

Rumen parameters and intake in goats fed cassava chips and alfalfa¹

Parâmetros ruminais e consumo em cabras alimentadas com alfafa e raspa de mandioca

Raquel Ornelas Marques², Heraldo Cesar Gonçalves^{3*}, Paulo Roberto de Lima Meirelles², Evelyn Prestes Brito², Helen Fernanda Barros Gomes⁴ and Giuliana Micai de Oliveira²

ABSTRACT - Pasture-based production systems and alternative foods can be used to reduce goat milk production costs by around 20%. The objective of this study was to examine the effect of substituting the corn and soybean meal of the concentrate with cassava chips and alfalfa, respectively, on the feed intake, fermentation, and rumen degradability parameters of adult, dry, empty, rumen-cannulated Saanen goats reared in a feedlot. The experiment was conducted as a Latin square design in which the following diets were tested: ground corn and soybean meal; cassava chips and soybean meal; ground corn and alfalfa; and cassava chips and alfalfa. The following variables were evaluated: feed intake, rumen parameters, short-chain fatty acid (SCFA) production, and feed degradation kinetics. Inclusion of cassava chips and alfalfa did not influence feed intake or ammonia production. Rumen pH and SCFA production were influenced by the collection times, presenting a high pH (6.29) at the first measurement (07 h 00) and then decreasing, thus influencing SCFA production throughout the day. Acetic acid and total SCFA production were influenced by the diets, with the highest values for the cassava/alfalfa diet (68.03 and 93.64 mM 100 mM⁻¹, respectively) and the lowest values for the corn/soybean diet (55.40 and 76.03 mM 100 mM⁻¹, respectively). Nutrient digestibility was also influenced by diets, with those containing cassava and cassava/alfalfa, providing the greatest effective degradability (57.57 to 0.02 h⁻¹ and 53.49 to 0.05 h⁻¹; 57.25 to 0.02 h⁻¹ and 53.26 to 0.05 h⁻¹, respectively). This finding demonstrates that cassava and alfalfa can substitute the corn and soybean meal of concentrates without changing feed intake or the ruminal environment of goats. Rather, this substitution improves acetic acid production and diet digestibility.

Key words: Ammonia. Degradability. Rumen pH. Short-chain fatty acids.

RESUMO - Sistemas de produção baseados em pastagens e alimentos alternativos podem ser utilizados para reduzir cerca de 20% os custos de produção do leite caprino. O objetivo deste trabalho foi avaliar a influência da substituição do milho e do farelo de soja do concentrado, pela raspa de mandioca e alfafa, respectivamente, sobre o consumo, fermentação e degradabilidade ruminal de cabras adultas Saanen confinadas, vazias, secas e canuladas no rúmen. O experimento foi conduzido no delineamento em quadrado latino, com as dietas: milho triturado e farelo de soja; raspa de mandioca e farelo de soja; milho triturado e alfafa; raspa de mandioca e alfafa. Foram avaliados: consumo, parâmetros ruminais, produção de ácidos graxos de cadeia curta (AGCC) e cinética da degradação das dietas. A inclusão da raspa de mandioca e da alfafa não influenciou o consumo e a produção de amônia. O pH ruminal e as produções de AGCC foram influenciados pelos tempos de colheita, apresentando um pH elevado (6,29) na primeira mensuração (7 h 00) e diminuindo em seguida, influenciando dessa forma as produções de AGCC ao longo do dia. O ácido acético e a produção total de AGCC foram influenciados pelas dietas, sendo os maiores valores para a dieta mandioca/alfafa (68,03 e 93,64 mM 100 mM⁻¹, respectivamente) e os menores valores para a dieta milho/soja (55,40 e 76,03 mM 100 mM⁻¹, respectivamente). A degradabilidade dos nutrientes foi influenciada pelas dietas, sendo que as com mandioca e mandioca/alfafa apresentaram as maiores degradabilidades efetivas (57,57 para 0,02 h⁻¹ e 53,49 para 0,05 h⁻¹; 57,25 para 0,02 h⁻¹ e 53,26 para 0,05 h⁻¹, respectivamente), demonstrando que a mandioca e a alfafa podem substituir o milho e o farelo de soja dos concentrados, sem alterar o consumo e o ambiente ruminal das cabras, melhorando a produção de ácido acético e a degradabilidade da dieta.

Palavras-chave: Ácidos graxos de cadeia curta. Amônia. Degradabilidade. pH ruminal.

DOI: 10.5935/1806-6690.20200038

*Author for correspondence

Received for publication 18/03/2019; approved on 04/03/2020

¹Parte da Tese do primeiro autor, apresentada ao Programa de Pós-Graduação em Zootecnia da Faculdade de Medicina Veterinária e Zootecnia, Universidade Estadual Paulista/UNESP

²Faculdade de Medicina Veterinária e Zootecnia, Universidade Estadual Paulista/UNESP, Botucatu-SP, Brasil, ra_ornelas@yahoo.com.br (ORCID ID 0000-0001-9541-7121), paulo.roberto@unesp.br (ORCID ID 0000-0001-9168-5081), evelynpbrito@gmail.com (ORCID 0000-0002-5728-5735), giuliana.micai@gmail.com (ORCID 0000-0002-4726-683X)

³Faculdade de Medicina Veterinária e Zootecnia, Universidade Estadual Paulista/UNESP, Botucatu-SP, Brasil, heraldo.cesar@unesp.br (ORCID ID 0000-0002-5030-5617)

⁴Instituto de Ciências Agrárias e Tecnológicas, Universidade Federal de Rondonópolis/UFR, Rondonópolis-MT, Brasil, gomesfb@gmail.com (ORCID ID 0000-0003-1168-0999)

INTRODUCTION

In the last decade, the creation of dairy industries in the southeast and south regions of Brazil has challenged goat milk producers to increase efficiency in terms of production costs, especially those pertaining to feeding. This would reduce the dependence on feedstuffs deemed 'commodities' such as corn and soybean, whose prices fluctuate yearly in the international market. This inconsistency in prices can render activities that depend on the use of those grains unviable.

A strategy to overcome this issue is the adoption of pasture-based production systems, which represents a lower production cost than the use of traditional ingredients like corn silage and hay. The substitution of corn and soybean meal with alternative energy and protein feedstuffs, respectively, which small farmers can produce and store on their farm, may constitute a measure to improve their production efficiency.

Before using alternative feedstuffs in ruminant diets, it is interesting to evaluate the quality of these ingredients in terms of physical characteristics, degradation potential, and, especially, nutritional value. In doing so, producers can ensure adequate dry matter intake, nutrient uptake, and, consequently, desirable productive performance by the herd (OLIVEIRA *et al.*, 2013).

The roughage feedstuffs consumed by ruminants undergo physical and chemical changes, generating nutritional compounds that result from their fermentation in the rumen. Short-chain fatty acids (SCFA) are the main by-products of carbohydrate fermentation, and they meet 85% of the energy requirement of ruminants (OLIVEIRA; SANTANA NETO; VALENÇA, 2013). The relative proportion of produced SCFA varies widely according to the type of feed provided. When forage is used, this proportion also varies with its maturation stage.

The rumen degradability and the rate of passage of the different feed fractions are data of great relevance, as they make it possible to change the diet ingredients, ultimately allowing for increased yield at lower costs.

On these bases, the present study proposes to investigate the effect of substituting the corn and soybean meal of the concentrate with cassava chips and alfalfa, respectively, on the feed intake, fermentation, and rumen degradability parameters of adult goats in a maintenance regime in a feedlot system.

MATERIAL AND METHODS

The study was carried out in Botucatu - SP, Brazil, after approval by the Local Committee of Ethics in Animal Experimentation (approval no. 180/2012 - CEUA).

The experimental area is situated at the following geographic coordinates: 22°52' S and 48°26' W, at an altitude of 800 m. According to the Köppen classification, the climatic type of Botucatu is a hot temperate mesothermal Cfa type. The average annual precipitation in the region is 1,479 mm (CUNHA; MARTINS, 2009) and the dry period is considered from May to September (30% of the annual precipitation).

A Latin square experimental design was implemented. Non-pregnant, non-lactating, rumen-cannulated Saanen goats with an average weight of 65 kg were distributed into two balanced (4 × 4) latin squares to evaluate the substitution of corn and soybean meal of the concentrate with cassava chips and alfalfa, respectively. The following diets were tested: COSO: ground corn and soybean meal; CASO: cassava chips and soybean meal; COAL: ground corn and alfalfa (*Medicago sativa* cv. Crioula); and CAAL: cassava chips and alfalfa. For all diets, tobiatã grass (*Panicum maximum* cv. Tobiatã) was offered as the roughage feed.

The experimental period was 80 days, which were divided into four 20-day sub-periods consisting of 15 days dedicated to acclimation and adjustment of voluntary feed consumption and five days of data collection. The animals were housed in individual 3.5 m² stalls in a covered shed equipped with automatic drinkers, salt troughs, and roughage and concentrate feed troughs.

Diets were supplied twice daily, at 07 h 00 and 17 h 00. Concentrate, alfalfa, and Tobiatã grass were provided in separate troughs, in the proportions previously established for each treatment and in a sufficient quantity to allow for 10%orts. Water was supplied *ad libitum*. Roughages were chopped daily. The areas cultivated with Tobiatã grass and alfalfa were managed so as to be at 30 days of vegetative growth upon being harvested to be supplied to the animals. The average dry matter (DM) yield of Tobiatã grass per harvest was 8,650 kgha⁻¹, whereas the DM yield of alfalfa per harvest was 5,500 kgha⁻¹, in the months of October and November.

The cassava chips were produced with newly harvested roots of cassava (*Manihot esculenta* Crantz) varieties IAC 13 and IAC 15 (mixed), which were washed, peeled, chopped to particles of approximately 2 to 3 cm, and dried in the sun until reaching a dry matter content of 89%.

The experimental diets were formulated in accordance with the National Research Council (2007) so as to meet the nutritional requirements of goats with a live weight of 60 kg (Table 1).

Samples of Tobiatã grass and alfalfa were harvested at every 20 days and dried in a forced-air oven at 55 °C for 72 h, ground to 1.0 mm in a Wiley mill, and packed

Table 1 - Proportions of ingredients and chemical composition of the diets

Ingredient (g kg ⁻¹ DM)	Diet			
	COSO	CASO	COAL	CAAL
Tobiatã grass	400	550	300	300
Alfalfa	0	0	140	280
Cassava	0	255	0	290
Soybean meal	50	65	0	0
Corn	420	0	430	0
Wheat bran	100	100	100	100
Dicalcium phosphate	10	10	10	10
Mineral mix ¹	20	20	20	20
Chemical composition (g kg ⁻¹ DM)				
Mineral matter	36.1	46.7	38.6	50.4
Crude protein	134.3	129.1	132.0	133.0
Ether extract	28.0	18.5	29.5	21.1
Neutral detergent fiber	399.6	443.1	397.3	405.6
Acid detergent fiber	198.7	248.5	199.2	232.5
Total digestible nutrients (TDN) ²	728.0	695.9	723.4	698.5

COSO: corn + soybean; CASO: cassava + soybean; COAL: corn + alfalfa; CAAL: cassava + alfalfa; DM - dry matter; ¹Composition per kilogram of product: Ca - 200 g; Co - 25 mg; Cu - 440 mg; Cr - 6 mg; S - 10 g; Fe - 340 mg; F - 700 mg; P - 70 g; I - 48 mg; Mg - 5000 mg; Mn - 1480 mg; Se - 20 mg; Na - 100 g; Zn - 3010 mg; vitamin A - 250000 IU; vitamin D3 40000 IU; vitamin E - 350 IU. ²Obtained from the equation proposed by National Research Council (2001): TDN = DCP + DNFC + DNDF + (DFA × 2.25) - 7, in which: DCP - truly digestible crude protein; DNFC - truly digestible non-fibrous carbohydrates; DNDF - digestible neutral detergent fiber; DFA - truly digestible fatty acid

in plastic containers. Chemical analyses were performed following Association of Official Analytical Chemists International (2007).

Weight was monitored by weighing the animals at the start of each period and at the end of the experiment, before the 07 h 00 feed supply. Voluntary feed intake was calculated as the difference between the total supplied feed and orts, during the five days of data collection.

To determine the rumen fermentation parameters, samples of rumen fluid were collected every two hours, for a period of 12 h, starting at 07 h 00 (before the supply of the experimental diet) and ending at 19 h 00, in a total of seven collections. The feed was supplied for the second time to the animals only after the last collection. Approximately 200 mL of rumen content were collected from several points in the rumen and then filtered through gaze to separate the solid from the liquid phase. After the aliquots of the liquid phase were obtained, both parts were returned to the rumen.

To measure the rumen pH, an aliquot of rumen fluid was deposited in a 100 mL beaker and readings were taken with a digital bench pH meter. Short-chain fatty acids (SCFA) were determined as proposed by Erwin,

Marco and Emery (1961). To quantify the ammoniacal nitrogen (N-NH₃) content, we adopted by method described by Kulasek (1972) and adapted by Foldager (1977), cited by Borgatti *et al.* (2012).

The *in situ* degradability of the experimental diets and roughages was determined by the technique described by Mehrez and Ørskov (1977), using Ankon[®] nylon bags (10 × 20 cm) with 50 µm porosity, with an incubation area of 10 × 10 cm. Approximately four grams of each sample were placed in each nylon bag, following the technique mentioned by Vanzant, Cochran and Titgemeyer (1998). The bags were closed and packed together with spherical weights (serving as ballast) inside a 2-mm-mesh bag tied to a nylon string that was then deposited at the bottom of the animal rumen.

The following incubation times were established: 0, 1.5, 3, 6, 12, 24, and 48 h for the concentrate and 0, 6, 12, 24, 48, 72, and 96 h for the roughages. Upon being removed from the rumen, the nylon bags were placed in a bucket with cold water to prevent any subsequent fermentation. They were then washed with mild agitation in a tank with a stirring propeller, renewing the water until it was colorless, and then dried in a forced-air oven

at 55 °C for 72 h, chilled in a desiccator, and weighed. Degradability at zero time was measured by placing the nylon bags in a water bath at 39 °C before the rest of the bags were washed. Chemical analyses of DM, crude protein (CP), and neutral detergent fiber (NDF) were performed to evaluate the degradability of the nutrients in the feedstuffs.

The following model, proposed by Ørskov and McDonald (1979), was used to estimate the nutrient digestibility parameters at the different times:

$$p = A + B(1 - e^{-ct}),$$

in which “p” is the degradation obtained at each time; “A” is the soluble fraction; “B” is the potentially degradable fraction of the insoluble fraction that would be degraded at a rate “C”; “C” is the degradation rate of fraction “B”; and “t” is the incubation time, in hours. The parameters were estimated using the PROC NLIN procedure of SAS software (Statistical Analysis System, version 9.0), by the Gauss-Newton method. The “A” and “B” parameters of the exponential equation were used to calculate the potential degradability (PD = A + B), which is represented by the amount of feed that can be solubilized or degraded inside the rumen if time is not a limiting factor. Effective degradability (ED), which represents the amount of feed actually degraded in the rumen, is defined by the time during which the feed is actually in the rumen. It was calculated according to the following mathematical model, proposed by Ørskov and McDonald (1979):

$$ED = A + [(B * C)/(C + k)],$$

in which “k” is the rate of passage of solids through the rumen. In the present study, we adopted the DM passage rates of 0.02 and 0.05 per hour.

The pH, N-NH₃ production, and SCFA were evaluated in a split-plot latin square design in which the diets were assigned to the plots and the collection times to the sub-plots (Model I). The covariance structure used was the first-order autoregressive type (AR (1)), evaluated by the AIC and BIC criteria of the PROC MIXED procedure of SAS software (Statistical Analysis System, version 9.0).

$$\text{Model I: } Y_{ijklm} = u + S_i + P_j + C_{k(i)} + T_l + P * C_{jk(i)} + H_m + T * H_{lm} + e_{ijklm},$$

in which Y_{ijklm} = trait observed at hour m, in diet l, in goat k, in period j, in square i; u = mean of the trait; S_i = effect of square i (i = 1 or 2); P_j = effect of period j (j = 1, 2, 3, or 4); $C_{k(i)}$ = effect of goat k within square i (k = 1, 2, 3, or 4); T_l = effect of diet l (l = 1, 2, 3, or 4); $P * C_{jk(i)}$ = error (a); H_m = effect of collection time m (m = 1, 2, 3, 4, 5, 6, or 7); $T * H_{lm}$ = effect of the interaction between diet l

and collection time m; and e_{ijklm} = random error referring to observation Y_{ijklm} .

Model II was employed in the analysis of feed intake, body weight, and degradability of DM, CP, and NDF.

$$\text{Model II: } Y_{ijkl} = u + S_i + P_{j(i)} + C_{k(i)} + T_l + T * S_{li} + e_{ijkl},$$

in which Y_{ijkl} = trait observed in goat k in period j receiving diet l, in square i; u = mean of the trait; S_i = effect of square i (i = 1 or 2); $P_{j(i)}$ = effect of period j within square i (j = 1, 2, 3, or 4); $C_{k(i)}$ = effect of goat within square i (1, 2, 3, or 4); T_l = effect of diet l (l = 1, 2, 3, or 4); $T * S_{li}$ = effect of the interaction between diet l and square i; e_{ijkl} = random effect referring to observation Y_{ijkl} .

Data were subjected to analysis of variance. The diet effects were compared by Tukey’s test. The effect of collection time was studied by polynomial regression, applying the “Sequential Regression” procedure, which evaluates the effect of each independent variable added to the analysis model. The chosen model was that which presented significance in the regression analysis of variance (F test) and in the model coefficients (T test). For all analyses and tests, a significance level of $\alpha = 0.05$ was adopted. Data were processed in SAS software (Statistical Analysis System, version 9.0).

RESULTS AND DISCUSSION

No influence of the treatments was observed on total dry matter (DM) intake, in any of the three units it was expressed (kg, % LW, and g DM/kg^{0.75}). In this way, the goats consumed similar quantities of crude protein (CP), neutral detergent fiber (NDF), and total digestible nutrients (TDN) (Table 2). The nutrient intakes were sufficient to meet the nutritional requirements determined by the National Research Council (2007). Accordingly, no differences were found in daily weight gain.

The average total DM intake of the goats was 34% lower than that recommended by the National Research Council (2007) for dairy animals in a maintenance regime. On the other hand, the ingested DM allowed for a 68% higher CP intake and a similar TDN intake to that established by the National Research Council (2007). This shows that DM intake was controlled by physiological factors, as the goats consumed DM until their energy or nutritional requirements were met (FERREIRA *et al.*, 2013).

The animals fed the COAL and CAAL diets compensated their lower DM intake from Tobiatã grass and from Tobiatã grass + concentrate, respectively, by consuming alfalfa. The lower DM intake from the

Table 2 - Mean values for the daily intakes of dry matter (DMI), crude protein (CPI), neutral detergent fiber (NDFI), and total digestible nutrients (TDNI) of concentrates and roughages and average daily gain (ADG) according to the diet

Variable	Diet				Average	CV (%)
	COSO	CASO	COAL	CAAL		
	Total					
DMI (kg)	0.98	0.88	0.97	0.99	0.95	10.09
DMI (% LW)	1.50	1.37	1.49	1.48	1.46	16.37
DMI (g DM/kgLW 0.75)	42.69	38.75	42.38	42.30	41.53	20.94
CPI (kg)	0.17	0.14	0.17	0.17	0.16	9.73
NDFI (kg)	0.42	0.44	0.50	0.49	0.46	12.82
TDNI (kg)	0.76	0.64	0.76	0.64	0.70	11.60
	Concentrate					
DMI (kg)	0.55a	0.42b	0.46a	0.30b	0.43	19.54
CPI (kg)	0.11a	0.08b	0.08b	0.03c	0.08	10.77
NDFI (kg)	0.05	0.06	0.06	0.03	0.05	37.04
TDNI (kg)	0.47a	0.35b	0.39ab	0.24c	0.36	18.61
	Alfalfa					
DMI (kg)	-	-	0.14	0.37	0.26	15.04
CPI (kg)	-	-	0.05	0.11	0.08	10.51
NDFI (kg)	-	-	0.08	0.19	0.14	16.33
TDNI (kg)	-	-	0.10	0.19	0.15	14.21
	Tobiatã grass					
DMI (kg)	0.43 a	0.46 a	0.37 b	0.32 b	0.40	15.82
CPI (kg)	0.06	0.06	0.04	0.03	0.05	12.88
NDFI (kg)	0.37 a	0.38 a	0.36 a	0.27 b	0.35	16.21
TDNI (kg)	0.29 a	0.29 a	0.27 a	0.21 b	0.27	14.23
R:C	44:56	52:48	53:47	70:30		
DWG (g day ⁻¹)	85	-68	14	-32	0.0002	26.97

Means followed by different lowercase letters (a, b) in the rows differ from each other (P<0.05) by Tukey's test; COSO: corn + soybean; CASO: cassava + soybean; COAL: corn + alfalfa; CAAL: cassava + alfalfa; R:C - roughage-to-concentrate ratio; DWG - daily weight gain

concentrate in the CAAL diet compared with COAL led to lower intakes of CP and TDN from the concentrate. The deficit of those nutrients was compensated by the higher DM intake from alfalfa and consequently higher intakes of CP, NDF, and TDN from this ingredient. Because of the higher NDF intake from alfalfa in the CAAL diet, the animals that received this treatment had lower intakes of NDF and TDN from Tobiatã grass, which shows that they maintained a similar NDF intake.

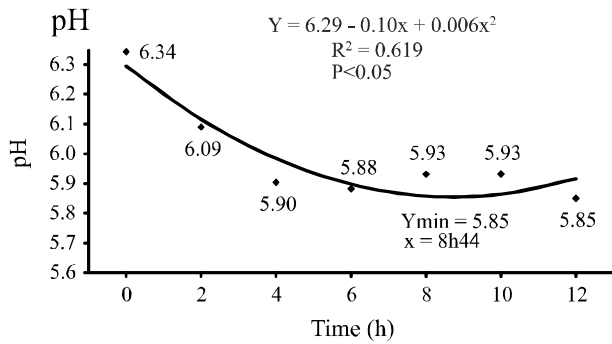
A lower DM intake from the concentrate was observed in the goats fed the diets containing cassava in comparison with those consuming the diets including corn. This response is attributed to the lower palatability and to the dustiness of cassava, which

cause an unpleasant sensation during consumption (MEDINA *et al.*, 2009).

Before the morning feed (07 h 00), the rumen pH was elevated (6.29) (Figure 1), explained by the increased rumination during nighttime, which led to greater saliva production and consequently increased rumen buffering, thereby elevating the pH. After the feed was supplied, it started to decline, reaching a minimum of 5.85 at 08 h 44, because of the fermentation activity of the rumen microorganisms and short-chain fatty acid (SCFA) production.

Acetic and butyric acid concentrations (Figure 2) increased when the rumen pH was above 5.99 and 6.00, respectively (Figure 1), indicating that the fiber degradation

Figure 1 -Effects of collection time after feed supply on rumen pH



potential is modulated by the pH value, whose optimum point is between 6.0 and 7.0 (OLIVEIRA; SANTANA NETO; VALENÇA, 2013).

After the morning feed, total SCFA production (Figure 3) responded in the opposite direction of rumen pH, increasing and reaching a maximum estimated value of 95.58 mM 100 mM⁻¹ at 03 h 59. Acetic and butyric acid (Figure 2) had their peaks estimated at 03 h 53 and 03 h 44, respectively. Acetic acid production declined, which

is a result of decreased cellulolytic activity at pH levels below 6.0 and consequent depression of fiber degradation (OLIVEIRA; SANTANA NETO; VALENÇA, 2013). A rumen pH decline favors the growth of non-fibrous carbohydrate-fermenting microorganisms and reduces the action of fibrous-carbohydrate fermenters, reducing the acetic-to-propionic acid ratio (SOUZA; GUIM; TORRES, 2010). The peak productions of total SCFA, acetic acid, and butyric acid occurred at the pH values of 5.98, 5.99, and 6.00, respectively. The increased total SCFA production after the meal was prompted by the production of acetic and butyric acids, which responded similarly.

The ammoniacal nitrogen concentration was not influenced by diets or collection times (Table 3), averaging 17.18 mgdL⁻¹, value that indicates a synchronism between the amounts of nitrogen and energy available in the rumen (ALVES *et al.*, 2010).

The COSO diet showed the lowest roughage-to-concentrate ratio (44:56) (Table 2) and led to a lower acetic acid production than the CAAL diet (Table 3), which had the highest roughage-to-concentrate ratio (70:30) (Table 2). Diets with higher proportions of concentrate favor the development of non-fibrous carbohydrate-fermenting bacteria, which are resistant to acidity, whereas the

Figure 2 - Concentrations of short-chain fatty acids (SCFA), acetic acid, butyric acid, and propionic acid and acetic-to-propionic acid ratio as a function of collection time

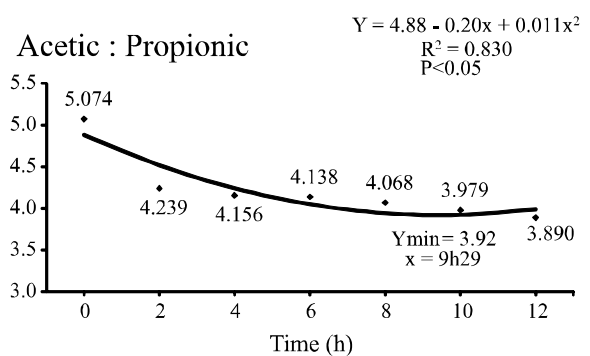
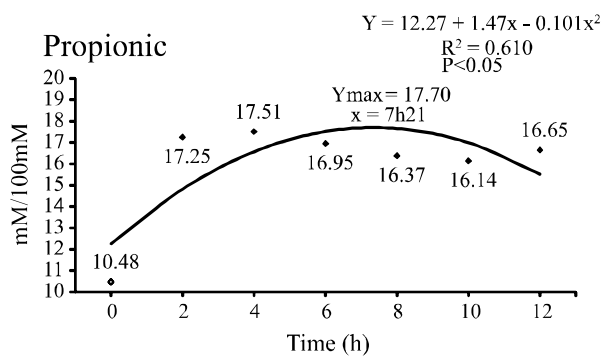
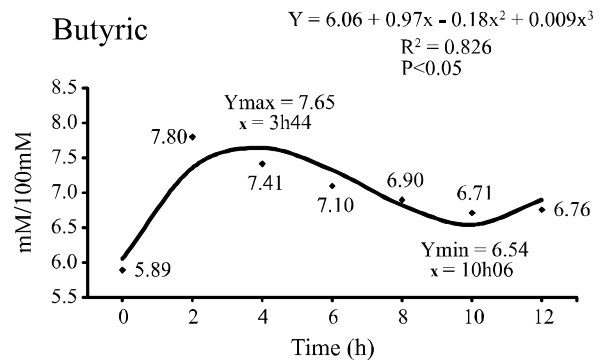
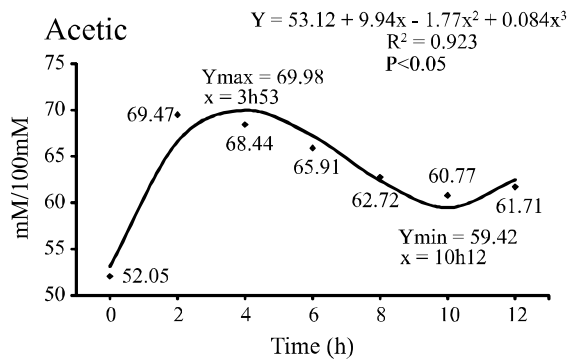
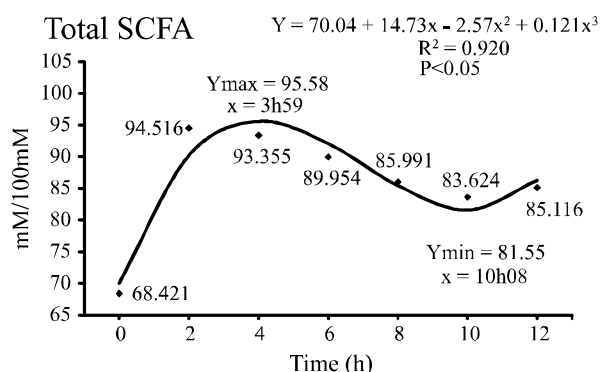


Figure 3 -Total short-chain fatty acid (SCFA) concentration as a function of collection time



population of fibrous carbohydrate-fermenting bacteria decreases, reducing acetic acid production (SILVA; NEUMANN, 2012). Moreover, as the time to ruminate the fiber from forages is extended, saliva production is increased, causing a buffering effect. This buffering effect generates a rumen environment suitable to the development of cellulolytic bacteria, maximizing acetic acid production (OLIVEIRA *et al.*, 2016).

The highest acetic acid production seen in the CAAL diet (Table 3) can also be explained by the greater synchronism between the energy from the cassava starch, which is immediately fermented because of its high amylopectin content (SANTOS *et al.*, 2016), and the protein from alfalfa, which is rapidly degraded in the rumen (JOBIM *et al.*, 2011). Coupled with the high-quality fiber of alfalfa, it resulted in a rumen environment favorable to high acetic acid production. Because of its greater contribution, acetic acid is responsible for the larger total SCFA production observed in that treatment group.

In the diets containing soybean as a protein component, the presence of cassava increased fraction A and the effective degradability (ED) of DM, CP, and NDF at 0.02 and 0.05 h⁻¹. In the diets in which alfalfa was the

protein component, cassava also elevated the degradation rate (Table 4).

Compared with corn, the starch from cassava is more rapidly degraded in the rumen, which explains the highest ED and degradation rate of the diets with cassava. This difference is related to the structure of the starch granules in cassava, which have a high amylopectin content, and the lack of an association thereof with the protein matrix (SANTOS *et al.*, 2016), which increases the speed of rumen degradation (LARSON; HOFFMAN, 2008).

The lower degradability of fraction A of the DM from the COSO and COAL diets may be related to the structural characteristic of corn, which has a large amount of protein associated with the cell wall (MARCONDES *et al.*, 2009), complicating its degradation, in relation to the diets that do not contain CASO and CAAL. In comparing COSO and CASO, we can infer that the protein and NDF of soybean are more degradable than that of corn (MARCONDES *et al.*, 2009), since the corn protein is not present in CASO, and, in COSO, most of the protein derives from corn.

When cassava was used as an energy component, the presence of alfalfa reduced fraction A and increased the degradation rates of DM, CP, and NDF. In the diets in which corn was the energy component, in turn, alfalfa increased both fraction A and the degradation rate (Table 4). The differences between the diets with alfalfa indicate that, irrespective of the energy base used, alfalfa elevates the degradation rate of the diet, and, when corn is the energy base, alfalfa also increases fraction A. However, when cassava is the energy base of the diet, this fraction is reduced.

In the treatments with cassava, the presence of alfalfa led to a lower fraction A values and higher degradation rates of DM, CP, and NDF in the CAAL diet than in the CASO diet. The higher fraction A of CASO compared with that of CAAL may be attributed to the higher degradability of the soluble fraction of soybean meal (MARCONDES *et al.*, 2009) (57.13%) compared

Table 3 - Ammoniacal nitrogen (N-NH₃) production and concentrations of acetic acid and total short-chain fatty acids (total SCFA) according to the diet

Variable	Diet				Average	CV (%)
	COSO	CASO	COAL	CAAL		
N-NH ₃ (mg dL ⁻¹)	17.06	15.49	19.37	16.81	17.18	6.48
Acetic acid (mM 100mM ⁻¹)	55.40 b	63.62 ab	65.00 ab	68.03 a	63.01	13.45
Total SCFA (mM 100mM ⁻¹)	76.03 b	84.75 ab	88.99 ab	93.64 a	85.85	13.89

Means followed by different lowercase letters (a, b) in the rows differ from each other (P<0.05) by Tukey's test; COSO: corn + soybean; CASO: cassava + soybean; COAL: corn + alfalfa; CAAL: cassava + alfalfa; CV - coefficient of variation

Table 4 - Degradability of the soluble fraction (A), potentially degradable fraction (B), degradation rate of fraction B (C), and effective degradability (ED) for the passage rates of 0.02 and 0.05 per hour and potential degradability (PD) of the diets in goats

Variable	Diet				Average	CV (%)
	COSO	CASO	COAL	CAAL		
Dry matter						
A	20.36 d	38.33 a	23.71 c	35.56 b	29.49	3.97
B	43.22 a	23.79 b	40.53 a	26.10 b	33.41	5.90
C (% h ⁻¹)	0.10 c	0.10 c	0.13 b	0.16 a	0.13	32.08
ED (0.02 h ⁻¹)	56.38 b	57.57 a	56.85 b	57.25 a	57.01	2.56
ED (0.05 h ⁻¹)	49.18 b	53.49 a	50.00 b	53.26 a	51.48	3.21
PD	63.58	62.11	64.25	61.66	62.90	2.69
Crude protein						
A	22.41 d	38.85 a	25.56 c	36.62 b	30.86	4.43
B	44.34 a	28.11 b	40.94 a	30.52 b	35.98	14.62
C (% h ⁻¹)	0.18 c	0.19 c	0.22 b	0.24 a	0.21	22.58
ED (0.02 h ⁻¹)	62.04 b	64.18 a	62.40 b	64.55 a	63.29	6.27
ED (0.05 h ⁻¹)	56.62 b	60.94 a	57.65 b	61.44 a	59.16	5.83
PD	66.75	66.95	66.50	67.13	66.83	4.68
Neutral detergent fiber						
A	31.59 d	42.66 a	33.07 c	41.39 b	37.18	4.29
B	26.67 a	14.69 b	22.03 a	16.53 b	19.98	16.72
C (% h ⁻¹)	0.07 c	0.09 c	0.12 b	0.14 a	0.11	25.46
ED (0.02 h ⁻¹)	51.36 b	53.84 a	52.18 b	53.06 a	52.61	2.53
ED (0.05 h ⁻¹)	46.05 b	51.29 a	48.81 b	50.55 a	49.18	3.00
PD	58.25	57.35	55.37	57.91	57.22	3.77

Means followed by different lowercase letters (a,b) in the rows differ from each other ($P < 0.05$) by Tukey's test; COSO: corn + soybean; CASO: cassava + soybean; COAL: corn + alfalfa; CAAL: cassava + alfalfa; CV - coefficient of variation

with the 32.76% of alfalfa. The higher degradation rate in the CAAL diet compared with CASO may be explained by the elevated degradation rate of 0.31% of alfalfa in comparison with the 0.08% of soybean meal (MARCONDES *et al.*, 2009).

In the corn-containing diets, the increase in fraction A and the degradation rate of the COAL diet in comparison with COSO were due to the participation of alfalfa in the former, which has higher values than tobiatã grass (16.03% fraction A and 0.05% degradation rate).

Although CASO presented high levels of readily available fraction (A), it also showed a low value for the degradation rate of fraction B for DM (0.10% h⁻¹) (Table 4), differing from CAAL treatment (0.16% h⁻¹). The lower degradation rate of the CASO diet in comparison with that of CAAL is likely a result of the higher percentage of tobiatã grass in CASO, which had a lower effective degradability. This shows that even though a feedstuff

may have a higher percentage of disappearance at the beginning of fermentation, the rate of disappearance during the total incubation period may not be higher (JOBIM *et al.*, 2011).

The CAAL diet showed the highest degradation rates of fraction B for DM, CP, and NDF. The higher degradation rate of the CAAL diet was probably due to the greater concentration of alfalfa in it. This legume is highly degradable because it contains protein fractions that are rapidly degraded in the rumen and because of the faster digestion rate of the potentially digestible fraction of NDF (JOBIM *et al.*, 2011).

The CASO and CAAL diets showed the highest ED rates at 0.02 and 0.05% h⁻¹ for DM, CP, and NDF (Table 4), indicates greater possibilities of degradation, which are likely due to the chemical and physical characteristics of the cassava starch. According to Santos *et al.* (2016),

ED is influenced by factors such as the proportion of starch components (amylose and amylopectin), structure (presence or lack of pericarp and endosperm), and feed processing type (milling, grinding, flocculation).

Although the diets influenced the ED values, potential degradability (PD) was similar across the treatments (Table 4), suggesting that when time was not a limiting factor, the inclusion of cassava and/or alfalfa did not affect the efficiency of degradation.

CONCLUSIONS

In a grazing system, cassava chips and alfalfa can substitute the corn and soybean meal in the concentrate fed to adult goats for maintenance without changing their feed intake or body weight. Rather, their use improves rumen parameters in these animals.

ACKNOWLEDGEMENTS

The authors wish to thank the Foundation for Research Support of the State of São Paulo for the concession of the scholarship (Process: 2012/19261-6).

REFERENCES

- ALVES, E. M. *et al.* Importância da sincronização do complexo proteína/energia na alimentação de ruminantes. **PUBVET - Publicações em Medicina Veterinária e Zootecnia**, v. 4, n. 20, p. 1-15, 2010.
- ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS INTERNATIONAL. **Official Method of Analysis of AOAC International**. 18 th ed. Gaithersburg: AOAC International, 2007.
- BORGATTI, L. M. O. *et al.* Evaluation of relative biological efficiency of additives in sugarcane ensiling. **Revista Brasileira de Zootecnia**, v. 41, n. 4, p. 835-845, 2012.
- CUNHA, A. R.; MARTINS, D. Classificação climática para os municípios de Botucatu e São Manuel, SP. **Irriga**, v. 14, n. 1, p. 1-11, 2009.
- ERWIN, E. S.; MARCO, G. J.; EMERY, E. M. Volatile fatty acids analyses of blood and rumen fluid by gas chromatography. **Journal Dairy Science**, v. 44, n. 9, p. 1768-1771, 1961.
- FERREIRA, S. F. *et al.* Fatores que afetam o consumo alimentar de bovinos. **Arquivos de Pesquisa Animal**, v. 2, n. 1, p. 9-19, 2013.
- JOBIM, C. C. *et al.* Cinética de degradação ruminal dos fenos de alfafa e Tifton-85 e da silagem de milho. **Semina: Ciências Agrárias**, v. 32, n. 2, p. 747-758, 2011.
- LARSON, J.; HOFFMAN, P. C. Technical note: a method to quantify prolamin proteins in corn that are negatively related to starch digestibility in ruminants. **Journal Dairy Science**, v. 91, n. 12, p. 4834-4839, 2008.
- MARCONDES, M. I. *et al.* Degradação ruminal e digestibilidade intestinal da proteína bruta de alimentos para bovinos. **Revista Brasileira de Zootecnia**, v. 38, n. 11, p. 2247-2257, 2009.
- MEDINA, F. T. *et al.* Silagem de maniçoba associada a fontes energéticas na alimentação de caprinos: consumo e digestibilidade. **Acta Scientiarum Animal Sciences**, v. 31, n. 3, p. 265-269, 2009.
- MEHREZ, A. Z.; ØRSKOV, E. R. A study of the artificial fiber bag technique for determining the digestibility of feeds in the rumen. **Journal of Agriculture Science**, v. 88, n. 3, p. 645-665, 1977.
- NATIONAL RESEARCH COUNCIL. **Nutrient requirements of dairy cattle**. 6.ed. Washington: National Academic Press, 2001. 387 p.
- NATIONAL RESEARCH COUNCIL. **Nutrient requirements of small ruminants**. Washington, D. C.: The National Academy Press, 2007. 362 p.
- OLIVEIRA, R. L. *et al.* Alimentos alternativos na dieta de ruminantes. **Revista Científica de Produção Animal**, v.15, n.2, p.141-160, 2013.
- OLIVEIRA, V. S. *et al.* Carboidratos fibrosos e não fibrosos na dieta de ruminantes e seus efeitos sobre a microbiota ruminal. **Veterinária Notícias**, v. 22, n. 2, p. 1-18, 2016.
- OLIVEIRA, V. S.; SANTANA NETO, J. A.; VALENÇA, R. L. Características químicas e fisiológicas da fermentação ruminal de bovinos em pastejo: revisão de literatura. **Revista Científica Eletrônica de Medicina Veterinária**, v. 11, n. 20, p. 1-21, 2013.
- ØRSKOV, E. R.; MCDONALD, I. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. **Journal of Agricultural Science**, v. 92, n. 1, p. 499-508, 1979.
- SANTOS, S. A. *et al.* Degradação ruminal da proteína dos alimentos e síntese de proteína microbiana. In: VALADARES FILHO, S. C. *et al.* (org.). **Exigências nutricionais de zebuínos puros e cruzados**: BR-Corte. 3. ed. Viçosa, MG: UFV, 2016. p. 45-88.
- SILVA, M. R. H.; NEUMANN, M. Fibra efetiva e fibra fisicamente efetiva: conceitos e importância na nutrição de ruminantes. **FAZU em Revista**, v. 9, n. 1, p. 69-84, 2012.
- SOUZA, E. J. O.; GUIM, A.; TORRES, T. R. Efeitos da fibra fisicamente efetiva sobre a produção de ácidos no rúmen. **Revista Eletrônica Nutritime**, v. 7, n. 3, p. 1269-1279, 2010.
- VANZANT, E. S.; COCHRAN, R. C.; TITGEMEYER, E. C. Standardization of in situ techniques for ruminant feedstuff evaluation. **Journal of Animal Science**, v. 76, n. 10, p. 2717-2729, 1998.



This is an open-access article distributed under the terms of the Creative Commons Attribution License