc	50.00 Aba	32.64
Méan	45	31.11	30	23.06	23.89	29.44	38.89	50.56	
	Other activities (% of time)								
0	38.89 a	10.00 b	8.89 b	25.56 a	25.56 Ba	25.56 a	26.67 Aa	27.78 a	23.61
33	31.11 a	7.78 c	15.56 bc	25.56 ab	35.56 ABa	26.67 ab	11.11 Bc	16.67 bc	21.25
67	32.22 ab	16.67 cd	20.00 bcd	28.89 abc	42.22 Aa	33.33 ab	12.22 Bd	22.22 bcd	25.98
100	34.44 a	6.67 c	16.67 bc	18.89 bc	27.78 ABab	28.89 ab	15.56 Bbc	17.78 bc	20.83
Mean	34.17	10.28	15.28	24.72	32.78	28.61	16.39	21.11	
	Idle agreed (% of time)								
0	13.33 b	18.89 b	35.55 a	17.78 b	18.89 b	15.56 ABb	16.67 b	16.67 b	19.17
33	6.67 b	16.67 ab	27.78 a	26.67 a	17.78 ab	15.56 ABab	28.89 a	15.56 ab	19.44
67	7.78 c	18.89 abc	29.30 a	20.00 abc	12.22 bc	14.44 Bbc	23.33 ab	13.33 bc	17.5
100	20.00	18.89	22.22	20.00	18.89	28.89 A	25.55	23.33 a	22.22
Mean	11.95	18.33	28.89	21.11	16.95	18.61	23.61	17.22	
	Idle sleeping (% of time)								
0	3.34 Abc	8.89 b	22.22 Aa	0.00 c	6.67 bc	1.11 bc	6.67 Bbc	2.22 bc	6.39
33	6.67 Abc	8.89 ab	16.67 ABa	3.34 bc	0.00 c	3.34 bc	10.00 Bab	4.45 bc	6.67
67	5.56 Aabc	1.11 bc	5.56 Cabc	2.22 abc	0.00 c	5.56 abc	10.00 Ba	8.89 ab	4.86
100	1.11 Ac	2.22 c	12.22 BCab	6.67 bc	2.22 c	5.56 bc	18.89 Aa	7.78 bc	7.09
Mean	4.17	5.28	14.17	3.06	2.22	3.89	11.39	5.83	

Averages with lowercase letters in the same row and uppercase in the column followed by equal letters do not differ ( $p > 0.05$ ), by Tukey's test.

The feed intake time showed a quadratic response ( $\hat{Y} = 3.91 + 0.01DCC - 0.00008DCC^2$ ;  $R^2 = 0.57$ ;  $p \leq 0.0052$ ) depending on the levels of substitution of SM by DCC. The estimated values for feed intake between the 0 and 100% replacement levels were, respectively, 3.91 and 4.11 h day<sup>-1</sup> and maximum of 4.53 h day<sup>-1</sup> with 62.5% of SM substitution by DCC. At the lowest levels of DCC, the selectivity of the animals increased the time of feed intake up to 62.5% of DCC. From this level, the decrease in dry matter intake was responsible for the reduction in the time spent in the intake of feed possibly due to the lower palatability of DCC in relation to the SM, a result corroborated by the visual evaluation of the animals during the confinement, because there were concentrate leftovers in the treatments with higher levels of SM substitution by DCC.

There was no effect ( $p > 0.05$ ) between levels of substitution of SM by DCC on rumination time, with an average of 33.99% of the period dedicated to this activity. This fact was not expected, since the NDF content of The DCC was 47.99% against 13.28% of the SM and that the increase in the amount of fiber in the diet promotes the stimulation of masticatory activity. DCC probably had a small particle size, which led to a decrease in the rate of digestion, increasing the rate of passage of this food in the gastrointestinal tract of the animals. A quadratic response was observed for rumination time ( $\hat{Y} = 8.30 + 0.006DCC - 0.0001DCC^2$ ;  $R^2 = 0.68$ ;  $p \leq 0.0055$ ) depending on the levels of SM replacement by DCC. The longest rumination time obtained was 8.39 h day<sup>-1</sup> when replacing 30% of the SM with DCC. Greater consistency of the data was obtained in relation to the period of the day, where the highest frequencies of rumination occurred during the early hours (2 to 5 hours) and early morning (5 to 8 hours), due to the fact that this is the moment of rest of the sheep, sometimes sleeping and sometimes processing the food ingested during the day, significantly reducing at times of higher feeding frequency. In this context, Araújo et al. (2021b) reported that the distribution of rumination activity is greatly influenced by feeding, since rumination takes place soon after feeding periods, when the animal is calmer. It is noticed that although there was a reduction in dry matter intake (Table 5), this did not reflect the time spent in feeding and rumination, possibly due to the lower acceptability of The DCC in relation to the SM.

As for the other activities (distracting, walking and observing), it was observed a lower occurrence in the periods that comprised the hours from 8h00 to 14h00. This result is due to the longer time spent with food intake, rumination and idleness at these times. Idleness (awake and sleeping) was considered the period in which the animals did not perform any activity. Idle awake and sleeping were not influenced ( $p > 0.05$ ) by the levels of substitution of SM by DCC, with averages of 19.58 and 6.25% of the day dedicated to these activities, respectively. The highest frequency of idleness was observed from 11h00 to 14h00, just after the peak food intake. It is likely that the digestion of the feed in the first hours after ingestion, increasing body heat, associated with a higher load of thermal radiation at this time, stimulated the permanence of the animals in idleness for longer.

When adding the periods spent to other activities and to the idleness awake and sleeping, it is observed that all treatments presented an average of 48.61% dedicated to these activities, possibly because they reached their daily nutritional requirements. However, Vieira et al. (2011) working with confined sheep fed diets based on detoxified castor bean bran observed that the percentage of mean time in random activities was 52.8%, being higher than that observed in this research, probably due to the fact that the diets had higher and lower protein and neutral detergent fiber contents, respectively than this research, leading the animals to reach their daily nutritional requirements more quickly.

Water intake was influenced ( $p < 0.05$ ) only by the periods of the day (Table 4), with predominance in the hours from 8h00 to 11h00 am and 14h00 to 17h00, the same periods where the feed was supplied. Periods where feed supply occurs represent a higher peak frequency of water intake due to the stimulus to feed consumption (Furtado, Carneiro, Pereira, Moreira Filho, & Silva, 2016), being still associated with higher ambient temperatures at these times that increase the rate of water consumption (Berchielli, Pires, & Oliveira, 2011). For food metabolism, water is initially necessary in the chewing and swallowing process, as well as for digestion processes, which require homogenization and translocation of digesta and fluids within the gastrointestinal lumen (Barreto et al., 2011).

**Table 4.** Punctual activities of sheep confined and fed detoxified castor cake in place of soybean meal.

Level (%)	Periods								Total
	5h00 – 8h00	8h01 – 11h00	11h01 – 14h00	14h01 – 17h00	17h01 – 20h00	20h01 – 23h00	23h01 – 2h00	2h01 – 5h00	
	Water intake (times day <sup>-1</sup> )								
0	2.00 Aabc	2.40 Aa	0.60 Abc	2.20 ABab	2.20 ABab	1.80 Aabc	0.40 Ac	1.80 Aabc	13.4
33	1.40 Ab	3.60 Aa	0.20 Ab	1.20 Bb	1.40 Bb	1.00 Ab	0.60 Ab	0.60 Ab	10.0
67	1.40 Ab	3.40 Aa	1.80 Aab	3.20 Aa	3.20 Aa	0.40 Ab	0.80 Ab	0.40 Ab	14.6
100	1.00 Aabc	2.40 Aa	0.80 Aabc	2.00 ABab	1.60 ABabc	0.40 Abc	0.20 Ac	0.60 Abc	9.0
Mean	1.45 bc	2.95 a	0.85 c	2.15 ab	2.10 b	0.90 cd	0.50 d	0.85 cd	
	Urination (times day <sup>-1</sup> )								
0	2.60 ABa	1.80 Aa	2.20 ABa	2.20 Aa	2.00 Aa	1.60 Aa	1.60 Aa	1.80 Aa	15.8
33	2.83 ABa	1.80 Aa	2.00 ABa	2.00 Aa	3.20 Aa	1.80 Aa	1.80 Aa	2.00 Aa	17.4
67	3.60 Aa	1.80 Ab	2.80 Aab	3.20 Aab	2.40 Aab	2.00 Aab	1.60 Ab	2.40 Aab	19.8
100	2.60 Aa	0.80 Ab	1.00 Bab	2.00 Aab	1.80 Bab	2.20 Aab	1.40 Aab	1.60 Aab	13.4
Mean	2.91 a	1.55 b	2.00 ab	2.35 ab	2.35 ab	1.90 ab	1.60 b	1.95 ab	
	Defecation (times day <sup>-1</sup> )								
0	1.60 Ba	2.20 ABa	1.60 Ba	1.60 Ba	1.40 Ba	1.60 Aa	1.20 Aa	0.80 Aa	12.0
33	3.20 Aab	2.00 ABbc	3.60 Aa	3.00 ABab	3.20 Aab	1.40 Ac	1.40 Ac	1.40 Ac	19.2
67	3.80 Aa	3.40 Aa	3.20 Aab	3.20 Aab	2.60 ABab	2.60 Ab	1.80 Ab	1.80 Ab	22.4
100	1.60 Babc	1.20 Bbc	2.40 ABab	2.80 ABa	2.20 ABabc	1.20 Abc	0.80 Ac	0.60 Ac	10.8
Mean	2.55 a	2.20 ab	2.70 a	2.65 a	2.35 ab	1.70 bc	1.30 c	1.15 c	

Averages with lowercase letters in the same row and uppercase in the column followed by equal letters do not differ ( $p > 0.05$ ), by Tukey's test.

No effect ( $p > 0.05$ ) of SM substitution levels by DCC on urination was observed. However, more consistent results were observed during the day time, especially from 5h00 to 8h00, which is characterized as the most propitious time for urination, due to the lower temperature, which reduces the transpiration of the animals, demanding another means for urea excretion. Defecation was less frequent during the night, a period of rest for sheep. During the day, the defecation peaks occurred after the feed supply, coinciding with the highest frequencies of urination. SM replacement levels by DCC did not influence  $RE_{NDF}$ , TCT, number of misplaced chewings per day, for bolus, time of mastic chewing per bolus and NDM, according to Table 5. Gomes, Cândido, Carneiro, Furtado, and Pereira (2017) evaluating alternative treatments of detoxification of castor bean cake in the feeding of finishing sheep, also did not find changes in ingestive behavior, attributing this response to the fact that the diets are isonitrogenous and isoenergetic.

The DMI decreased linearly with SM replacement levels by DCC. Each percentage point of inclusion of DCC reduced the DMI by 1.88 g of DM day<sup>-1</sup>, resulting in a variation from 959.1 to 771.1 g of DM day<sup>-1</sup> between levels 0 and 100%, respectively (Table 5). In the present study, DCC contained 15% of castor bean bark fragments, which explains the high content of NDF in DCC. Castor bark in the feed decreases the DMI at high levels of inclusion (Pompeu et al., 2013). The presence of castor bean bark associated with a high proportion of ricinoleic acid in DCC had a lower palatability of DCC in relation to SM (Pompeu et al., 2009; Araújo et al. 2021a), depressing the DMI.

**Table 5.** Means and regression equation for behavior variables of sheep confined and fed different levels of soybean meal substitution by detoxified castor cake.

Replacement level (% DM)				CV (%)	Equation	P-value
0	33	67	100			
970.50	864.70	864.40	757.90	11.94	DMI = 959.10 – 1.88 DCC; R <sup>2</sup> = 0.33	0.0104
396.80	406.30	419.70	473.30	9.89	NDFI = 389.00 + 0.71 DCC; R <sup>2</sup> = 0.39	0.0175
249.90	241.70	206.40	196.20	13.07	FE <sub>DM</sub> = 250.50 – 0.55 DCC; R <sup>2</sup> = 0.35	0.0155
120.60	101.50	109.50	107.20	17.38	RE <sub>DM</sub> = 110.50 ± 19.21	–
48.30	46.01	51.17	62.08	18.07	RE <sub>NDF</sub> = 46.17 + 0.12 DCC; R <sup>2</sup> = 0.22	0.0471
12.20	12.58	12.96	11.96	11.21	TCT = 12.41 ± 1.39	–
778.71	756.20	734.06	649.71	13.76	NRB = 790.80 – 1.22 DCC; R <sup>2</sup> = 0.39	0.0468
41,154	45,116	41,284	41,429	15.22	MC <sub>ND</sub> = 42,181 ± 6418	–
55.80	59.86	55.26	68.01	14.57	MC <sub>NB</sub> = 59.50 ± 8.67	–
60.28	60.49	60.12	60.03	1.77	MCTB = 60.23 ± 1.07	–
44.60	39.00	46.25	27.50	33.28	NDM = 40.65 ± 13.53	–
5.51	5.59	6.27	8.36	30.62	ALM = 5.11 + 0.03 DCC; R <sup>2</sup> = 0.25	0.0448

Dry matter intake (DMI, g day<sup>-1</sup>) and NDF (NDFI, g day<sup>-1</sup>), Dry matter feed efficiency (FE<sub>DM</sub>, g DM h<sup>-1</sup>) and rumination efficiency of dry matter (RE<sub>DM</sub>, g DM h<sup>-1</sup>) e NDF (RE<sub>NDF</sub>, g NDF h<sup>-1</sup>), total chewing time (TCT, h day<sup>-1</sup>), number of ruminal bolus (NRB, n° day<sup>-1</sup>), number of daily mericics chews (MC<sub>ND</sub>, n° day<sup>-1</sup>), mericics chews per number bolus (MC<sub>NB</sub>, n° bolus<sup>-1</sup>), time of mericics chews per bolus (MCTB, seg bolus<sup>-1</sup>), number of daily meals (NDM, n° day<sup>-1</sup>) and average length of each meal (ALM, minutes).

The NDFI increased linearly with SM replacement levels by DCC, estimated at 389.0 and 460.0 g day<sup>-1</sup> for 0 and 100% replacement levels, respectively. For each 1% inclusion of DCC, the NDFI increased 0.71 g day<sup>-1</sup>. The high content of NDF in DCC (46.49%) in relation to the SM (13.28%) is responsible for this result.

Feed efficiency of dry matter, expressed in g of DM h<sup>-1</sup>, decreased with DCC levels in the total diet. Each percentage point of inclusion of DCC reduced FE<sub>DM</sub> by 0.55 g of DM h<sup>-1</sup>. The prolongation in the time spent with food intake at the highest levels of DCC, resulting from the greater selection of animals during the intake of the concentrate, associated with the reduction in the DM, were responsible for the reduction of FE<sub>DM</sub>. On the other hand, RE<sub>NDF</sub> presented linear response with DCC levels in the total ration. Each percentage point of DCC included in the feed increased the RE<sub>NDF</sub> by 0.12 g of NDF h<sup>-1</sup>.

The NRB was reduced (p < 0.05) in 1.22 bolus day<sup>-1</sup> for each 1% increase in DCC in the total feed. The ALM increased 0.03 minutes for every 1% of DCC included in the ration. These results prove that the selectivity exercised by animals on diet, at the highest levels of DCC, was the main mechanism of adaptation of animals to DCC with a high proportion of bark and had as a consequence the increase in ALM, depression in NRB.

## Conclusion

Detoxified castor cake can be used in the feeding of finishing lambs as protein food, even promoting changes in ingestive behavior.

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