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Ingestive behavior of dairy goats fed increasing levels of sugarcane in replacement of corn silage

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ABSTRACT - The objective of this experiment was to evaluate levels of replacement (0, 33, 67 and 100%) of corn silage with fresh sugarcane in dairy-goat diets on the ingestive behavior of these animals. Eight lactating Alpine goats (after lactation peak) with a live weight of 51.95±3.29 kg were distributed into two 4 × 4 Latin squares according to their milk production. Animals were placed in individual pens where they received diets *ad libitum*, twice a day, with a roughage:concentrate ratio of 40:60, during 72 days of experiment. The evaluated variables were time spent feeding (TSF), ruminating (TSR), idle (TSI) and chewing (TSC), dry matter intake (DMI), neutral detergent fiber intake (NDFI), feeding efficiency of dry matter (FE_{DM}) and neutral detergent fiber (FE_{NDF}), rumination efficiency of dry matter (RE_{DM}) and neutral detergent fiber (RE_{NDF}), number of ruminal boli per day (NRB) and number of rumination chews per day (NRC). The different treatments had no effect on TSF or TSR. However, a linear effect was observed on TSC. There was a linear effect on TSI, in which the highest value was observed in the treatment with 0% of sugarcane inclusion. A quadratic effect was observed on dry matter intake, with minimum point of 2.14 kg/day for 68.04% of sugarcane inclusion; however, NDFI was not affected by the different treatments. There was no effect of treatments on FE_{DM}, although a quadratic effect was observed on FE_{NDF}, wherein the lowest value was observed in the treatment with 67% of sugarcane inclusion. There was no effect of different levels of corn silage replacement on RE_{DM}, RE_{NDF}, NRB or NRC. Sugarcane can be replaced with corn silage without changing the times spending on feeding and rumination.

Key Words: chewing, feeding, ruminal bolus, rumination

Introduction

In dairy goat farming, the objective of farmers is to improve the productivity and stability of milk production throughout the year. The lack of food in times of scarcity concerns producers about storing it, be it stored or in the form of grass for cutting. Thus, fresh sugarcane is an alternative food source in times of food shortages, helping to maintain the production of goat milk and avoiding the use of other food sources that can raise feed costs.

Due to its balanced composition, corn silage is undoubtedly the most suitable food stored and used for dairy animals, especially in view of its high production. But its high cost has made its use impossible by small producers (Ribeiro et al., 2000). However, the lower cost of sugarcane production as compared with that of corn silage and excellent availability precisely in the period of food shortage have proved it as a feasible alternative.

In diets formulated with the participation of roughage, knowing the ingestive behavior of animals is necessary to prepare these roughages and understand problems related to declining intake at critical times for milk production. The feeding behavior of ruminants has been studied for a long time, and in dairy goats it helps to choose the foods and formulate diets aiming at the production of either milk or meat.

Chewing and rumination cycles are longer in goats than in cattle and sheep; consequently, their feed-intake rate is lower and chewing efficiency is better, resulting in a higher percentage of particles smaller than 1.00 mm (Goetsch et al., 2010). Better-ground feed is easily mixed with the ruminal fluid and therefore easily digested.

According to Van Soest (1994), the rumination time is influenced by the nature of the diet and seems to be proportional to the cell-wall content of the roughage. Thus, the physical form of diet influences the time spent on the chewing and rumination processes (Dado and Allen, 1994). However, food concentrates and finely ground or pelleted hay reduce rumination, and roughages with a high cell-wall content tend to increase the rumination time.

For goats, time spent feeding is interspersed with one or more periods of rumination or idleness, wherein time spent

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on rumination is longer during the night. However, there are differences between individuals in relation to the duration and the distribution of feeding and rumination activities, which seem to be connected to the appetite of animals, anatomical differences and energy requirement supply, or rumen fill, influenced by the roughage:concentrate ratio of diets (Fischer et al., 1998).

In this sense, the objective of this work was to evaluate the effects levels of replacement of corn silage by fresh sugarcane in diets on ingestive behavior parameters of lactating Alpine goats.

Material and Methods

The experiment was carried out at the Goat Farming Section of the Faculty of Veterinary Medicine and Animal Science at UNESP, Lageado Farm, located in Botucatu/SP, Brazil. Botucatu city is located at 22°53'09" south latitude, 48°26'42" west longitude, and 840 msnm altitude; its climate is classified as a mild Cwa, according to Köppen, with an average temperature of 22 °C.

Eight lactating Alpine goats (after lactation peak) with a live weight of 51.95±3.29 kg were used in this experiment. Goats were housed in a covered shelter, placed in individual pens with 3.5 m^2 with free access to drinkers and feed bunks to evaluate their ingestive behavior variables.

Feed (Table 1) was supplied, twice a day, at 08.00 and 16.00 h, as a complete mixed diet and in a quantity to allow for 10% of feed surplus. Water was supplied *ad libitum* in a plastic bucket with a support installed in each pen and cage.

The experimental design adopted was a double 4 × 4 Latin square to evaluate the effect of four diets composed of levels of replacement of corn silage by fresh sugarcane: Treatment 1 - 0% of sugarcane and 100% of corn silage; Treatment 2 - 33% of sugarcane and 67% of corn silage; Treatment 3 - 67% of sugarcane and 33% of corn silage; and Treatment 4 - 100% of sugarcane and 0% of corn silage.

The sugarcane variety used was SP 813250, whose seedlings for planting where obtained from cane fields of the region. The corn silage was produced on the very farm in a bag-type silo. Sugarcane was chopped daily, and mixed with the concentrate and corn silage at a forage:concentrate ratio of 40:60, on a DM basis. These proportions were maintained along the experiment and the quantity of forage supplied was adjusted according to the DM determination of feeds.

The experimental diets were previously formulated to meet the nutritional requirements of goats according to NRC (2007), with an average crude protein content of 14% on a DM basis. The nutritional content of feed ingredients and experimental diets (Tables 2 and 3) (dry matter (DM), crude protein (CP), ash, ether extract (EE)) was determined according to the methodology described by Silva and Queiroz (2002). Neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose (CEL) lignin (LIG) and acid detergent insoluble nitrogen (ADIN) were determined according to the methodology described by Van Soest et al. (1991). Total carbohydrates (TCH), non-fiber carbohydrates (NFC) and total digestible nutrients (TDN) were estimated by the following equations:

TC = 100 – %CP – %EE – %ash, as described by Sniffen et al. (1992);

NFC = 100 – (%CP + %EE + %ash + %NDF), as described by Van Soest et al. (1991); and

TDN = DCP + DNFC + DNDF + DFA × 2.25 – 7, as described by NRC (2001), in which DCP = CP × Exp[−1.2 × ADIP/CP] for the forage; DCP = [1 – (0.4 × ADIP/CP)] × CP for three concentrate; DNFC = 0.98 × NFC; and DNDF = 0.75 × (NDF – ADL) × [1 – (ADL/NDF) × 0.667]. DCP represents truly digestible crude protein; DNFC, digestible non-fiber carbohydrate; DNDF, digestible neutral detergent

Table 1 - Proportions of ingredients in different treatments, expressed in g/kg of dry matter

Ingredients	Treatments[1] (%)				F:C
	0	33	67	100	
Fresh and chopped sugarcane	-	13.20	26.80	40.00	
Corn silage	40.00	26.80	13.20	-	40
Dry-ground corn	42.60	41.50	40.20	39.00	
Soybean meal	13.80	14.80	16.00	17.10	
Limestone	1.00	1.00	1.00	1.00	60
Dicalcium phosphate	1.00	1.00	1.00	1.00	
Urea	0.60	0.70	0.80	0.90	
Mineral premix[2]	1.00	1.00	1.00	1.00	

F:C - forage:concentrate ratio.
[1] Treatment with 0, 33, 67 and 100% of sugarcane in replacement of corn silage.
[2] Mineral premix composition (per kg): S - 200 g; Mg - 150 g; Zn - 47,210 mg; Fe - 27,000 mg; Cu - 20,000 mg; Mg - 1,200 mg; Co - 1,400 mg; I - 1,250 mg; Se - 315 mg.

fiber; DFA, digestible fatty acids; ADIP, acid detergent insoluble protein; and ADL, acid detergent lignin.

Metabolizable energy (ME) and net energy (NE) were determined using TDN and digestible energy (DE) values, suggested by NRC (2001), as follows:

DE (Mcal/kg) = 0.04409 × TDN (%);
ME (Mcal/kg) = 1.01 × DE (Mcal/kg) − 0.45; and
NE (Mcal/kg) = 0.0245 × TDN (%) − 0.12.

The total experimental period was 72 days, divided into four periods of 18 days, where 12 days were used for diet adaptation and DM intake adjustment and six days for data collection. The ingestive behavior was observed and recorded on the 13th day of each experimental period.

Ingestive behavior activities – times spent on feeding (TSF), rumination (TSR), idleness (TSI), rest (TSRE) and drinking water (TSDW) – were recorded every 10 min during 24 h in each experimental period. The number of total observations was 144 per period. The time spent chewing (TSC) was calculated as the sum of the TSF and TSR activities, according to Armentano and Pereira (1997). On the same day, the number of ruminal chews per bolus (NRCB) and time spent on ruminal chews per bolus (TRCB) were counted using a digital chronometer. To obtain these measures, three ruminal chews were observed in two periods of the day (from 10.00 to 12.00 and from 18.00 to 20.00 h), when the animals were in rumination. During the night observations, the room was kept with low-intensity artificial light so as not to interfere in the behavior of the animals.

The animals were weighed at the beginning and end of each experimental period, before morning milking, to evaluate their body development.

Results regarding ingestive behavior factors were obtained according to the following equations:

Feeding efficiency of DM (FE_{DM}) = DMI/TSF;
Feeding efficiency of NDF (FE_{NDF}) = NDFI/TSF;
Rumination efficiency of DM (RE_{DM}) = DMI/TSR;
Rumination efficiency of NDF (RE_{NDF}) = NDFI/TSR;
Number of ruminal boli per day (NRB) = TSR/TRCB; and
Number of ruminal chews per day (NRC) = NRB × NRCB,

Table 2 - Nutrient content of concentrates and forages, expressed in g/kg of dry matter

Nutrients	Sugarcane	Corn silage	Concentrates			
			A	B	C	D
Dry matter	31.42	32.10	86.58	85.29	86.12	87.58
Organic matter	98.49	95.89	93.84	94.43	94.26	94.49
Ash	1.51	4.11	6.16	5.57	5.74	5.51
Crude protein	1.94	7.21	18.97	20.51	22.50	21.29
Ether extract	1.59	3.86	2.19	2.33	3.41	3.94
Neutral detergent fiber	41.55	40.69	15.00	18.76	15.07	13.63
Acid detergent fiber	28.37	26.32	9.00	9.79	9.60	9.79
Total carbohydrates	94.97	84.81	72.68	71.59	68.35	67.92
Non-fibrous carbohydrates	53.42	44.12	57.68	52.83	53.28	54.29
Cellulose	22.82	23.13	6.15	5.63	7.71	7.62
Lignin	6.88	4.11	3.68	6.38	5.73	5.10
Total digestible nutrients	71.58	74.86	77.46	74.49	77.43	79.10
Metabolizable energy (Mcal/kg)	2.796	2.945	3.063	2.928	3.061	3.137
Net energy (Mcal/kg)	1.634	1.714	1.778	1.705	1.777	1.818

Table 3 - Nutrient content of experimental diets, expressed in % of dry matter

Nutrients	Treatments[1] (%)			
	0	33	67	100
Dry matter	64.79	63.92	64.33	65.12
Organic matter	94.66	95.36	95.42	96.09
Ash	5.34	4.64	4.58	3.91
Crude protein	14.27	14.49	14.97	14.35
Ether extract	2.86	2.64	2.98	3.00
Neutral detergent fiber	25.28	27.65	25.55	24.80
Acid detergent fiber	15.93	16.67	16.84	17.22
Total carbohydrates	77.53	78.23	77.47	78.74
Non-fiber carbohydrates	52.25	50.58	51.92	53.94
Cellulose	12.94	12.59	13.76	16.75
Lignin	2.37	5.84	5.82	5.81
Total digestible nutrients	76.42	74.20	75.52	76.09
Metabolizable energy (Mcal/kg)	3.015	2.915	2.975	3.001
Net energy (Mcal/kg)	1.720	1.698	1.730	1.744

[1] Treatment with 0, 33, 67 and 100% of sugarcane in replacement of corn silage.

in which FE (g DM or NDF intake/h) is feeding efficiency; DMI (g DM/day) is DM intake; NDFI (g NDF/day) is NDF intake; RE (g DM or NDF intake/h) is rumination efficiency; NRB (n/day) is the number of ruminal boli (Polli et al., 1995); and NRC (n/day) is the number of rumination chews according to methodology proposed by Bürguer et al. (2000).

Experimental data were subjected to analysis of variance by SAS (Statistical Analysis System, version 8.2). The effect of treatments to determine the best replacement level was evaluated by polynomial regression, separating the effects into linear, quadratic and cubic.

Results and Discussion

As regards the ingestive behavior results, there was no significant effect for time spent feeding (TSF) and rumination (TSR) among the levels of replacement of corn silage with sugarcane. However, the sum of these two values, represented by the time spent chewing (TSC), was significant (P<0.05) among the different treatments (Table 4). The increase in DM intake (min/d) occurred as an attempt of animals to meet the energy requirements. The feed particle size and sugarcane fiber digestibility might have contributed to the higher TSR. Consequently, TSC increased in animals fed diets with increasing levels of sugarcane. Feed particle size is related to physically effective fiber, which stimulates rumination, thus increasing the time spent chewing (Mertens, 1997).

In experiments with lactating goats fed diets with different forage:concentrate ratios, Gonçalves et al. (2001) observed a reduction in TSF and TSR as the concentrate inclusion in diets increased. The authors described that the increase in the dietary concentrate level resulted in lower TSF and TSR due to the high energy density of the diets; consequently, the time spent idle (TSI) was longer.

Polli et al. (1995) and Mendonça et al. (2004) worked with feedlot cattle and buffalo and dairy cows fed diets based on sugarcane and/or corn silage, respectively, and did not observe differences in TSF and TSR. Also, with increasing levels of NDF in lactating dairy goat diets, Carvalho et al. (2006) observed linear increase in TSF and TSR, and consequently in TSC and reduction in TSI.

A linear effect (P<0.05) was observed for TSI with the different levels of sugarcane inclusion. Animals fed 100% of corn silage rested more than the other groups, probably due to lower TSC. Sugarcane has low-digestibility fibrous stalks and, as a consequence, animals spent more time feeding and ruminating. However, Mendonça et al. (2004) observed lower TSI in animals fed corn silage-based diets as compared with those fed sugarcane-based diets.

A quadratic effect was observed on DM intake, (P<0.05) for the different levels of corn silage replaced by sugarcane, wherein the minimum value was 2.136 kg/d with 68.04% of sugarcane inclusion in diets (Table 5). Magalhães et al. (2004) observed negative linear DMI with increasing levels of sugarcane replacement in corn silage, and Mendonça et al. (2004) observed higher DMI for corn silage than sugarcane at a concentrate:forage of 40:60, both studies on lactating dairy cows. These authors found that DMI might be affected by forage quality regardless of the feeding strategy, indicating that sugarcane inclusion has a reducer effect on intake as a consequence of low fiber digestibility. The concentration of non-fiber carbohydrates, especially sugars, and the preference for the most juicy parts of sugarcane might have contributed to the higher DMI in the diets composed of 100% sugarcane.

For NDFI, no differences were observed among the different treatments. Contradictory results were observed by Magalhães et al. (2004) and Mendonça et al. (2004), who observed that NDFI decreased as the sugarcane inclusion in replacement of corn silage increased. These results for NDFI may be a consequence of the similar chemical composition of the diets (Table 3), and according to Abijaoudé et al. (1997), diets with similar NDF content provide similar daily intakes.

No difference among treatments was observed for FE_{DM}. This variable averaged 621 g/day. Contrary to this observation, FE_{NDF} had a quadratic effect (P<0.05) at the different levels of replacement, wherein the lowest

Table 4 - Mean values of time spent feeding (TSF), ruminating (TSR), idle (TSI) and chewing (TSC) by lactating goats fed diets with sugarcane replacing corn silage at different levels

Variables	Treatments[1] (%)				Regression equation	r^2	CV
	0	33	67	100			
TSF (min/d)	223	253	250	274	$\hat{Y} = 250$	-	16.40
TSR (min/d)	295	288	304	309	$\hat{Y} = 300$	-	17.72
TSI (min/d)	923	900	886	858	$\hat{Y} = 922.73777 - 0.62619X$*	0.98	7.64
TSC (min/d)	518	540	554	583	$\hat{Y} = 517.26223 + 0.62619X$*	0.98	12.42

[1] Treatment with 0, 33, 67 and 100% of sugarcane in replacement of corn silage.
r^2 - coefficient of regression; CV - coefficient of variation; *P<0.05.

Table 5 - Mean values for the feeding behavior of lactating goats fed diets with sugarcane replacing corn silage at different levels

Variables	Treatments[1] (%)				Regression equation	r^2	CV
	0	33	67	100			
DMI (kg/d)	2.49	2.27	2.10	2.23	$\hat{Y} = 2.50239 - 0.0107805X + 0.0000792201X^2$*	0.97	9.69
NDFI (kg/d)	0.47	0.43	0.38	0.44	$\hat{Y} = 0.429$	-	14.23
FE_{DM} (g DM/h)	775	600	557	551	$\hat{Y} = 621$	-	27.24
FE_{NDF} (g NDF/h)	182	149	134	143	$\hat{Y} = 18.467832 - 1.35348X + 0.00958X^2$*	1.00	26.36
RE_{DM} (g DM/h)	806	476	452	439	$\hat{Y} = 543$	-	84.22
RE_{NDF} (g NDF/h)	186	118	110	114	$\hat{Y} = 132$	-	76.18
NRB (n/d)	7	8	8	7	$\hat{Y} = 7.5$	-	23.19
NRC (n/d)	445	422	463	450	$\hat{Y} = 445$	-	18.33

[1] Treatment with 0, 33, 67 and 100% of sugarcane in replacement of corn silage.
r^2 - coefficient of regression; CV - coefficient of variation; *P<0.05.
DMI - dry matter intake; NDFI - neutral detergent fiber intake - FE - feed efficiency; RE - rumination efficiency; RB - number of ruminal boli; NRC - number of rumination chews.

efficiency (134 g/d) was observed for the treatment with 67% of sugarcane inclusion in the diet and the highest efficiency (182 g/d) for the treatment with 100% corn silage inclusion (Table 5). The higher TSF in animals fed diets with sugarcane inclusion might have resulted in lower FE_{NDF} when compared with diets composed exclusively of corn silage or sugarcane. Carvalho et al. (2006), working with Alpine goats, observed that feed efficiency, expressed in g DM/h, reduced linearly, but when expressed in g NDF/h, although there was no significant effect, showed an increasing response with the increasing levels of NDF in the diets.

There was no difference among treatments for RE_{DM} and NDF (RE_{NDF}). The animals had similar TSR in the sugarcane and corn silage treatments. This suggests efficiency in rumination by goats, which are able to reduce larger particles of sugarcane, as well as a greater proportion of concentrate in relation to forage (60:40).

Rumination efficiency was reflected on the number of ruminal boli (NRB) and number of ruminal chews (NRC), which were not different among treatments.

Conclusions

Sugarcane can be used in replacement of corn silage in diets for lactating goats, as this forage does not the alter the times spent feeding and ruminating or the rumination efficiency.

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