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Evaluation of performance and nutrient intake of lambs fed sugarcane hydrolyzed under different conditions

Desempenho e consumo de nutrientes em cordeiros alimentados com cana-de-açúcar hidrolizada sob diferentes condições

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Abstract

Twenty-four Ile de France lambs, born in the same period, were used to evaluate performance and nutrient intake throughout the feedlot period (starting with 15 ± 0.221 until 32 ± 0.265 kg of body weight). Treatments were: IN (*in natura* sugarcane + concentrate), AER (sugarcane hydrolyzed using 0.6% calcium oxide (CaO) under aerobic condition + concentrate) and ANA (sugarcane hydrolyzed using 0.6% CaO under anaerobic condition + concentrate). The experimental design was completely randomized with eight replicates per treatment. Lambs were housed in individual pens and fed diet allowing 10% refusals. Lambs were weighed weekly to obtain the average daily weight gain and feed conversion. Nutrient intake was computed based on the amount of nutrients fed to the animals and the amount of nutrients of the refusals. Means were tested by Tukey HSD range test ($P < 0.05$). No difference was observed between treatments for performance, in which average daily weight gain was 0.241 kg and feed conversion was 3.99. Lambs fed sugarcane hydrolyzed under anaerobic condition had the highest mineral matter intake (69.97 g day^{-1}) compared to other treatments. No differences for the other nutrient intakes were observed. Sugarcane hydrolyzed under aerobic and anaerobic conditions do not affect the performance neither the nutrient intake of the animals. The choice between supplying *in natura* or hydrolyzed sugarcane will depend on an economic analysis.
Key words: Feed conversion, hydrolysis, *Saccharum officinarum,* weight gain

Resumo

Foram utilizados 24 cordeiros Ile de France confinados, nascidos no mesmo período para a avaliação do desempenho e consumo de nutrientes (entrada no experiemento com 15 ± 0,221 até 32 ± 0,265 kg de peso corporal). Os tratamentos foram: IN (cana-de-açúcar *in natura* + concentrado), AER (cana-de-açúcar hidrolizada com 0,6% de óxido de calico (CaO) sob condições aeróbicas + concentrado) e ANA (cana-de-açúcar hidrolizada com 0,6% de CaO sob condições anaeróbicas + concentrado). O delineamento foi inteiramente casualizado com oito repetições por tratamento. Os cordeiros foram confinados em baias individuais e alimentados com dieta que permitia 10% de sobras. Os cordeiros foram pesados

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semanalmente para obtenção do ganho de peso diário e conversão alimentar. O consumo de nutrientes foi mensurado com base na quantidade de nutrientes presente nos alimentos que foram fornecidos aos animais e a quantidade de nutrientes das sobras. As médias foram testadas pelo teste de Tukey para 5% de significância (P < 0,05). Não foi observado diferença entre os tratamentos para desempenho, que tiveram ganho médio de peso diário de 0,241 kg e conversão alimentar de 3,99. Cordeiros alimentados com cana-de-açúcar hidrolisada sob condições anaeróbicas tiveram maior consumo de matéria mineral (69,97 g dia^{-1}) comparado com os demais tratamentos. Não houve diferença entre os tratamentos para consumo dos demais nutrientes. A cana-de-açúcar hidrolizada sob condições aeróbicas e anaeróbicas não afetaram o desempenho e nem o consumo de nutrientes pelos cordeiros. A escolha entre o fornecimento da cana-de-açúcar *in natura* ou hidrolizada dependerá de uma análise econômica.
Palavras-chave: Conversão alimentar, ganho de peso, hidrólise, *Saccharum Officinarum*

Introduction

Efficiency in animal production is closely linked to the intake ability of the animal and the quality of the feed provided. Nutrient intake is important to understand what affects the weight gain and feed conversion. The rate of degradation of nutrients by rumen microorganisms varies depending on the different fractions in the feed (VAN SOEST, 1994). The nutrient intake is inversely proportional to the cell-wall content, which is regulated by physical, chemical, and metabolic mechanisms when its content is greater than 55% (RESENDE et al., 2005). Therefore, the choice of the feed that will be provided to the animals must account for favorable nutritional and economical aspects for production.

There are many advantages of using sugarcane: easily cultivated, high content of energy, and high potential of dry matter production per unit of area, especially when forage is scarce. It has, however, some disadvantages: low crude protein content that requires protein supplementation, and a need for daily cut due to the high concentration of soluble carbohydrates which makes the environment propitious for the development of microorganisms that deteriorate the chopped sugarcane. To overcome the latter disadvantage, alkaline treatment of sugarcane has been promoted using calcium oxide (CaO), which can also improve the nutritive value of sugarcane by increasing the digestibility of fibers (ZEOULA et al., 2006, MORENO et al., 2010; OLIVEIRA, 2010; BERCHIELLI; PIRES; OLIVEIRA, 2011; CARVALHO et al., 2011).

A pH increase due to the application of CaO in sugarcane is followed by a gradual pH decrease due to aerobic exposure of sugarcane. This decrease is linear, but it is not interesting, because the pH decrease occurs by action of microorganisms. These microorganisms consume the soluble carbohydrates and cause acidification of sugarcane, therefore its aerobic stability decreases (RABELO et al., 2011). With the hydrolysis of sugarcane under anaerobic condition, i.e., with no exposure to oxygen, theoretically, in the course of time, pH gradually decreases slower than in hydrolysis under aerobic exposure, which may result in a less favorable environment for the development of aerobic microorganisms, such as yeasts. Therefore, this study aimed to evaluate the performance and nutrient intake of lambs fed sugarcane either *in natura* or hydrolyzed under aerobic and anaerobic conditions.

Material and Methods

The experiment was conducted at São Paulo State University (Unesp) in Jaboticabal, Brazil. Twenty-four Ile de France lambs, uncastrated and weaned at 14 kg body weight (BW) were used. At 15 ± 0.221 kg BW, lambs were identified with numerical marking on the back region. Lambs were housed in individual pens (1.0 m^2), with slatted and suspended floor. These facilities were equipped with bunks and waterers installed in covered sheds. Lambs were distributed in a completely randomized design with three treatments and eight replicates; *in natura* sugarcane + concentrate (IN), sugarcane hydrolyzed using 0.6% CaO under aerobic condition + concentrate (AER) and sugarcane hydrolyzed using 0.6% CaO under anaerobic condition + concentrate (ANA). Chemical composition of the ingredients is in Table 1. Composition, percentage and chemical analysis of diets are in Table 2.

Table 1. Chemical and crude energy composition of the ingredients of the experimental diets (expressed in DM).

Percentual composition	Sugarcane			Soybean meal	Ground corn
		Hydrolyzed using CaO (0.6%)			
	In natura	Aerobic	Anaerobic		
Dry matter (%)	33.75	30.64	30.71	90.18	89.80
Organic matter (%)	32.01	27.06	26.78	83.29	87.39
Mineral matter (%)	1.74	3.58	3.93	6.89	2.41
Crude protein (%)	1.51	1.49	1.46	47.50	10.48
Ether extract (%)	1.85	1.45	1.27	1.75	6.85
Lignin (%)	5.63	5.19	5.53	7.75	2.51
Neutral detergent fiber (%)[1]	41.09	37.54	37.67	20.89	10.11
Neutral detergent acid (%)	22.90	20.10	20.11	8.51	2.70
Hemicellulose (%)	18.19	17.44	17.56	12.38	7.41
Cellulose (%)	17.27	14.91	0.76	7.60	0.19
Total carbohydrates (%)[2]	95.87	92.72	94.29	43.87	80.25
Non-fibrous carbohydrates (%)[3]	53.81	55.94	55.67	22.97	70.15
Crude energy (Mcal kg^{-1})	3.88	3.70	3.82	4.56	4.37

[1]Neutral detergent fiber corrected for ash and protein.
[2]Total carbohydrates = 100 - (%CP + %EE + %MM)
[3]Non-fibrous carbohydrates = 100 – (% NDFap +% CP +% EE +% MM)
Source: Elaboration of the authors.

Table 2. Ingredients percentage, chemical and crude energy composition of the experimental diets (expressed in DM).

Percentual composition	Treatment		
	IN	AER	ANA
Sugarcane	49.93	52.69	50.99
Urea	1.27	1.20	1.21
Ground corn	8.09	7.64	7.76
Soybean meal	37.97	35.87	36.41
Sodium chloride	0.33	0.31	0.31
Limestone	1.15	1.08	1.10
Phosphate Dicalcium	0.80	0.76	0.77
Mineral mixture[1]	0.47	0.44	0.45
Chemical and bromatological (on DM)			
Dry matter (%)	50.07	47.31	48.01
Crude protein (%)	22.73	21.48	21.80
Mineral matter (%)	6.24	6.96	7.19
Neutral detergent fiber (%)[2]	27.53	28.15	29.79
Neutral detergent acid (%)	13.17	13.56	14.92
Hemicellulose (%)	14.36	14.59	14.87
Cellulose (%)	7.48	7.85	9.03
Lignin (%)	5.69	5.71	5.89
Ether extract (%)	2.14	1.92	1.83
Organic matter (%)	93.76	93.04	92.81
Total carbohydrates (%)[3]	68.89	68.72	69.18
Non-fiber carbohydrates (%)[4]	41.36	41.49	39.39
Crude energy (Mcal kg^{-1})	4.02	3.92	3.99

IN: *in natura* sugarcane + concentrate, AER: sugarcane hydrolyzed using 0.6% CaO under aerobic condition + concentrate, ANA: sugarcane hydrolyzed using 0.6% CaO under anaerobic condition + concentrate.
[1]Mineral mixture: zinc 1600 mg, copper 300 mg, manganese 1500 mg, iron 1100 mg, cobalt 10 mg, iodine 27 mg, selenium 22 mg.
[2]Neutral detergent fiber corrected for ash and protein.
[3]Total carbohydrates = 100 - (%CP + %EE + %MM)
[4]Non-fiber carbohydrates = 100 – (% NDFap +% CP +% EE +% MM).
Source: Elaboration of the authors.

Diets were formulated according to NRC (2007) for lamb weight gain of 250 g day^{-1}, constituting diets with 22% crude protein (CP), 3.9 Mcal of crude energy (CE) and 2.68 Mcal of metabolize energy (ME) per kg of dry matter (DM), with roughage:concentrate rate of 50:50.

Lime had a chemical composition of 93.4% CaO, 0.6% of magnesium oxide (MgO) and 0.1% phosphorus (P). The IAC 86-2480 was the variety of sugarcane used. A second cut of sugarcane with nine months of growing, non-defoliated and chopped in particle size from 0.8 to 1.0 cm was provided *in natura* or hydrolyzed under aerobic and anaerobic conditions, depending on the treatment.

In natura sugarcane was cut daily and was kept for 2-day ripening, after that, it was chopped in specific equipment and provided to the lambs. Hydrolyzed sugarcane was cut daily, chopped and treated using 0.6% CaO per 100 kg of sugarcane. A solution was made by diluting 0.6 kg of CaO in 2.0 liters of water. Sugarcane remained under aerobic and anaerobic conditions for 2-day ripening before being provided to the lambs.

To obtain the hydrolyzed sugarcane, it was chopped and spread on a tarp, forming a stack.

Calcium oxide solution was poured slowly over the sugarcane, and after that, the stack was revolved for complete homogenization to assure that the fibers were hydrolyzed. The stack of sugarcane hydrolyzed under aerobic condition remained on the tarp. Whereas, sugarcane hydrolyzed under anaerobic condition was stored in screw-top drums, which avoided the contact of oxygen with the hydrolyzed sugarcane. Temperatures of *in natura* and hydrolyzed sugarcane were measured at the time of delivery to the animals with an infrared laser thermometer.

When reaching 15 kg body weight, lambs were treated with anthelmintic and supplemented with vitamins A, D and E, and then, confined in individual pens. The animals received a mixed diet in the bunks, allowing 10% refusals of what was supplied. Diets were delivered twice daily, at 8 and 17 hours. The adaptation period was 14 days. Refusals were weighed daily to determine the dry matter intake (DMI), whereas lambs were weighed weekly to obtain the average daily gain (ADG) and feed conversion (FC), which was obtained by dividing DMI by weight gain (WG) (Table 3). Lambs were evaluated fortnightly for worms using the Famacha® method (MOLENTO et al., 2004) and also by counting of eggs per gram of feces (EPG), performed according to the method of Gordon and Whitlock (1939). Lambs were treated when necessary. Samples of 10% of the refusals of each animal were collected weekly and stored in a freezer at -18°C, yielding at the end of the experiment a composite sample. These were pre-dried in a forced-ventilation oven at 55ºC for 72 hours and subsequently ground using a knife mill (mesh of 1.0 mm) for posterior determination of DM, organic matter (OM), mineral matter (MM), crude protein (CP) and ether extract (EE), according to methodologies of AOAC (1990). The lignin (LIG), neutral detergent fiber and ash-free protein (NDFap), and acid detergent fiber (ADF) were determined according to Van Soest (1994). Total carbohydrates (TC) were calculated by the equation: TC = 100 - (% CP +% EE +% MM), while the non-fiber carbohydrates (NFC) were calculated by the equation: NFC = 100 – (%NDFap +% CP +% EE +% MM) (SNIFFEN; CONNOR, VAN SOEST, 1992). Nutrient intake was calculated by the difference between the amount of nutrient in the feed supplied and in the refusals.

Experimental design was the completely randomized with three treatments and eight replicates. Data were subjected to analysis of variance by PROC GLM using the statistical software SAS (2001), at 5% significance level. When significant differences were detected, means were tested by Tukey HSD range test at 5% significance level.

The mathematical model used was:

$$Y_{ij} = \mu + \pi_i + e_{ij},$$

where Y_{ij} is the observed value of the variable studied in animal j, diet i; μ is the general mean common to all observations (constant); π_i is the effect of treatment, e_{ij} is the random error associated with each observation (measurement errors, uncontrollable factors, differences between experimental units).

Results and Discussion

High dry matter content of hydrolyzed sugarcane in the chemical composition (Table 1) may have occurred because of the lime used in the experiment that showed 99% of DM, increasing sugarcane DM (RABELO et al., 2011). Another possibility is that the 2-day ripening period applied to sugarcane under all conditions, when it was stored between the cutting and chopping period, resulted in loss of moisture from the material.

Table 3. Initial and final BW, dry matter intake (DMI), average daily gain (ADG), and feed conversion (FC) of the total period on feed of lambs with diets containing sugarcane either *in natura* or hydrolyzed under aerobic and anaerobic conditions.

Performance	Treatment			Pr > F	CV (%)
	IN	AER	ANA		
Initial BW (kg)	15.35 ± 0.13	15.09 ± 0.19	15.03 ± 0.30	ns	3,88
Final BW (kg)	31.87 ± 0.38	32.24 ± 0.08	31.79 ± 0.30	ns	2,20
Days on feed	61.00 ± 3.12	60.00 ± 3.03	55.00 ± 2.19	ns	12.28
DMI (g day^{-1})	913.27 ± 0.02	953.27 ± 0.04	981.89 ± 0.03	ns	8.10
DMI (g $kg^{-0,75}$ day^{-1})	85.88 ± 1.98	88.87 ± 4.13	92.34 ± 3.15	ns	7.86
DMI (%BW day^{-1})	2.57 ± 0.06	2.51 ± 0.12	2.40 ± 0.10	ns	8.22
ADG (g)	0.23 ± 0.01	0.24 ± 0.01	0.25 ± 0.01	ns	13.03
FC	4.14 ± 0.24	4.09 ± 0.20	3.90 ± 0.23	ns	13.54

IN: *in natura* sugarcane + concentrate, AER: sugarcane hydrolyzed using 0.6% CaO under aerobic condition + concentrate, ANA: sugarcane hydrolyzed using 0.6% CaO under anaerobic condition + concentrate. Tukey test (* = P < 0.05, ns = non-signicance).
Source: Elaboration of the authors.

Results of the initial and final body weight, days on feed, dry matter intake, average daily weight gain and feed conversion are in Table 3, and were not affected (P > 0.05) by treatments. The lambs had an average of 58 days on feed to achieve the final body weight of 31.97 kg and consumed approximately 951 g $animal^{-1}$ day^{-1} of DM, i.e., 89.02 g DM per unit of metabolic size (g $kg^{-0.75}$ day^{-1}), representing an intake of 2.5% of its BW and had a feed conversion of 4.0.

The DMI is an important factor in the performance of feedlot lambs because it is related to the supply of nutrients, which is essential to meet the requirements of weight gain of the animals (SNIFFEN, CONNOR; VAN SOEST, 1992). Freitas, Rocha and Zonta (2008) evaluated the performance of sheep with initial BW of 22.0 kg, under 42 days of experiment, fed diets based on sugarcane either *in natura* or hydrolyzed using calcium hydroxide ($Ca(OH)_2$) 0.5 and 0.9%, and found no difference (P > 0.05) among treatments for a DMI of 954.77 g day^{-1} and a ADG of 120.67 g. When analyzing the performance of lambs and digestibility of diets containing corn or sugarcane silage and two levels of concentrate, Moreno et al. (2010) found a mean value of feed conversion of 3.0, which is better than 4.0 found in our study.

Nutrient intake was not affected (P > 0.05) by treatments, except for the MM intake (P < 0.05) (Table 4). The average intake of: DM was 951.29 g day^{-1}, OM was 792.49 g day^{-1}, CP was 203.67 g day^{-1}, EE was 18.42 g day^{-1}, NDFap was 245.80 g day^{-1}, ADF was 120.33 g day^{-1}, TC was 647.45 g day^{-1} and CNF was 401.90 g day^{-1}. Lambs fed sugarcane hydrolyzed under anaerobic condition had higher intake of MM (69.97 g day^{-1}) than lambs fed *in natura* sugarcane (50.38 g day^{-1}). This difference is likely to be due the addition of 0.6% CaO in the treatments of hydrolysis, although no difference in MM intake was observed between treatments with *in natura* (50.38 g day^{-1}) and sugarcane hydrolyzed under aerobic condition (64.21 g day^{-1}). CP intake is in accordance to Freitas, Rocha and Zonta (2008) who found 194.43 g day^{-1}, whereas NDFap intake was slightly higher in their study (271.77 g day^{-1}) than ours. Moreno et al. (2010) observed values of 705.47 g day^{-1} for OM intake and 457.05 g day^{-1} for NFC intake, which agrees with the results found in our study, which were 792.49 g day^{-1} for OM intake and 401.90 g day^{-1} for NFC intake. According to the same authors, the EE intake was 12.15 g day^{-1} and TC was 541.53 g day^{-1}, lower values than ours, which were 18.42 g day^{-1} for EE and 647.45 g day^{-1} for TC.

Table 4. Nutrient intake based on dry matter of lambs fed diets containing sugarcane either *in natura* or hydrolyzed under aerobic and anaerobic conditions.

Nutrient intake (g day^{-1})	Treatment			Pr > F	CV (%)
	IN	AER	ANA		
Dry matter	913.27 ± 0.02	953.27 ± 0.04	981.89 ± 0.03	ns	9.20
Mineral matter	50.38^{b} ± 1.86	64.21^{ab} ± 5.75	69.97^{a} ± 8.32	*	17.41
Organic matter	742.14 ± 28.74	798.40 ± 73.75	829.72 ± 49.45	ns	18.26
Crude protein	186.17 ± 7.11	206.53 ± 17.81	215.82 ± 10.68	ns	16.69
Ether extract	18.69 ± 0.64	18.25 ± 1.61	18.36 ± 1.04	ns	16.69
Neutral detergent fiber[1]	238.83 ± 10.32	241.28 ± 23.26	256.30 ± 18.57	ns	16.99
Acid detergent fiber	121.14 ± 5.80	116.73 ± 11.74	123.24 ± 9.28	ns	19.84
Total carbohydrates	597.86 ± 23.41	650.93 ± 61.50	686.46 ± 43.21	ns	18.87
Non-fiber carbohydrates	386.47 ± 18.77	407.22 ± 36.76	409.81 ± 23.99	ns	18.25

IN: *in natura* sugarcane + concentrate, AER: sugarcane hydrolyzed using 0.6% CaO under aerobic condition + concentrate, ANA: sugarcane hydrolyzed using 0.6% CaO under anaerobic condition + concentrate. Tukey test (* = $P < 0.05$, ns = non-signicance). Different letters in rows shows significant differences between means. [1]Neutral detergent fiber corrected for ash and protein.
Source: Elaboration of the authors.

The percentage of NDFap in sugarcane ranged from 37.54% to 41.09% (Table 1) which is considered low according to Oliveira (2010). This low amount of fiber might have hindered hydrolysis resulting in similar NDFap intake among treatments (Table 4). The low NDFap found for the sugarcane used in this experiment is explained by its growing age (nine months) which indicates that it was not yet mature.

Conclusions

Sugarcane hydrolyzed under aerobic and anaerobic conditions do not affect the performance neither the nutrient intake of the animals. The choice between supplying *in natura* or hydrolyzed sugarcane will depend on an economic analysis.

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Ethics and Biosecurity Committee

This research is in accordance with the Ethical Principles in Animal Experimentation, adopted by the Colégio Brasileiro de Experimentação (COBEA) and was approved by COMISSÃO DE ÉTICA NO USO DE ANIMAIS (CEUA).

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