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Replacement of corn with pre-dried cassava root silage in the diet for dairy goats

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ABSTRACT. The objective of this study was to evaluate the effect of replacement of corn with pre-dried cassava root silage (CRS) on intake, ingestive behavior, production and composition of goat milk. Five lactating Saanen goats were used, with 42.5 ± 4.2 kg body weight and production of 2 kg milk day^{-1}, distributed in a 5 x 5 Latin square with five treatments: 0, 28.6, 58.0, 81.6 and 100% replacement of corn with CRS in the diet dry matter. Goats were monitored for five periods of 15 days each. The intake of dry matter, crude protein and neutral detergent fiber decreased linearly ($p < 0.05$) with the replacement of corn with CRS. Feeding (348.5 ± 62.1 min.) and rumination (468.8 ± 83.8 min.) times were not influenced ($p > 0.05$) by the replacement of corn with CRS, but the ingestion and rumination efficiencies had a linear increase ($p > 0.05$). Milk production (2.17 ± 0.45 kg day^{-1}), fat (3.49 ± 0.42%), protein (3.11 ± 0.13%) and lactose (4.47 ± 0,11%) of goat milk were not influenced ($p > 0.05$) by the replacement of corn with CRS. Therefore, it is recommended the total replacement of corn with pre-dried cassava root silage in the diet for dairy goats with an average production of 2 kg day^{-1}.

Keywords: goat milk; ingestive behavior; *Manihot esculenta*; root silage.

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Introduction

The world herd of more than one billion goat heads is concentrated mainly in the arid and semi-arid areas of the planet. In these regions, goat milk - the total volume produced in more than 15.3 million tons year^{-1} - contributes to food security for populations installed in areas of less economic development (Pulina et al., 2018). However, due to the seasonality of forage production in tropical areas, it is common to use concentrate foods (e.g. grain and meal) in dairy goat feeding (Vasconcelos et al., 2019).

Corn grain is the most used source of starch in the formulation of diets for dairy goats. But, due to the difficulties in growing corn in arid and semi-arid areas, the costs of this cereal tend to limit its acquisition by goat milk producers, especially in the dry period of the year. Thus, the use of alternative sources of starch that are available in tropical areas during the dry period, such as cassava, has been increasing (Wanapat & Kang, 2015).

The production of cassava root is estimated at 277 million tons year^{-1}, a large part of this amount is used for the production of starch by the industry, generating a series of by-products that can be used for animal feed (Salami et al., 2019). However, the whole root can also be used in ruminant feed when dehydrated (Chanjula, Ngampongsai, & Wanapat, 2007; Faria et al., 2011; Santos et al., 2015). For dairy goats specifically, the replacement of corn with cassava shavings improved the digestibility of non-fiber carbohydrates in the feed, but did not influence the animal ingestive behavior (Silva et al., 2012). However, due to the powderiness caused by the dry root and the difficulties in storage and cyanide toxicity of the fresh root, a viable alternative for the preservation of the cassava root is ensiling. Cassava root silage is a non-powdery product with lower cyanide levels than fresh cassava root. There are no studies in the literature evaluating cassava root silage for ruminants. But, Zambom et al. (2015) evaluated the replacement of corn with silage made with the residue from the extraction of cassava starch in the diet for cows and reported increases in production and improvements in the composition of milk.

Thus, the goal was to evaluate the effect of replacing corn with cassava root silage on intake, ingestive behavior, production and composition of goat milk.

Material and methods

The entire experimental protocol was analyzed and authorized by the Ethics Committee on Animal Use (CEUA) of the Federal University of Alagoas (License 48/2016).

The work was conducted in the municipality of Limoeiro de Anadia, state of Alagoas, Brazil, at the following geographical coordinates: Latitude: 9° 44'17'' South, Longitude: 36° 30' 11'' West. The climate of the region is tropical with an average temperature of 26°C, the demographic density is 85.5 inhabitants per km² in the territory of the municipality. The experiment took place between June 29, 2016 and September 31, 2016.

Five Saanen dairy goats, approximately 36 months of age, second order of birth, in the sixth week of lactation were used. The animals started the experiment with an average body weight of 42.5 ± 4.2 kg and an average milk production of 2 kg day-1. Goats were housed in a shed covered with ceramic tiles and a ceiling height of 2.8 meters, distributed in individual folds with a slatted floor, 1.5 m² area, provided with individual feeders and drinkers. Goats were fed twice a day, at will, at 7:00 am and 3:00 pm, as a complete ration, in order to allow a 20% surplus of the total dry matter supplied; water was provided at will. Milking was performed twice a day, the first at 5:30 am and the second at 4:00 pm.

Diets were prepared according to the nutritional requirements of lactating goats, with an average weight of 40 kg, with production of 2.5 kg milk per day and percentage of fat in milk of 3.5% (National Research Council [NRC], 2007) (Table 1 and 2). The treatments consisted of increasing levels (0, 28.6, 58.0, 81.6 and 100% in the dry matter) of replacement of corn grain with pre-dried silage of cassava root. The treatments were distributed in a Latin square design (5 x 5) in five periods. The experimental periods comprised 15 days each, with 10 days of adaptation to the experimental diets and five days for data and sample collection, totaling 75 days.

Table 1. Nutritional composition of the ingredients of the experimental diets.

	Ingredientes			
	Tifton 85 hay	Corn grain	Soybean meal	Cassava root silage
Dry matter[1]	859.2	831.0	841.9	402.9
Organic matter[2]	946.2	981.1	935.4	900.2
Mineral matter[2]	53.8	18.9	64.9	39.8
Crude protein[2]	116.5	65.5	490.4	60.2
Neutral detergent fiber[2]	798.9	117.5	154.6	65.8
Acid detergent fiber[2]	395.4	35.4	88.5	30.8

[1] g kg^{-1} natural matter; [2] g kg^{-1} dry matter

Table 2. Percentage and chemical composition of experimental diets.

	Levels of pre-dried cassava root silage (%)				
	0	28.6	58.0	81.6	100
Proportion of Ingredients (% DM)					
Tifton 85 Hay	57.28	55.35	53.10	52.40	52.07
Cassava root silage	0.00	8.00	16.22	22.80	29.10
Grain corn	27.95	20.94	13.93	7.01	0.00
Soybean meal	13.26	14.21	15.25	16.29	17.33
Mineral salt	1.00	1.00	1.00	1.00	1.00
Limestone	0.50	0.50	0.50	0.50	0.50
Composição química					
Dry matter[1]	889.3	785.3	70.40	63.72	58.19
Organic matter[2]	940.3	934.1	927.7	922.2	917.1
Mineral matter[2]	59.6	61.0	62.4	64.0	65.7
Crude protein[2]	150.0	152.7	155.5	159.2	163.2
Neutral detergent fiber[2]	493.8	477.6	459.3	451.9	447.2
Acid detergent fiber[2]	248.1	244.1	239.1	239.1	240.5

[1] g kg^{-1} natural matter; [2] g kg^{-1} dry matter

For silage making, root of cassava (*Manihot esculenta* Crantz) cv. Sergipana was harvested about 13 months after planting in the same area and immediately after harvesting, the roots were ground in a forage machine (MC1001n Laboremus®, 7 vertical razor mode) and pre-dried in the sun for 36 hours. The crushed and pre-dried root was compacted (900 kg m^{-3}) by human trampling in 250 μm thick polyethylene plastic bag silos. The first silo was opened 10 months after, when the experimental period started.

During the collection period, daily samples of concentrate feed, cassava root silage, Tifton hay and food leftovers from each animal were collected before each morning meal. At the end of each period, the leftover samples were mixed according to the treatment, by period and by animal, making up samples composed of each period and storing in a freezer for later laboratory analysis. Subsequently, they were dried in a forced ventilation oven at 55°C for 72 hours, and ground in a knife mill to 1 mm in diameter. The analysis of food and leftovers was carried out, according to the methodology described by Detmann et al. (2012) for dry matter (DM), mineral matter (MM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF).

Behavioral observations were made on the first day of each collection period, performed visually by the method of instantaneous scanning at 10-minute intervals, using the methodology proposed by Johnson and Combs (1991), adapted over a period of 24 hours. Observations started at 7:00 am and ended at 7:00 am the following day. During the whole experiment, the shed was kept under artificial lighting at night. Behavioral variables observed were: standing idle (SI), standing ruminating (SR), lying idle (LI), lying ruminating (LR), standing eating (SE) and sleeping (S).

The results regarding the factors of ingestive behavior were obtained using the following equations: FE_{DM} = DMI/TSF; RE_{DM}=DMI/TSR; where FE_{DM} (g DM consumed h^{-1}) = feed efficiency; TSF (h day^{-1}) = time spent on food daily; REms (g DM consumed h^{-1}) = rumination efficiency; TSR (h day^{-1}) = time spent in rumination, according to the methodology of Bürger et al. (2000), calculated using the equation described above.

Cud chewing per cud (sec cud^{-1}), number of cud chews (number day^{-1}), number of cud chews per cud (number cud^{-1}) and number of cuds (cuds, number day-^{1}) (Polli, Restle, Senna, & Almeida, 1996) were obtained using a digital timer in two periods from 6:30 to 8:30 pm and 10:00 pm to 12:00 am. Three samples of 15 seconds were collected during cud chewing and multiplied by four in order to obtain the average of chews in minutes according to the following formula: cuds (number day^{-1}) = TSR/cud chewing per cud; Cud chewing per cud (sec cud^{-1}) = TM/number of cuds; Number of cuds (number day^{-1}) = chews in minutes x TSR. The time series was discretized as described by Silva et al. (2006), counting the periods spent on rumination, food and idle. The division of the daily times of each activity by number of periods was performed to obtain the averages of each discrete period according to (Silva et al., 2006).

Milk production was recorded daily and sample collections were performed on the second day of each period, on the first and second milking. After weighing the milk, the calculation for milk production corrected for 3.5% fat (MPCF) was performed, using the equation suggested by Gravert (1987): MPCF (3.5%) = 0.4337 MP + 16,218 FP, Where: MPCF 3.5% = Milk production corrected to 3.5% fat; MP = Milk production (kg day^{-1}) and FP = Fat production (kg day^{-1}).

Chemical analyses were determined in the laboratory of the Northeast Dairy Management Program (PROGENE). To determine the protein, fat and lactose content of milk, samples were packed in plastic bottles, containing Bromopol (2-bromo-2-nitro-1,3-propanediol) and sent for analysis in the Bentley infrared analyzer method 2000 (Bentley, 1994).

Density was determined by reading the thermolactodensimeter cooled to 15°C (Instituto Adolfo Lutz, 1985). The procedure consisted of transferring the previously homogenized sample to the beaker, allowing the milk to flow slowly along the cylinder walls without forming foam. The thermolactodensimeter was slowly immersed in the sample, until resistance was felt, allowing it to float freely. Enough time was waited for the densimeter and temperature to stabilize. The reading was recorded on the meniscus, on the free surface of the liquid. The temperature was measured at the same time of density using a thermolactodensimeter. The pH was measured by direct measurement of the digital potentiometer.

Data obtained in the experiment were tested by analysis of variance and regression with a 5% probability significance using the SAS software.

The model applied was Yijk = μ + Ti + Pj + Ak + ejk (i), where: μ is a common constant for all plots; Ti is the effect of treatment; Pj is the effect of period j; Ak is the effect of animal k; ejk (i) in the random error in the graphs i, j, k, where i, j, k = 1,2,..., I.

Results and discussion

Intake of dry matter (DMI), organic matter (OMI), crude protein (CPI) and neutral detergent fiber (CNDF) decreased linearly ($p < 0.05$) with the replacement of corn with pre-dried cassava root silage (CRS) in the diet for goats (Figure 1).

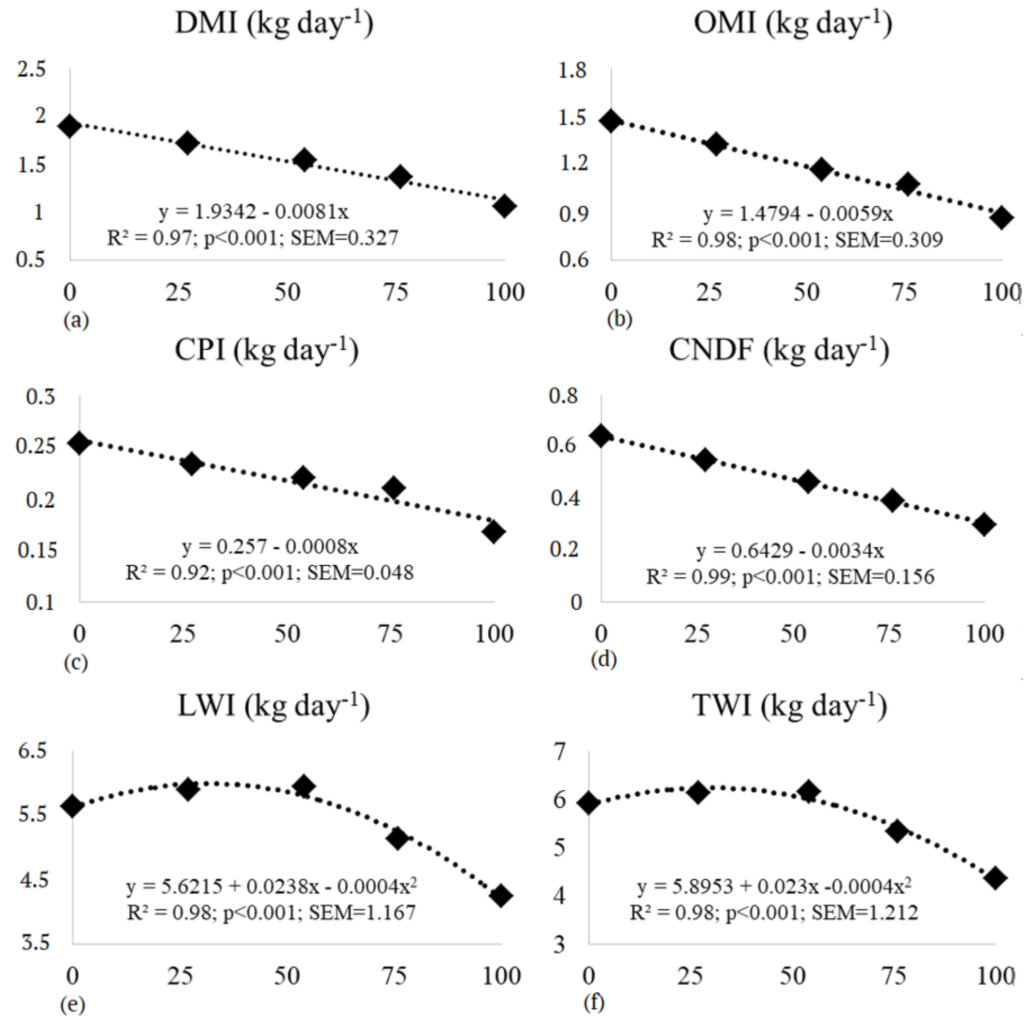

Figure 1. Dry matter intake (DMI), organic matter intake (OMI), crude protein intake (CPI), neutral detergent fiber intake (NDFI), liquid water intake (LWI), total water intake (TWI) of dairy goats fed increasing levels of replacement of grain corn with pre-dried cassava root silage in the diet.

Possibly the sensory characteristics of the silage, especially acidity, negatively influenced the acceptability of silage by goats, reducing the DMI of the animals (Grant & Ferraretto, 2018). Fernandes et al. (2015) evaluated the effect of replacing corn grain with dry residue from the extraction of cassava starch and observed a linear decrease in DMI and OMI of lactating cows. For goats, Chanjula et al. (2007) also observed a quadratic effect on DMI when the corn grain was replaced with dried whole cassava root.

Intake of crude protein and neutral detergent fiber also decreased with the replacement of corn with CRS. Probably, the linear reduction in the DMI and the selection process by the animals at the time of ingestion explain the reduction in CPI and NDFI by the goats. Persichetti Júnior et al. (2014) also observed a linear reduction in the CPI of cows when grain corn was replaced with corn grain silage. Similarly, Canizares et al. (2011) observed a quadratic effect on the NDFI of dairy goats when grain corn was replaced with corn grain silage.

Total water intake (TWI), which includes liquid drinking water and water present in food, shows a quadratic effect of the replacement levels of corn with CRS. This fact shows that the total intake of water followed the behavior of the consumption of liquid drinking water and, therefore, suffered little effect from the water from food.

Times of feeding (348.5 ± 62.1 min.) and rumination (468.8 ± 83.8 min.) of the goats were not influenced ($p > 0.05$) by the replacement of corn with CRS, however there was a linear increase ($p < 0.05$) in the ingestion and rumination efficiencies of DM by goats according to the increased level of CRS in the diet (Table 3).

Probably, the maintenance of feeding and rumination times associated with a reduction in the DMI has resulted in increased feed and rumination efficiencies for goats. Evaluating the replacement of whole grain corn with whole cassava root, Silva et al. (2012) found no effect on the times and efficiencies of ingestion and rumination of dairy goats, as well as on the number of cuds and daily cud chews of the animals.

Table 3. Ingestive and cud chewing behavior of dairy goats fed increasing levels of replacement of corn grain with pre-dried cassava root silage in the diet.

	Levels of replacement with cassava root silage					SEM	Pr > F		R^2
	0	28.6	58.0	81.6	100		L	Q	
Feeding time (min. day^{-1})	368	366	338	332	0.84	62.08	>0.05	>0.05	-
Rumination time (min. day^{-1})	454	434	500	464	0.36	83.79	>0.05	>0.05	-
Idle time (min. day^{-1})	618	640	602	646	0.00	110.16	>0.05	>0.05	-
Intake efficiency (g DM min^{-1})	198.2	213.4	220.4	244.4	0.80	74.54	0.004	>0.05	0.80
Rumination efficiency (g DM min.$^{-1}$)	247.8	251.4	329.8	335.8	0.86	96.36	0.000	>0.05	0.86
Number of cuds (cuds day^{-1})	31453	31318	30890	28091	29251	9936.94	>0.05	>0.05	-
Chewing time (sec cud^{-1})	42.78	43.58	38.43	37.89	47.93	15.09	>0.05	>0.05	-
Number of chews (n cud^{-1})	49.18	51.84	45.01	42.07	49.48	12.96	>0.05	>0.05	-
Rumination cycle time (min. cycle $^{-1}$)	8.24	9.84	7.46	6.40	11.40	4.75	>0.05	>0.05	-
Ruminated dry matter (g cud^{-1})	2.99	2.83	2.56	2.48	2.46	1.06	>0.05	>0.05	-

CV- Coefficient of variation, R^2 – Coefficient of determination, Regression equation, L –Linear effect1-Y= 1923.1 – 8.07539X, 2-Y=183.280 + 1.14160X, 3-Y=221.72 + 2.09440X, 4- Y= 405.120 + 3.23200X.

The replacement of corn with CRS did not influence (p >0.05) the production or composition of the goat milk (Table 4). Mouro et al. (2002) also found no effect on the production of goat milk when the corn grain was replaced with the cassava root meal.

Table 4. Milk production and composition of goat fed increasing levels of replacement of corn grain with pre-dried cassava root silage in the diet.

	Levels of replacement with cassava root silage					SEM	Pr > F		R^2
	0	28.6	58.0	81.6	100		L	Q	
Milk production (kg day^{-1})	2.25	2.17	2.13	2.25	2.08	0.45	>0.05	>0.05	-
Corrected milk production (kg day^{-1})	2.28	2.17	2.24	2.28	2.01	0.44	>0.05	>0.05	-
pH	6.32	6.47	6.41	6.29	6.40	0.43	>0.05	>0.05	-
Density (g L^{-1})	1.04	1.04	1.04	1.04	1.04	0.03	>0.05	>0.05	-
Fat (%)	3.56	3.47	3.49	3.59	3.36	0.42	>0.05	>0.05	-
Protein (%)	3.12	3.10	3.14	3.12	3.07	0.13	>0.05	>0.05	-
Lactose (%)	4.45	4.52	4.47	4.48	4.45	0.10	>0.05	>0.05	-
Total solids (%)	12.05	12.00	12.29	12.07	11.79	0.53	>0.05	>0.05	-
Defatted extract (%)	8.48	8.52	8.50	8.48	8.43	0.18	>0.05	>0.05	-

We suggest that, although it reduced the DMI, the increasing inclusion of CRS increased the digestibility of dietary organic matter, mainly due to the recognized effect of silage on starch degradability (Moharrery, Larsen, & Weisbjerg, 2014; Persichetti Júnior et al., 2014). Nevertheless, Rangel, Leonel, Braga, Pinheiro, and Lima Júnior (2008) further explain that cassava starch is more degradable than corn starch due to its greater hydration capacity (amylose present only in the amorphous region, forming less hydrogen bonds with amylopectin) and the lower formation of lipid-amylose complexes from cassava starch to the detriment of corn starch. Thus, even with a reduction in DMI, the goats managed to obtain sufficient nutrients from the diet to maintain milk production and composition. Thus, reinforcing the findings by Chanjula et al. (2007), who highlighted cassava as an alternative source of degradable starch in the rumen for goats.

The levels of fat (3.49 ± 0.42%), protein (3.11 ± 0.13%) and lactose (4.47 ± 0.11%) were not affected by the replacement of corn with CRS, indicating the potential of this food in maintaining the production and composition of goat milk. We suggest that the levels of fat and protein remained in the milk of the goats, even with the reduction in the DMI of the animals, due to the replacement of corn with CRS not to interfere with the volume of milk produced by the goats, therefore, there are no effects of dilution or concentration of milk components. Canizares et al. (2011) also did not verify the effect of substituting corn grain with wet corn grain silage on milk production and contents of fat (2.95%), protein (2.85%), lactose (4.36%) and total solids (10.96%) of goat milk.

Conclusion

The replacement of corn wit pre-dried cassava root silage reduces the intake of nutrients, but does not interfere with production and composition of goat milk. Total replacement of corn with pre-dried cassava root silage is recommended in the diet for dairy goats with an average production of 2.0 kg day^{-1} milk.

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