Sugarcane bagasse as only roughage for crossbred lactating cows in semiarid regions

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Abstract – The objective of this work was to evaluate the effects of different levels of sugarcane bagasse, as exclusive roughage, on nutrient intake and digestibility, feeding behavior, microbial protein synthesis, and dairy performance of crossbred cows. Ten lactating Girolando breed cows (600±34.3 kg body weight) were assigned to a replicated 5×5 Latin square design. The control diet, based on spineless cactus, sugarcane bagasse, and concentrate, was formulated to meet the average production of 20 kg of milk per day, with 3.5% fat. The evaluated levels of sugarcane bagasse were: 30, 38, 46, and 54% dry matter bases. The intake and digestibility of dry matter decreased linearly with sugarcane bagasse levels. Rumination time was higher in cows fed 54% sugarcane bagasse. The inclusion levels had no effect on non-esterified fatty acid contents or on the efficiency of microbial protein synthesis, but beta-hydroxybutyrate concentrations showed a quadratic pattern to the bagasse levels. Higher yields of 3.5% fat-corrected milk were obtained with cows fed 30% sugarcane bagasse. Sugarcane bagasse inclusion in the diet of crossbred dairy cows decreases their performance; however, the bagasse can be used as exclusive roughage when associated with 70% concentrate.

Index terms: alternative roughage, digestibility, feeding behavior, milk yield.

Bagaço de cana-de-açúcar como único volumoso para vacas mestiças lactantes em regiões semiáridas

Resumo – O objetivo deste trabalho foi avaliar o efeito de diferentes níveis de bagaço de cana-de-açúcar, como volumoso exclusivo, sobre consumo e digestibilidade de nutrientes, comportamento ingestivo, síntese de proteína microbiana e desempenho leiteiro de vacas mestiças. Dez vacas da raça Girolando (600±34,3 kg de peso corporal) foram distribuídas em delineamento de quadrado latino duplo 5×5. A dieta controle, baseada em palma forrageira, bagaço de cana-de-açúcar e concentrado, foi formulada para atender a média de produção de 20 kg de leite por dia, com 3,5% de gordura. Foram avaliados os seguintes níveis de bagaço de cana-de-açúcar: 30, 38, 46 e 54% da matéria seca. O consumo e a digestibilidade de matéria seca diminuíram linearmente com os níveis de bagaço. O tempo de ruminação foi maior para vacas alimentadas com 54% de bagaço. Os níveis de inclusão não tiveram efeito sobre o conteúdo de ácidos graxos não esterificados ou sobre a síntese de proteína microbiana, mas as concentrações de β-hidroxibutirato apresentaram comportamento quadrático com os níveis de bagaço. Maiores produções de leite corrigido a 3,5% de gordura foram obtidas com vacas alimentadas com 30% de bagaço. A inclusão do bagaço de cana-de-açúcar na dieta de vacas mestiças reduz seu desempenho; contudo, o bagaço pode ser utilizado como volumoso exclusivo quando associado a 70% de concentrado.

Termos para indexação: volumoso alternativo, digestibilidade, comportamento ingestivo, produção de leite.

Introduction

High variability in rainfall amounts and intensities are characteristic in dryland regions (Carbon…, 2004), like the Brazilian semiarid. According to Koohafkan & Stewart (2008), about 40% of the world total land area is considered drylands, which, nevertheless, provides much of the world grain and livestock. A significant part of cattle are reared in dryland regions by small

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farmers, and their livestock products (milk and meat) provide valuable inputs to their income and nutrition (Mortimore et al., 2009).

The climate challenges of many dryland regions require innovative solutions to maintain food production (Mortimore et al., 2009; Lobell & Gourdji, 2012). Among the alternatives to livestock production in these areas, the spineless cactus (*Opuntia* spp.) is considered the most important feed source (Ferreira et al., 2012). Its remarkable tolerance to drought conditions, its high water use efficiency, biomass yield, and contents of soluble carbohydrates justify the species importance for these regions (Ben Salem, 2010). However, the availability of spineless cactus has been limited by the occurrence of an insect known as the carmine cochineal – *Dactylopius opuntiae* (Hemiptera: Dactylopiidae) –, which compromised its production in a considerable part of the Brazilian semiarid. The introduction of pest resistant spineless cactus varieties is being studied, but it is an option viable only in the medium and long-term, due to limited availability of material for propagation and due to the long crop cycle (two years).

Sugarcane bagasse, however, is highly available in Brazil, which has plenty amount of sugarcane companies, including in states with semiarid regions. Every ton of sugarcane processed results in about 0.3 ton of bagasse (Hofsetz & Silva, 2012), which can be used as cheap roughage for cattle production (Ahmed & Babiker, 2015). Thus, the association of sugarcane bagasse and urea can be an attractive option for cattle production in the Brazilian Semiarid, especially in farms not far from sugar and alcohol industry.

Low-quality sugarcane bagasse requires, however, the use of great amounts of concentrate to maintain milk production, but most studies with this roughage were conducted with beef cattle. For dairy cattle, exacerbated amounts of concentrate can bring damage to milk productivity and cause metabolic disorders. Thus, it was hypothesized that the establishment of a proper roughage-to-concentrate ratio, using sugarcane bagasse as the exclusive roughage for lactating cows, could promote improvements in dairy performance and sustainability of livestock production in the Brazilian Semiarid.

The objective of this work was to evaluate the effects of feeding rations with different levels of sugarcane bagasse, as exclusive roughage, on nutrient intake, feeding behavior, dairy performance, and microbial protein synthesis of crossbreed dairy cows.

Materials and Methods

This study was carried out in the middle region of Agreste and Vale do Ipojuca microregion, in the municipality of Capoeiras, in the state of Pernambuco, Brazil (18º36'33"S, 36º37'30"W, and 733-m altitude), in a semiarid climate classified as BSh (Köppen, 1948).

The management and care of animals were performed as per the guidelines and recommendation of the Ethics Committee on Animal Studies of the Universidade Federal Rural de Pernambuco (License no. 033/2014), state of Recife, Brazil. Ten lactating, multiparous, Girolando cows (3/4 and 7/8 Holstein-Gir), with an average initial body weight (BW) of 600±34.3 kg, were randomly assigned to replicated 5×5 latin square design, according to the genetic group. The trial lasted 105 days, with five consecutive 21-day periods, divided into a 14-day adaptation and seven days for the sampling period. Animals were housed in individual 16-m^2 stalls, half-covered, equipped with sand bed and rice straw, automatic waterers, and feeders.

The experimental diets (Table 1) consisted of different levels of sugarcane bagasse: 30, 38, 46, and 54% of dry matter (DM). A common diet used for crossbred lactating cows in the region, aimed at producing 20 kg milk per day, based on spineless cactus, sugarcane bagasse, and concentrate (Ferreira et al., 2012), was used as control treatment (Table 2). The diets were formulated to be isonitrogenous, according to the requirements calculated by the NRC (2001) for 600-kg cows producing 20 kg per day milk, with 3.5% fat. Sugarcane bagasse was acquired from the local industry.

Animals were fed twice daily, at 7h and 16h, after the morning (4h) and afternoon (15h) milking sessions. The amount of feed supplied was corrected daily, which allowed ad libitum intake, with 10% refusal in the fresh matter, and water was available ad libitum. Samples of feeds and refusals were collected during the last seven days of each experimental period and stored at -20°C, in airtight plastic bags. The BW of each cow was measured at the start and at the end of each period, after the morning milking.

From the 17th to the 21st day of each period, from 6h to 14h, the fecal dry matter output was estimated. Spot fecal samples, collected directly from the animals' rectums, were used to assess the total apparent digestibility of nutrients. The indigestible neutral detergent fiber (iNDF) content was used as an internal marker analyzed in the fecal, feed, and refusal samples, obtained by using in situ procedures, with 288 h of rumen incubation in cattle (Valente et al., 2015).

Feeding behavior was evaluated by the scan sampling method and recording five-minute period intervals, for 24 hours, adapted to three consecutive days (72 hours), according to Martin & Bateson (2007). Cow observation started immediately after the morning feeding, and the assay occurred on the fourth day of each sampling period. The activity of each cow was recorded as rumination, feeding, and idling. The feeding and rumination efficiency (kg h^{-1}) were calculated by dividing DM intake by total feeding or rumination times, respectively.

Blood samples were collected on the 15th day, 4 hours after feeding, by coccygeal venipuncture, in two tubes: one with anticoagulant (heparin) and another containing sodium fluoride. After collection, the blood samples were immediately centrifuged at 3,500 *g*, for 15 min, and then one aliquot was taken from each tube for urea, non esterified fatty acids (Nefa), and beta-hydroxybutyrate (BHBA) determinations. For the determination of urea, Labtest commercial kit was used, and for Nefa and BHBA, Randox commercial kits were used.

Table 1. Nutrient composition of the experimental diets.

Item	Control	Sugarcane bagasse levels (%)			
		30	38	46	54
Ingredients (g kg^{-1})					
Sugarcane bagasse	300	300	380	460	540
Spineless cactus	400	0	0	0	0
Ground corn	75.0	493	411	328	246
Soybean meal	185	173	173	173	173
Urea + ammonium sulfate(1)	10.0	4.00	6.50	9.00	11.5
Salt	5.0	5.00	5.00	5.00	5.00
Sodium bicarbonate	10.0	10.0	10.0	10.0	10.0
Mineral mix(2)	15.0	15.0	15.0	15.0	15.0
Diet composition (g kg^{-1})					
Dry matter (DM)	394	719	685	654	626
Organic matter (OM)	899	932	927	922	917
Crude protein (CP)	142	145	146	145	149
Ether extract (EE)	15.6	32.5	28.9	25.2	21.5
NDFap(3)	373	281	345	405	463
Total carbohydrates	783	793	794	794	795
Non-fiber carbohydrates	354	439	382	323	266
Total digestible nutrients	693	698	663	662	652

(1)Proportion between urea and ammonium sulfate: 9:1. (2)Dicalcium phosphate, limestone, salt, sulfur, zinc sulfate, copper sulfate, manganese sulfate, potassium iodate, and sodium selenite. (3)NDFap, neutral detergent fiber corrected for ash and nitrogenous compounds.

Spot urine samples were obtained on the 15th day of each experimental period, 4 hours after the first feed supply of the day (Chizzotti et al., 2008). Analyses of allantoin were performed by using a colorimetric method (Chen & Gomes, 1992), and total nitrogen, urea, uric acid, and creatinine were obtained using an automatic biochemical analyzer, LabMax 240 (Labtest Diagnostica S.A., Lagoa Santa, MG, Brazil).

Samples of feeds, refusals, and feces were analyzed for dry matter (DM; method 934.01), organic matter (OM; method 930.05), crude protein (CP; method 968.06), and ether extract (EE; method 920.39) according to Horwitz (2000). Dry matter was analyzed by the gravimetric difference between dry and wet sample weights; CP using the macro-Kjeldahl procedure, multiplied by a factor of 6.25; and EE, by Soxhlet extraction with petroleum ether. Analysis of neutral detergent fiber (NDF) followed Mertens (2002), using a heat-stable alpha-amylase, without using sodium sulfite, and corrected for residual ash. The NDF was also corrected for the nitrogenous compounds content, using the method described by Licitra et al. (1996). These chemical analyses were performed in samples processed to pass through a 1-mm screen sieve. The quantification of non-fibrous carbohydrates (NFC) content was performed according to Hall (2001), and the total digestible nutrients (TDN) were determined according to Weiss (1999).

The nitrogenous compound balance (N-retained) was obtained by calculating the difference between total

Table 2. Chemical composition of the experimental diets.

Item	Ingredients (g kg^{-1})			
	Sugarcane bagasse	Spineless cactus	Ground corn	Soybean meal
Dry matter (DM)	502	252	899	901
Organic matter (OM)	951	920	985	932
Crude protein (CP)	15.2	41.0	89.0	471
Ether extract (EE)	9.50	13.9	54.1	18.7
NDFap(1)	831	279	76.8	92.8
iNDF(2)	382	50.7	25.8	18.9
Lignin	124.4	49.4	13.0	14.9
Total carbohydrates	926	866	842	445
Non-fiber carbohydrates	95.3	589	765	352

(1)NDFap, neutral detergent fiber corrected for ash and nitrogenous compounds. (2)iNDF, indigestible neutral detergent fiber.

nitrogen intake (NI) and total nitrogen excreted in the feces (N-fecal), urine (N-urinary), and milk (N-milk). The efficiency of dietary N compound utilization was assayed by using the following indicators: N-urea in plasma, urinary excretion of N-urea, and N balance.

Milk production was measured daily, during the collection period. Milk samples were collected on the 19th and 20th days of each period, for the analyses of protein, fat, lactose, urea, and total solid content, according to ISO 9622/IDF 141C (ISO, 2013). Milk yield values were corrected for 3.5% fat, according to Sklan et al. (1992).

The bioeconomics of the diets were evaluated considering the feeding cost per kg of milk produced and gross margin, for prices current in the first half of 2017.

The data were submitted to the analysis of variance, and regression analyses were performed with Proc Mixed procedure of SAS, version 9.4 (SAS Institute, Cary, NC, USA), at 5% probability, according to the model: $Y_{ijkl} = \mu + \tau_i + Q_j + P_k + (A/Q)_{lj} + \tau \times Q_{ij} + \varepsilon_{ijkl}$ in which: Y_{ijkl} is the observation ijkl; μ, the general mean; τ_i, the treatment fixed effect i; Q_j, the square fixed effect j; P_k, the period fixed effect k; $(A/Q)_{lj}$, the animal l into square j random effect; $\tau \times Q_{ij}$, the interaction effect of treatment i and square j; and ε_{ijkl}, the random error with mean 0 and variance σ^2.

Dunnett test was used to compare each treatment group mean (sugarcane bagasse levels), with the average of control diet. Comparisons between sugarcane bagasse levels in the diets were conducted by the decomposition of sum of squares in orthogonal linear contrasts, and quadratic effects, at 5% probability, with subsequent adjustments of the regression equations.

Results and Discussion

The intakes of DM, OM, CP, NFC, and TDN decreased linearly with the sugarcane bagasse levels (Table 3). There was a quadratic effect for NDFap intake, with a maximum value of 6.54 kg per day, estimated at 48.2% sugarcane bagasse. DM digestibility decreased linearly, while the digestibility of CP and NDF increased linearly with the increased levels.

Excess of low degradability fiber from sugarcane bagasse decreased dietary DM digestibility, which was reflected in the reduction of intake and increase of rumination activities. The fraction of slowly digestible, or indigestible fiber, taking up space in the animal's gastrointestinal tract, caused rumen-filling as a result of distension in the rumen (Mertens, 1997). Consequently, the cows ingested the diets until they reached their maximum capacity for NDF intake. According to Ahmed et al. (2013), the use of sugarcane bagasse for animal feeding is limited by their low-digestibility, and could be related to their high content of fiber with more than 60% cellulose, hemicellulose, and lignin.

A linear increase for feeding time and rumination was observed with bagasse increasing levels, and a linear decrease of idle time (Table 4). The animals spent more time ingesting feed; nevertheless, they presented lower DM intake (Table 3), suggesting that greater NDF in diets with more inclusion of bagasse increased animal selectivity (Parente et al., 2016) and, as a consequence, feeding efficiency was lower. The highest values observed for rumination time can be justified by the highest NDF intake observed for diets with greater bagasse inclusion. The rumination efficiency was better for diets with more concentrate inclusion and less bagasse (Table 4), since, in this case, the DM intake was high and the rumination time was lower.

The effects of sugarcane bagasse levels on Nefa and BHBA concentration showed a quadratic pattern, with the highest value estimated as 0.56 mmol L^{-1}, with 43.1% of bagasse (Table 5). In spite of the quadratic response of BHBA, this metabolite and Nefa ranged from 0.11 to 0.14, and from 0.51 to 0.58 mmol L^{-1}, respectively, indicating a normal metabolism condition, since they are great indicators of body mobilization and subclinical ketosis, respectively (Adewuyi et al., 2005; González et al., 2011). This can be better understood by observing the animal's weight gain during the trial.

Although a quadratic effect of the inclusion levels was observed on N balance, biologically, the linear effect was the most adequate for explaining such a response due to the behavior of N intake and N excretion in feces, urine, and milk (Table 5). N use efficiency was harmed with the bagasse inclusion, since it decreased for milk, and the concentration of urea in plasma and milk increased. A better efficiency for milk can be associated with quantitative increase in the microbial protein for diets with less bagasse inclusion (1,604 g per day), as most amino acids absorbed in the small intestine come from microbial protein and present a high-quality amino acid profile, even comparable to the milk profile (Titgemeyer, 2003). A lower urea concentration in plasma and milk is related to the synchronism (energy:N) in rumen (Siqueira et al., 2017) promoted by high levels of non-fibrous carbohydrates in the diets due to the inclusion of high concentrate levels (Inácio et al., 2017).

The urea concentration in urine showed a quadratic response, with minimal value estimated at 70.9 (mg dL^{-1}), with 41.97% bagasse inclusion (Table 5). Microbial protein decreased linearly with bagasse inclusion, while the efficiency of microbial synthesis did not differ. As the efficiency of synthesis did not change, the decrease in microbial syntheses was related to the low TDN intake, observed for diets with high bagasse inclusion. The efficiency of microbial protein synthesis (127 g crude protein per kg of TDN) is in accordance with the recommendation for crossbred cattle raised in tropical areas – 120 g kg^{-1} (Pina et al., 2010).

Milk yield, corrected for 3.5% fat, decreased linearly with bagasse inclusion, accordingly to the linear decrease observed for NDT and CP intakes (Table 3).

The milk fat was not altered by the bagasse inclusion levels, with a mean of 3.68 g per 100 g (Table 6), which can be justified by the adequacy of effective fiber content in experimental diets. According to NRC (2001), diets with 25% NDF in total and 44% non-fiber carbohydrates should present, at least, 76% NDF from the roughage (longer fiber) in order to guarantee the maintenance of milk fat at normal levels. Considering the bagasse inclusion of 30%, the total NDF was 281 g per 100g and NFC was 44 g per 100g; thus, the total NDF was 89%, provided by sugarcane bagasse (longer fiber), which meets the NRC recommendation.

Milk protein and lactose decreased linearly with the bagasse inclusion (Table 6). Milk components can be altered with diet composition, since the substrates for

Table 3. Intake and digestibility of nutrients in cows according to different sugarcane bagasse levels(1).

Item	Control	Sugarcane bagasse levels (%)				SEM(2)	Contrasts		Regression	R^2
		30	38	46	54		Linear	Quadratic		
							Intake (kg per day)			
Dry matter	18.3	18.3	17.8	16.1a	13.9a	0.506	**	ns	$\hat{Y} = 24.3162 - 0.1855x$	93.68
Organic matter	16.5	17.0	16.5	14.8a	12.7a	0.467	**	ns	$\hat{Y} = 22.9185 - 0.1822x$	94.52
Crude protein	2.60	2.66	2.60	2.38a	2.07a	0.069	**	ns	$\hat{Y} = 3.4673 - 0.0248x$	92.44
NDFap(3)	6.83	5.15a	6.13a	6.53	6.43	0.215	**	**	$\hat{Y} = -3.2204 + 0.4049x - 0.0042x^2$	99.97
NFC(4)	7.21	8.80a	7.51	5.93a	4.35a	0.202	**	ns	$\hat{Y} = 14.4734 - 0.1863X$	99.77
TDN(5)	12.7	12.8	11.8a	10.7a	9.06a	0.571	**	ns	$\hat{Y} = 17.1687 - 0.1461x$	97.51
							Digestibility (g kg^{-1})			
Dry matter	736	705a	685a	679a	671a	12.9	**	ns	$\hat{Y} = 741.575 - 1.344x$	91.59
Organic matter	760	724a	705a	709a	701a	12.7	ns	ns	-	-
Crude protein	814	749a	758a	777a	782	13.8	**	ns	$\hat{Y} = 706.013 + 1.441x$	95.96
NDFap	535	397a	431a	460a	492	22.7	**	ns	$\hat{Y} = 279.202 + 3.947x$	99.94

(1)Means followed by equal letters do not differ from the control treatment, according to the Dunnett test at 5% probability. (2)SEM, standard error of the mean. (3)NDFap, neutral detergent fiber corrected for ash and nitrogenous compounds. (4)NFC, non-fiber carbohydrates. (5)TDN, total digestible nutrients. **Significant at 1% probability. nsNonsignificant.

Table 4. Feeding behavior of cows according to different sugarcane bagasse levels(1).

Item	Control	Sugarcane bagasse levels (%)				SEM(2)	Contrasts		Regression	R^2
		30	38	46	54		L(3)	Q(4)		
Eating (min per day)	329	283a	324	320	325	9.45	*	*	$\hat{Y} = 12.13 + 13.33x - 0.14x^2$	87.99
Ruminating (min per day)	407	393	448	464	476a	26.5	*	*	$\hat{Y} = 1,404.59 - 30.75x + 0.30x^2$	95.81
Idle (min per day)	704	764	668	656	639	29.1	*	ns	$\hat{Y} = 306.1250 - 3.3125x$	87.03
Feed efficiency (kg min^{-1})	3,371	3,920a	3,304	3,028a	2,575a	78.6	**	ns	$\hat{Y} = 5,469.6316 - 53.8733x$	97.90
Rumination efficiency (kg min^{-1})	2,746	2,960	2,467	2,180a	1,776a	93.3	*	ns	$\hat{Y} = 4,362.1638 - 48.0074x$	99.04

(1)Means followed by equal letters do not differ from the control treatment, according to the Dunnett test at 5% probability. (2)SEM, standard error of the mean. (3)L, linear effect. (4)Q, quadratic effect. **and*Significant at 1 and 5% probability, respectively. nsNonsignificant.

mammary synthesis of milk components are provided by the fermentation in the rumen and by the digestion of the small intestine carbohydrates, affecting milk yield directly through the supply of glucose to the mammary gland and milk protein through the growth limitation of ruminal bacteria (Chalupa & Sniffen, 2000).

The diet bio-economics system evaluation (Table 7) showed that the feeding cost per kg of milk produced was lower for high-level bagasse diet; however, considering the gross margin (R$ per cow per day), the greater value was obtained with lower bagasse inclusion. Therefore, the high inclusion of expensive concentrated feedstuff was offset by the high milk production.

The control diet promoted the expected milk yield, as verified in other works with spineless cactus (Ferreira et al., 2010), and this result from an experiment with controlled diets corroborates the importance of the species for smallholder dairy system in semiarid regions.

Table 5. Blood metabolites, nitrogen balance, N use efficiency, urea nitrogen, and microbial protein synthesis of cows according to different sugarcane bagasse levels(1).

Item	Control	Sugarcane bagasse levels (%)				SEM(2)	Contrasts		Regression	R^2
		30	38	46	54		L(3)	Q(4)		
						Blood metabolite (mmol L^{-1})				
Nefa(5)	0.09	0.11	0.12	0.14	0.12	0.02	ns	ns	-	-
BHBA(6)	0.64	0.51a	0.55a	0.58a	0.52a	0.04	ns	*	$\hat{Y} = -0.1223 + 0.320x - 0.0003x^2$	91.74
						Nitrogen balance (g day^{-1})				
Total N intake	416	425	416	380a	332a	11.2	**	ns	$\hat{Y} = 554.9144 - 3.9731x$	92.58
N Feces	84.6	117 a	109a	90.0	76.9	4.06	**	ns	$\hat{Y} = 170.6985 - 1.7265x$	97.67
N Urine	0.34	0.44	0.28	0.26	0.29	0.06	ns	ns	-	-
N Milk	97.9	114a	102	89.3a	79.7a	2.91	**	ns	$\hat{Y} = 156.5534 - 1.4364x$	99.69
Balance	232	194a	204a	201a	174a	11.5	*	**	$\hat{Y} = -10.9849 + 11.0717x - 0.141383x^2$	99.21
						N use efficiency (NUE)				
Milk	0.236	0.260a	0.247	0.246	0.240	0.005	**	ns	$\hat{Y} = 0.2793 - 0.0007x$;	85.55
						Urea nitrogen (mg dL^{-1})				
Plasma	23.1	28.7	29.9	35.7	35.7	1.32	**	ns	$\hat{Y} = 39.5640 - 0.7152x$	85.99
Urine	74.9	87.3	71.3	74.2	86.6	7.65	ns	*	$\hat{Y} = 1{,}665.7391 - 58.2670x - 0.6943x^2$	97.87
Milk	17.1	19.4	22.5a	26.4a	27.1a	1.21	**	ns	$\hat{Y} = 9.5945 + 0.3395x$	94.10
						Microbial protein synthesis				
MCP(7) (g per day)	1,594	1,604	1,487	1,275a	1,248a	91.8	**	ns	$\hat{Y} = 2{,}076.1955 - 16.0168x$	93.29
EMPS(8) (g kg^{-1})	125.5	125.3	126.0	119a	137.7	5.37	ns	ns	-	-
Daily gain (kg per cow)	0.31	0.34	0.30	0.31	0.31	-	-	-	-	-

(1)Means followed by equal letters do not differ from the control treatment, according to the Dunnett test at 5% probability. (2)SEM, standard error of the mean. (3)L, linear effect. (4)Q, quadratic effect. (5)Nefa, non-esterified fatty acids. (6)BHBA, Beta-hydroxybutyrate. (7)MCP, microbial crude protein. (8)EMPS, efficiency of microbial protein synthesis. **and*Significant at 1 and 5% probability, respectively. ^{ns}Nonsignificant.

Table 6. Milk yield and composition of cows according to different sugarcane bagasse levels(1).

Item	Control	Sugarcane bagasse levels (%)				SEM(2)	Contrasts (p-value)		Regression	R^2
		30	38	46	54		Linear	Quadratic		
						Milk yield (kg per day)				
Milk	19.7	22.4a	20.6	18.5a	16.4a	0.74	**	ns	$\hat{Y} = 29.9765 - 0.2507x$	99.85
3.5% FCM(3)	19.9	22.7a	21.4	19.4	16.5a	1.03	**	ns	$\hat{Y} = 30.8634 - 0.2589x$	97.17
						Milk composition (g per 100g)				
Fat	3.56	3.61	3.77	3.78	3.54	0.19	ns	ns	-	
Protein	3.19	3.25	3.19	3.11	3.11	0.07	*	ns	$\hat{Y} = 3.43 - 0.0063x$	87.05
Lactose	4.71	4.82	4.77	4.71	4.66	0.04	**	ns	$\hat{Y} = 5.0176 - 0.0065x$	99.71
Total solids	12.3	12.3	12.5	12.2	12.2	0.15	ns	ns	-	-

(1)Means followed by equal letters do not differ from the control treatment, according to the Dunnett test at 5% probability. (2)SEM, standard error of the mean. (3)FCM, fat content milk. **and*Significant at 1 and 5% probability, respectively. ^{ns}Nonsignificant.

Table 7. Bioeconomic system evaluation.

Item[1]	Control	Sugarcane bagasse levels (%)			
		30	38	46	54
		Feeding costs			
Daily total diet offered (kg per cow)	5.63	5.63	5.48	4.95	4.28
Diet cost ($ kg^{-1})	0.22	0.27	0.26	0.24	0.23
Daily feeding cost ($ per cow)	4.10	4.94	4.56	3.90	3.17
		Gross revenue			
Daily milk yield (kg)	6.12	6.98	6.58	5.97	5.08
Milk price ($ kg^{-1})	0.46	0.46	0.46	0.46	0.46
Daily gross revenue ($ per cow)	9.18	10.48	9.88	8.95	7.62
Gross margin ($ per cow day^{-1})	5.09	5.53	5.31	5.06	4.44
Feeding cost per kg of milk produced ($)	0.21	0.22	0.21	0.20	0.19

(1)Brazilian Reais quotation for U.S. dollar in July 2017: R$ 3.25.

Conclusion

The inclusion of sugarcane bagasse as roughage for crossbred dairy cow's diet decreases their performance; nevertheless, the bagasse can be used as exclusive roughage, when associated with 70% of the concentrate, which is a sound alternative for dairy production in the Brazilian semiarid region due to the low availability of roughage in prolonged dry seasons.

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