Scientific Electronic Archives
Issue ID: Sci. Elec. Arch. Vol. 14 (1)
January 2021
DOI: http://dx.doi.org/10.36560/14120211283
Article link
http://sea.ufr.edu.br/index.php?journal=SEA&page=article&op=view&path%5B%5D=1283&path%5B%5D=pdf
Included in DOAJ, AGRIS, Latindex, Journal TOCs, CORE, Discoursio Open Science, Science Gate, GFAR, CIARDRING, Academic Journals Database and NTHRYS Technologies, Portal de Periódicos CAPES, CrossRef, ICI Journals Master List.

ISSN 2316-9281

Intake and rumen parameters in goats fed avocado (Persea americana Mill.) pulp and oil

F. J. P. López[1]; M. F. Martins[2], R. O. Marques[3]; R. V. Lourençon[4], E. P. Brito[3], H. F. B. Gomes[5]*, P. R. Lima Meirelles[3], H. C. Gonçalves[3]

[1] Instituto Nacional de Pesquisas Florestais, Agrícolas e Pecuárias do México
[2] Universidade de São Paulo, Campus de Pirassununga
[3] Universidade Estadual Paulista, Campus de Botucatu
[4] University Langston, Oklahoma
[5] Universidade Federal de Rondonópolis

*** Author for correspondence: gomeshfb@gmailcom**

Abstract. The objective of this study was to examine the effect of supplementing goat diets with avocado pulp and oil, with respective ether extract (EE) contents of 14 and 6% (dry matter [DM] basis), on the intakes of DM and nutrients and on the rumen fermentation parameters of pH, ammonia (N-NH3), and volatile fatty acids (VFA). Non-pregnant, non-lactating, rumen-cannulated Saanen goats with an average weight of 66.6±4.6 kg were distributed into two 3 × 3 Latin squares. Concentrate DM intake (g/day) was higher in the animals that consumed the diet with pulp than in the goats fed the control and oil treatments. However, this higher concentrate intake was not sufficient to influence total diet DM intake or the intakes of crude protein, EE, mineral matter, neutral detergent fiber, acid detergent fiber, and total digestible nutrients (TDN). All evaluated rumen parameters were influenced by collection time, except N-NH3, which was influenced by the diets, with lower concentrations obtained with the pulp diet in relation to the control and oil treatments, yet within the limits considered normal to maximize DM intake and digestion. The pulp diet provided a lower butyric acid content than control at the collection times of two and eight hours after the meal, which was attributed to the proportional reduction of roughage in relation to concentrate. Diets with 6% EE do not influence intake or rumen parameters in non-pregnant, non-lactating goats. However, diets with 14% EE (DM basis) induce a reduction in the proportional intake of roughage in relation to concentrate and in the butyric acid and N-NH3 contents in the goat rumen.
Keywords: acetic acid, butyric acid, lipids, propionic acid, volatile fatty acids

Introduction

In Brazil, the diversity of available non-conventional feedstuffs with high lipid content as well as their by-products has aroused the interest of producers and researchers in using them in animal diets. This dietary addition would constitute a way to improve the nutraceutical quality of the generated products, especially the milk of small ruminants such as goats (Silva et al., 2012).

In this scenario, one of the prominent foods under research is avocado (*Persea americana* Mill.), a fruit whose composition includes high lipid contents with high levels of monounsaturated fats—oleic acid, mainly (Massafera et al., 2010; Ariza et al., 2011).

According to Vargas et al. (2002), Lana et al. (2007), and Costa et al. (2009), the inclusion of unsaturated lipids in the diet increases its energy concentration, besides providing other desirable effects such as inhibiting methane production; reducing rumen N-NH3, due the decrease in the population of protozoa and deaminating bacteria (Lana et al., 2007); as well as increasing the efficiency of microbial synthesis. On the other hand, when used in excessive amounts (above 7%), undesirable effects can occur, e.g., decreased digestibility of dry matter (DM), organic matter (OM), and cellulose and reduced acetate:propionate (A:P) ratio.

With respect to volatile fatty acids (VFA), dietary addition of unsaturated lipids stimulates propionate-producing rumen bacteria. As a consequence, there is a reduction in A:P ratio as well as in the supply of acetic acid, a direct precursor of 50% of milk fat (Santos et al., 2001; Lana et al., 2007).

Although it can be done with relative ease and at a low cost on small farms, there are no literature reports on the use of a feedstuff considered a natural source of vegetable oil, such as avocado, in ruminant feeding. Likewise, no studies have examined these natural sources at higher concentrations in the diet with a view to improving the fatty acid profile of the produced milk.

Therefore, the present study was developed to evaluate the impact of supplementing avocado in its natural form and avocado commercial oil in the diet of Saanen goats on intake and rumen pH, VFA composition and production, and ammonia concentration.

Methods

Animal research was carried out in accordance with the institutional animal use committee, approval no.: 31/2012-CEUA.

The experiment was carried out in the municipality of Botucatu - SP, Brazil, (22o53'09 "S, 48o26'42" W, 840 m asl).

Non-pregnant, non-lactating, rumen-cannulated Saanen goats with an average weight of 66.6±4.6 kg were used. Before the experiment, the animals were treated with anthelmintic. The goats were housed individually in 3.5-m2 stalls in a covered shed with slatted wooden floors. Stalls were equipped with individual drinkers, salt troughs, and feed troughs.

The experiment was laid out in a Latin square design with two balanced 3 × 3 squares. Treatments consisted of three diets and 14-day experimental periods, corresponding to nine days for adaptation and adjustment of voluntary consumption of the diets and five days of data collection.

Diets were adjusted to meet the requirements of goats with a live weight of 60 kg according to the NRC (2007). For all diets, 2 kg/day of *Panicum maximum* cv. Tobiatã was provided as roughage. The experimental diets differed in the concentrate composition (Table 1) in terms of the source used and its lipid content, as follows: control - 2% ether extract (EE); avocado pulp - 14% EE; and avocado oil - 6% EE (DM basis).

The avocado pulp used was obtained from the Geada variety, and the avocado oil was extracted from the commercial brand Hass.

The experimental diets were supplied twice daily (at 08.00 h and 16.00 h). The pulp and the oil were mixed with the rest of the concentrate according to the treatments immediately before their supply to the animals. Feed was offered in the amount of 500 g/day (DM basis). To ensure the intake of EE from the pulp treatment, half of the amount offered in the morning and in the afternoon was placed directly in the goat rumen.

Prior to its use, the avocado was stored at room temperature until it ripened, which was evidenced by softening of the pulp by palpation. Upon reaching that point, the avocado was washed with soap and water and its pulp was removed, packed in plastic bags in the amount of 0.5 kg and frozen, following the methodology of Simon (2008). The amount required for supplementation was removed from the freezer the day before, for thawing.

At the beginning of each experimental period, an adaptation was made to the new concentrate feed, with 70% of the old diet being supplied on the first and second days; 30% of the old diet on the third and fourth days; and 100% of the new diet from the fifth day.

The forage was harvested by the grazing-simulation method (hand-plucking collection, after previous observation of the grazing habit of the animals), in accordance with Sollenberger and Cherney (1995). This was performed within the grazing area of the goat pen, which had 11 paddocks of 500 m2 and was covered with *Panicum maximum* cv. Tobiatã. Samples of 300 g of grass were collected in the last five days of each period and mixed to form a composite sample.

The grass was supplied in troughs separately from the concentrate. In the last five days of each period, before the meals, orts were weighed to determine intake.

All samples of grass, concentrate, and orts were frozen in a freezer until analysis in the laboratory, where the DM, crude protein (CP), crude fiber (CF), mineral matter (MM), and EE contents were determined according to the method proposed by AOAC International (Cuniff, 1995). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined following the methodology of Van Soest et al. (1991), and the total digestible nutrient (TDN) content was calculated using the equation developed by Kearl (1982):

$$TDN = 40.2625 + 0.1969\ \%CP + 0.4228\ \%NFE + 1.1903\ \%EE - 0.1379\ \%CF,$$

in which CP: crude protein; NFE: nitrogen-free extract; EE: ether extract; and CF: crude fiber. The NFE was determined using the formula of Budiño and Castro Junior (2009), as shown below:

$$NFE\ (\%) = 100 - (\%CP + \%EE + \%CF + \%MM).$$

The fatty acids in the feed supplied to the goats were determined by gas chromatography. Initially, lipids were extracted from the (ground) feedstuffs using an hexane:isopropanol (3:2) organic solvent mixture, in accordance with the methodology described by Hara and Radim (1978), and the lipid fraction was esterified with a basic sodium methoxide solution, following Christie (1982). Once the sample was esterified, it was injected into the chromatograph and fatty acids were identified using Chromquest 4.1 software (Thermo Electron, Italy), with the fatty acid results expressed as a percentage of area (Table 3).

To evaluate the rumen parameters, samples of rumen fluid were collected manually at 0, 2, 4, 6, and 8 h on the last day of each period, starting at 08.00 h before half of the experimental diets were supplied and ending at 16.00 h. An aliquot 200 mL of rumen content was collected and filtered through four layers of gauze to separate the liquid from the solid part.

After the aliquots of the liquid part were collected, the rest was returned to the rumen.

For the measurement of rumen pH, an aliquot of rumen fluid was placed in a 100-mL beaker and individual readings were taken at different times using a digital bench pH meter (previously calibrated in buffer solutions with pH 4.0 and 7.0). To determine the VFA, rumen fluid aliquots were placed in 15-mL tubes and centrifuged at 3000 rpm for 15 min. Two milliliters of the supernatant were transferred to 5-mL vacutainer test tubes containing 0.4 mL of formic acid A.R. and stored in a freezer until laboratory analysis.

To evaluate ammoniacal nitrogen (N-NH3) production, the same procedure was adopted, but using 1 mL of 1N sulfuric acid for preservation. These samples were also stored in the freezer until laboratory analysis. The N-NH3 was determined following the technique of Fenner (1965), whereby 2 mL of rumen fluid are distilled in five mL of 2N KOH; this distillate is then collected in 10 mL of boric acid and titrated with 0.005N HCl.

Volatile fatty acids were analyzed on a chromatograph (Shimadzu, GC-2014) with an automatic injector (AOC - 20i), equipped with a 30-m long glass column; 0.32-mm ID; 0.50-µm film (HP INNOwax - 19091N); and flame ionization detector, kept at 250 °C. The column temperature during analysis was 80 °C/3 min until reaching 240 °C (20 °C/min), and the injector temperature was 200 °C. Nitrogen was used as the carrier gas at a flow rate of 3.18 mL/min.

Data were subjected to analysis of variance using SAEG software (Sistema de Análises Estatísticas e Genéticas, version 9.0). Model I was used for the analysis of feed and nutrient intakes and Model II was applied for rumen parameters, which includes the collection time as a split-plot. To study the influence of collection times on rumen parameters, polynomial models of up to third order were tested, and that which showed regression analysis of variance (F-test) and all coefficients significant (T test) was adopted. The contrasts of means for diet were performed by Tukey's test, with a significance level of 5% for both procedures.

Model I:

$$Y_{ijkl} = u + Q_i + p_{j(i)} + c_{k(i)} + T_l + T * Q_{li} + e_{ijkl},$$

in which Y_ijkl = trait observed in goat k in period j, treatment l, and square i; u = mean of trait; Q_i = effect of square i (i = 1 and 2); p_(j(i)) = effect of period j within square i (j = 1, 2, and 3); c_(k(i)) = effect of goat k, within square i (k = 1, 2, and 3); T_l = effect of treatment l (l = 1, 2, and 3); 〖T*Q〗_li = interaction effect between treatment l and square i; and e_ijkl = random error referring to observation Y_ijkl.

Model II:

$$Y_{ijklm} = u + Q_i + p_j + c_{k(i)} + T_l + p * c_{jk(i)} + H_m + T * H_{lm} + e_{ijklm},$$

in which Y_ijklm= trait observed at time m, in treatment l, goat k, period j, belonging to square i; u = mean of the trait; Q_i = effect of square i (i = 1 and 2); p_j = effect of period j (j = 1, 2, and 3); c_(k(i)) = effect of goat k within square i, (k = 1, 2, and 3); T_l = effect of treatment l (l = 1, 2, and 3); 〖p*c〗_(jk(i)) = error (a); H_m = effect of collection time m, (m = 0, 2, 4, 6, and 8); and e_ijklm = error (b).

Results and discussion

The diets did not influence (P>0.05) the intakes of DM or nutrients (CP, MM, TDN, NDF, and ADF) from the total diet, roughage intake (g/day), or the roughage:concentrate ratio. However, the intakes of dietary EE and concentrate DM (g/day) differed (P<0.05). The pulp diet provided the highest EE intake, followed by the oil diet and, lastly, control diet. Additionally, the pulp diet also provided a higher concentrate intake in relation to the oil and control diets, which showed no difference for this parameter (P>0.05) (Table 4).

Among the evaluated ruminal parameters (Table 5), there was a diet × collection time interaction effect (P<0.05) for butyric acid concentration. The pulp diet had a lower concentration of butyric acid than control at the collection times of 2 and 8 h. At the other times, this variable did not differ (P>0.05) between the treatment groups (Table 6) (Figure 4).

However, collection times affected (P<0.05) most traits (pH, total fatty acids, acetic acid, propionic acid, and acetic:propionic acid ratio), whereas the diets influenced (P<0.05) only the ammonia (N-NH3) concentration (Table 5). The pulp diet provided a lower rumen N-NH3 concentration than the control and oil treatments, which did not differ (P>0.05) (Table 6).

In terms of N-NH3 production over the collection times, the pulp diet provided lower values than the control and oil diets, and these two showed a similar behavior (Figure 1).

The rumen pH was not influenced by the diets throughout the collection times (Figure 2). Before the first meal was supplied, the pH value was 6.47, just below neutrality. From then on, it started to decline, reaching a minimum of 6.16 after 05h54min and rising again towards the last measurement, which occurred 8 h after the first meal.

In addition, the concentration of short-chain fatty acids (SCFA) was also not influenced by the diets throughout the collection times (Figure 3). This variable responded inversely to pH, reaching its maximum value of 70.48 mg/dL at 04h33min after the supply of the first meal. A lag period of 1h20min was observed for the reflection of the SCFA peak to cause the minimum pH value. After the morning meal, the A:P ratio (Figure 5) decreased until reaching a minimum value at 5h33min.

The higher intake of concentrate DM from the pulp diet was expected, due to the forced ingestion of this feed. However, it was not sufficient to influence total diet DM intake, as there was a compensatory reduction in roughage intake by the animals that received this diet, which did not show a significant difference, but was sufficient not to cause a difference in total intake.

The similar total DM intakes between the treatment groups resulted in a difference occurring only for EE intake, which was already expected. Accordingly, the pulp treatment provided an EE intake higher than that normally described in the literature. Silva et al. (2007) supplemented the diet of non-pregnant, non-lactating goats with an average weight of 48.66 kg with 4.5% of soybean oil and observed an EE intake of 53.10 g/day vs. 20.77 g/day in those not supplemented. Maia et al. (2006), in turn, evaluated lactating goats weighing 54±1.02 kg and found EE intakes of 49.08 g/day in the non-supplemented animals and 163.27, 167.72, and 176.83 g/day in those supplemented with rice, canola, and soybean oils, respectively, at the inclusion level of 5.1%.

The average DM intake of 649.30 g/day was below the 1280 to 1370 g/day observed by Lana et al. (2005) in goats supplemented with soybean oil (5% DM) plus propolis and in those only supplemented with soybean oil (5% DM). This result was possibly because they were producing milk, unlike the animals used in the present study, which were empty.

An explanation for the similar DM intakes across the diets is that energy intake (TDN) was also similar and, according to Mertens (1987), DM intake is related to the energy requirements of animals being met, when the fiber content (NDF) is not a limiting factor. As stated by Chilliard et al. (2003) and Martínez-Marín et al. (2012), in small ruminants, supplementation with feedstuffs rich in fatty acids can have different effects on rumen fermentation when compared with cattle. Sanz-Sampelayo et al. (2007) noted that a higher rate of digestion in goats and sheep was able to mitigate the negative effects of unsaturated fatty acids on rumen digestion, leaving the gastrointestinal tract free for the animal to consume more food.

On the other hand, the NRC (2001) points out that lipid supplementation can compromise feed intake by reducing ruminal and intestinal motility; the release of intestinal hormones; fiber digestion, by the physical coating of fiber; and the population of cellulolytic microorganisms. Fiorentini et al. (2013) mentioned other effects, such as decreased intake by a direct action on intestinal hormones, fatty acid oxidation in the liver, and the acceptability of lipid sources themselves.

The N-NH3 concentration obtained in this study was 20.07 mg/dL, which is close to the 22.9 mg/dL reported by Maia et al. (2006) and below the 35.82 mg/dL found by Silva et al. (2007) in goats supplemented with lipids. Although the N-NH3 concentration in the pulp diet was below the others, the estimated value of 14.61 mg/dL is greater than the 5 mg/dL of nitrogen in the form of ammonia—the minimum level necessary for maximum digestion of DM (NRC, 1996) in the rumen. The estimated value is in an intermediate position to the concentration of 10 mg/dL indicated by Leng (1990) to maximize the digestion of DM and 20 mg/dL to maximize intake in tropical regions.

For Doreau and Ferlay (1995), the main reason for the decrease in N-NH3 is rumen defaunation, which mostly results from the reduction in the number of protozoa and deaminating bacteria. In vitro and in vivo studies show that protozoa are sensitive to the following unsaturated fatty acids: linolenic (C18:3), linoleic (C18:2), and oleic (C18:1), in this order (Fiorentini et al., 2013).

Likewise, the reduction or elimination of protozoa may be related to improved microbial efficiency, which prevented bacterial consumption by the protozoa. Because protozoa phagocyte the starch particles, this reduction would be associated with a possible decrease in rumen ammonia concentration and a lower and more variable pH. Thus, carbohydrate fermentation reduces the pH and maintains it stable (Fiorentini et al., 2013). As the concentration of protozoa is lowered, there is also a decrease in the ammonia concentration in the rumen resulting from the decreased predatory and proteolytic activity of the protozoa (Doreau and Ferlay, 1995).

Therefore, supplementing the goat diet with 14% EE using avocado pulp would lead to decreased N-NH3 production, restricting rumen microorganism growth due to lack of substrate and/or due to the direct toxic effect of lipids on protozoa. However, it could also provide coating of the feed particles, hindering fermentation (Palmquist and Mattos, 2006).

The initial pH decline is due to the intake of feed that was made available right after the first measurement. This is because the rumen pH value is a variable related to the feeding behavior of the animal that depends on chewing time, salivation, frequency of ingestion, and rumination (Paziani, 2004).

The drop in pH after the meal can be attributed to the peak of rumen fermentation and SCFA production, which was 70.48 mg/dL at 04h33min after the first meal. This maximum acid production caused the pH to reach its minimum value, with the pH and SCFA curves being opposite (Figures 2 and 3). These results are in line with Lana et al. (1998), who reported that the rumen pH value is negatively correlated with the SCFA concentration and positively correlated with the A:P ratio, as found in the present study (Figure 5). The increase in pH after it reaches its minimum value can be explained by the buffering capacity of saliva, which neutralizes the acid effects, and/or by a reduction in SCFA production (Church, 1993).

The observed pH value was always above the 6.16. This value is deemed adequate, since, according to Hoover (1986), a moderate drop in pH to approximately 6.00 promotes a small depression in the fermentation of the fiber, but the cellulolytic bacteria population is not yet changed. Nonetheless,

a drop in pH to values equal to or less than 5.5 results in a decrease in this population and fiber digestion is highly compromised, possibly being completely inhibited. As stated by Nagaraja and Titgemeyert (2007), when the available substrates are not in excess and the SCFA absorption rate follows their production rate, rumen fermentation is stable, with a pH above 5.5 that generally varies between 5.8 and 6.5 within 24 h.

The shape of the SCFA production curve as a function of time is a reflection of the acetic and propionic acid curves, which showed the same growth model, as well as the butyric acid curve, which displayed similar growth despite not obtaining fit to the collection times (Figure 4).

The lower concentration of butyric acid at the collection times of 2 and 8 h is similar to those reported by Lana et al. (2007), who found a butyric acid concentration of 5.05 mM in goats on diets with no added lipids and 2.95 mM in goats fed a diet supplemented with 7.5% soybean oil. According to Martinele et al. (2008), the reduction in the molar proportion of butyric acid is also due to rumen defaunation, a process similar to the decrease in N-NH3, as observed in the present study.

In addition, the main species of butyrate-producing bacteria, especially Butyrivibrio fibrisolvens, which degrade fiber, possibly had their substrate reduced due to the lower proportional intake of roughage in relation to concentrate, in the pulp treatment (Table 4). When the pH approaches 6.00, it constitutes another factor able to reduce butyrate production due to the sensitivity of these bacteria to acidic conditions in the rumen, which cause them to cease or slow their growth (Kozloski, 2011). Abubakr et al. (2013) described that rumen protozoa produce butyric acid at the end of carbohydrate fermentation.

The reduction in A:P ratio and pH after the morning meal may have been influenced by the preference exerted by the goats when consuming the concentrate feed, which favored the reduction of pH and the activity of starch-fermenting bacteria. This resulted in an increase in SCFA production, especially propionic acid, thereby reducing the A:P ratio. In the opinion of Valadares Filho and Pina (2006), the intake of concentrate reduces the pH of the rumen, which exerts selection on sensitive microorganisms, reducing structural carbohydrate-fermenting bacteria and increasing the population of bacteria that ferment non-fibrous carbohydrates. This ultimately increases the activity of amylase in relation to cellulase. Russell and Wallace (1997) found that the greater propionic acid production was due to the probable decrease in Gram-positive bacteria and increase in the population of Gram-negative bacteria, which produce propionic acid.

A desirable effect reported in the literature following the increase in the proportion of propionate are reduced methane losses in diets that promote defaunation (Martinele et al., 2008).

Table 1. Ingredients and nutritional composition of the concentrate and experimental diets (g/Kg DM)

Ingredients	Concentrate		
	Control	Pulp	Oil
Soy bran	100.00	147.60	112.40
Corn	560.00	382.40	182.60
Wheat	300.00	-	533.70
Limestone	10.00	10.70	14.10
Dicalcium phosphate	10.00	10.70	14.10
Mineral salt[1]	20.00	23.10	28.10
Avocado pulp[2]	-	377.10	-
Avocado oil[3]	-	-	115.00
Chemical composition (g/Kg DM)			
Mineral matter	66.50	71.00	93.20
Crude protein	181.10	183.60	193.90
Ether extract	44.70	222.80	137.90
Crude fiber	57.90	54.50	105.90
Total digestible nutrients	758.20	894.40	788.70
Neutral detergente fiber	196.90	238.90	250.50
Acid detergente fiber	56.70	95.90	74.70
Bromatologic composition (g/Kg DM[4])			
Mineral matter	86.30	86.00	97.80
Crude protein	147.30	169.30	154.50
Ether extract	20.60	146.30	63.70
Crude fiber	270.90	177.00	280.40
Total digestible nutrients	619.20	736.20	640.50
Neutral detergente fiber	484.90	368.60	541.30
Acid detergente fiber	261.50	209.70	288.30

[1]Mineral salt composition (g/Kg): Ca 150 g, P 80 g, Na 110 g, S 40 g, Zn 2.700 mg, Cu 300 mg, Mn 810 mg, I 62 mg, Co 64 mg, Se mg. [2]The avocado pulp used was obtained from the Geada variety. [3]The avocado oil was extracted from the commercial brand Hass. [4]Based on nutritional composition of the concentrates and chemical composition of *Panicum maximun* cv. Tobiatã (Table 2) and DM intake (Table 4).

Table 2. Bromatologic composition (g/Kg DM) of forage and avocado pulp used to fed goats

Nutrients	*Panicum maximun* cv. Tobiatã	Avocado variety Geada
Mineral matter	91.10	38.50
Crude protein	137.30	80.30
Ether extract	14.20	430.10
Crude fiber	322.40	102.80
Total digestible nutrients	586.00	1155.80
Neutral detergente fiber	696.00	381.20
Acid detergente fiber	336.40	268.60

Table 3. Profile of forage fatty acids, concentrates and supplements (g/100g fat)

Fatty acids	Forage	Control	No pulp	Pulp	No oil	Oil
Saturated						
C16:0	30.29	16.372	16.053	22.646	18.739	23.706
C18:0	2.619	1.932	2.713	1.192	1.746	0.494
C18:1n c9	3.262	23.205	25.488	36.618	19.815	35.288
C18:1n c11	0.483	1.947	1.477	4.447	1.358	6.978
Others C18:1	0.607	1.526	1.469	3.332	1.202	4.536
C18:2n 6	17.98	51.15	48.70	14.52	51.99	12.84
C18:3n 3	27.71	1.77	1.98	3.31	2.47	0.37
Saturated fatty acids	40.37	18.91	19.38	26.36	21.17	24.31
Unsaturated fatty acids	55.38	80.57	79.92	68.36	78.02	74.04
Mono unsaturated fatty acids	8.94	27.64	29.23	50.48	23.56	60.83
Poli unsaturated fatty acids	46.44	52.93	50.69	17.88	54.46	13.21
MUFA/SFA[1]	0.22	1.46	1.51	1.91	1.11	2.50
PUFA/SFA[2]	1.15	2.80	2.62	0.68	2.57	0.54

[1]MUFA/SFA: relation between mono unsaturated fatty acids/ saturated fatty acids, [2]PUFA/SFA: relation between poli unsaturared fatty acids/ saturated fatty acids.

Table 4. Average daily consumption of nutrients according to experimental diets

Nutrients	Treatments			Average ± SD
	Control	Pulp	Oil	
		Diet intake		
Dry matter (g/day)	656.88	697.74	593.27	649.30 ± 33.97
Crude protein (g/day)	96.75	120.09	91.70	102.84 ± 5.81
Ether extract (g/day)	13.51 c	102.31 a	37.81 b	51.20 ± 9.49
Mineral matter (g/day)	56.72	61.62	58.07	58.80 ± 2.92
Total digestible nutrients (g/day)	406.77	521.29	380.00	436.02 ± 25.96
Neutral detergente fiber (g/day)	318.55	267.91	321.09	302. 51± 18.03
Acid detergente fiber (g/day)	171.78	152.39	171.02	165.06 ± 9.73
		Forage intake		
Dry matter (g/day)	350.29	215.08	331.92	299.10 ± 25.03
		Concentrated intake		
Dry matter (g/day)	306.59 b	482.67 a	261.36 b	350.20 ± 32.48
Forage/Concentrated	53.33/46.67	30.83/69.17	55.95/44.05	

*Means followed by the same letter, in line, did not differ themselves by the Tukey test (P > 0.05).
SD: Standart deviation

Table 5. Summary of analysis of variance for ruminal parameters as a function of diets (D), collection time (CT) and D * TC interaction

Feature	Effect			Average ± SD
	Diet (D)	Time (TC)	D * CT	
pH	ns	*	ns	6.13 ± 0.34
N-NH_3 (mg/dL)	*	ns	ns	20.07 ± 6.52
Fatty acids (mM)	ns	*	ns	61.31 ± 1.84
Acetic acid (mM)	ns	*	ns	43.54 ± 1.39
Butyric acid (mM)	ns	*	*	4.75 ± 0.18
Propionic acid (mM)	ns	*	ns	11.05 ± 0.41
Acetic/ Propionic	ns	*	ns	4.11 ± 0.11

SD: standart deviation, ns: no significant, *P > 0.05.

Table 6. Ruminal parameters mean as a function of diets and regression equations as a function of collection time

Treatment			Time (h)
Control	Pulp	Oil	
		pH	
6.19	6.12	6.38	$\hat{Y} = 6.4694 - 0.1054 * t - 0.0089\, t^2$, R^2 = 90.19%. P, Min. = 70.48 (t = 05h:54)
		N-NH3 (mg/dL)	
23.84 a	14.61 b	21.78 a	no[1]
		Acetic acid (mM)	
47.90	48.13	43.91	$\hat{Y} = 36.8991 + 4.9282 * t - 0.5549\, t^2$, R^2 = 90.19%, P. Max. = 47.84 (t = 04h:26)
		Propionic acids (mM)	
11.82	12.35	12.91	$\hat{Y} = 7.8775 + 2.0616 * t - 0.2157\, t^2$, R^2 = 90.19%, P. Max. = 12.80 (t = 04h:28)
		Acetic/Propionic	
4.11	4.15	3.66	$\hat{Y} = 4.7326 - 0.3685 * t + 0.0331\, t^2$, R^2 = 90.19%, P. Max. = 3.71 (t = 05h:33)
		Short chain fatty acids (mM)	
67.84	66.87	63.67	$\hat{Y} = 52.7085 - 7.8084 * t - 0.85756\, t^2$, R^2 = 90.19%, P. Max. = 70.48 (t = 04h:33)
		Butyric acid (mM)	
	time = 2 h		
5.60 a	3.65 b	5.29 ab	no[1]
	time = 8 h		
5.64 a	3.35 b	4.24 ab	

*Means followed by the same letter, in line, did not differ themselves by the Tukey test (P > 0.05).
[1] no = polynomial model up to the third degree not adjusted the observations.

Conclusion

The inclusion of 6% ether extract (dry-matter basis) in goat diets through the use of commercial avocado oil does not influence intake or rumen parameters.

A diet with 14% ether extract (dry-matter basis), obtained using avocado pulp, induces a reduction in the following parameters, in goats: proportional intake of concentrate (roughage:concentrate ratio); ammonia concentration, to levels below the limit necessary for maximizing the carbohydrate fermentation activity; and butyric acid concentration at two and eight hours after the meal, due to the decreased substrate for the fiber-degrading bacteria that are responsible for the production of this acid. Supplementing goat diets with ether extract levels greater than 6% produces undesirable effects on rumen fermentation.

Acknowledgment

Thanks to Fapesp for supporting research founding.

References

ABUBAKR, A. R.; ALIMONAB, A. R.; YAAKUBA, H.; ABDULLAHBC, N. and IVANB, M. 2013. Digestibility, rumen protozoa, and ruminal fermentation in goats receiving dietary palm oil by-products. Journal of the Saudi Society of Agricultural Sciences 12: 147-154. https://doi.org/10.1016/j.jssas.2012.11.002

ARIZA, O. J. A.; VALDEZ, F. L.; HUERTA, J. C.; CASSELLIS, M. E. R.; REYES, J. D. and ZAVALA, A. M. 2011 Effect of different extraction methods on the fatty acid profile in the avocado (*Persea americana* Mill. var. Hass) oil. Revista Venezolana de Ciencia y Tecnología de Alimentos 2:263-276. Disponível em: <http://www.rvcta.org/Publicaciones/Vol2Num2/ArchivosV2N2/Ariza-Ortega_et_al._RVCTA-V2N2.pdf>. Acesso em: 18 mar. 2015.

BUDIÑO, F. E. L. and CASTRO JUNIOR, F. G. 2009. Digestible energy and apparent digestibility of the crude protein and dry matter of the aquatic plants hay for growth phase swine. Ciência Animal Brasileira 10:802-807. Disponível em: <http://www.revistas.ufg.br/index.php/vet/article/viewArticle/4493>. Acesso em: 11 ago. 2014

CHILLIARD, Y.; FERLAY, A.; ROUEL, J. and LAMBERET, G. 2003. A review of nutritional and physiological factors affecting goat milk lipid synthesis and lipolysis. Journal of Dairy Science 86:1751-1770. https://doi.org/10.3168/jds.S0022-0302(03)73761-8

COSTA, R. G.; QUEIROGA, R. C. R. E. and PEREIRA, R. A. G. 2009. Influence of feed on the production on quality of goat milk. Revista Brasileira de Zootecnia 38:307-321. https://doi.org/10.1590/S1516-35982009001300031

CHRISTIE, W. W. 1982. A simple procedure for rapid transmethylation of glycerolípids and cholesteryl esters. Journal of Lipid Research 23:1072-1075. Disponível em: <http://www.jlr.org/content/23/7/1072.full.pdf+html>. Acesso em: 19 set. 2014.

CHURCH, D. C. 1993. The ruminant animal. Digestive physiology and nutrition. Long Grove, Waveland Press.

AOAC – ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTRY. 1995. Official methods of analysis. 16. ed. of AOAC International, Arlington, VA.

DOREAU, M. and FERLAY, A. 1995. Effect of dietary lipids on nitrogen metabolism in the rumen: a review. Livestock Production Science 43: 97-110. https://doi.org/10.1016/0301-6226(95)00041-I

FENNER, H. 1965. Method for determining total volatile bases in rumen fluid by steam distillation. Journal of Dairy Science 48: 249-251. https://doi.org/10.3168/jds.S0022-0302(65)88206-6

FIORENTINI, G.; MESSANA, J. D.; DIAN, P. H. M.; REIS, R. A.; CANESIN, R. C.; PIRES, A. V. and BERCHIELLI, T. T. 2013. Digestibility, fermentation and rumen microbiota of crossbred heifers fed diets with different soybean oil availabilities in the rumen. Animal Feed Science and Technology 181:26-34. https://doi.org/10.1016/j.anifeedsci.2013.01.011

HARA, A. and RADIN, N. S. 1978. Lipid extraction of tissues with low-toxicity solvent. Analitical Biochemistry .90: 420-426. http://dx.doi.org/10.1016/0003-2697(78)90046-5

HOOVER, W. H. 1986. Chemical factors involved in ruminal fiber digestion. Journal of Dairy Science 69:2755-2766. https://doi.org/10.3168/jds.S0022-0302(86)80724-X

KEARL, L. C. 1982. Nutrients requirements of ruminants in developing countries. Logan, Utah State University/International Feedstuffs Institute.

KOZLOSKI, G. V. 2011. Bioquímica dos ruminantes. 3th ed. Santa Maria, Rio Grande do Sul.

LANA, R. P.; RUSSELL, J. B. and AMBURGH, M. E. V. 1998. The role of pH in regulating ruminal methane and ammonia production. Journal of Animal Science 76:2190-2196. https://doi.org/10.2527/1998.7682190x

LANA, R. P.; CAMARDELLI, M. M. L.; QUEIROZ, A. C.; RODRIGUES, M. T.; EIFERT, E. C.; MIRANDA, E. N. and ALMEIDA, I. C. C. 2005. Soybean oil and propolis in the diets of dairy goats. Revista Brasileira de Zootecnia 34:650-658. https://doi.org/10.1590/S1516-35982005000200035

LANA, R. P.; CAMARDELLI, M. M. L.; RODRIGUES, M. T.; EIFERT, E. C.; OLIVEIRA, M. V. M.; STRADIOTTI JÚNIOR, D. and OLIVEIRA, J. S. 2007. Soybean oil and propolis in the diets of dairy goats: intake of nutrients and ruminal metabolism. Revista Brasileira de Zootecnia 36:191-197. https://doi.org/10.1590/S1516-35982007000100023.

LENG, R. A. 1990. Factors affecting the utilization of "poor-quality" forages by ruminants particularly under tropical conditions. Nutrition Research Reviews 3:277-303. https://doi.org/10.1079/NRR19900016

MAIA, F. J.; BRANCO, A. F.; MOURO, G. F.; CONEGLIAN, S. M.; SANTOS, G. T.; MINELLA, T. F. and MACEDO, F. A. F. 2006. Feeding vegetable oil to lactating goats: nutrient digestibility and ruminal and blood metabolism. Revista Brasileira de Zootecnia 35:1496-1503. https://doi.org/10.1590/S1516-35982006000500032

MARTINELE, I.; EIFERT, E. C.; LANA, R. P.; ARCURI, P. B. and D'AGOSTO, M. 2008. Effect of monensin and soybean oil on rumen ciliate protozoa and correlation between protozoa with ruminal fermentation and digestive parameters. Revista Brasileira de Zootecnia 37:1129-1136. https://doi.org/10.1590/S1516-35982008000600025

MARTÍNEZ-MARÍN, A. L.; PÉREZ-HERNÁNDEZ, M.; PÉREZ-ALBA, L. M.; CARRIÓN-PARDO, D. and GÓMEZ-CASTRO, A. G. 2012. Adición de aceites vegetales a la dieta de cabras lecheras: efecto sobre la digestibilidad y los resultados productivos. Archivos de Medicina Veterinaria 44:21-28. http://dx.doi.org/10.4067/S0301-732X2012000100004

MASSAFERA, G. L.; COSTA, T. M. B. and OLIVEIRA, E. D. 2010. Composição de ácidos graxos do óleo do mesocarpo e da semente de cultivares de abacate (*Persea americana*, Mill.) da região de Ribeirão Preto, SP. Alimentos e Nutrição Araraquara

21:325-331. Disponível em: <http://200.145.71.150/seer/index.php/alimentos/article/viewFile/940/a20v21n2.pdf>. Acesso em: 15 mar. 2015.

MERTENS, D. R. 1987. Predicting intake and digestibility using mathematical models of ruminal function. Journal of Animal Science 64: 1548-1558. https://doi.org/10.2527/jas1987.6451548x

NAGARAJA, T. G. AND TITGEMEYERT, E. C. 2007. Ruminal acidosis in beef cattle: The current microbiological and nutritional outlook. Journal of Dairy Science 90:17-38. https://doi.org/10.3168/jds.2006-478

NRC - NATIONAL RESEARCH COUNCIL. 1996**.** Nutrient Requirements of Beef Cattle. 7th.ed. Washington, D.C.

NRC - NATIONAL RESEARCH COUNCIL. 2001. Nutrient Requirements of Dairy Cattle. 7th.ed. Washington, D.C.

NRC - NATIONAL RESEARCH COUNCIL. 2007. Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids. Washintgton, D.C.

PALMQUIST, D. L. AND MATTOS, W. R. S. 2006. Metabolismo de lipídeos. p. 287-309 In: Nutrição de ruminantes. Berchieli, T. T.; Pires, A. V.; Oliveira, S. G., ed. Jaboticabal, Funep.

PAZIANI, S. F. 2004. Controle de perdas na ensilagem, desempenho e digestão de nutrientes em bovinos de corte alimentados com rações contendo silagens de capim tanzânia. Tese (D.Sc.). Universidade de São Paulo, Piracicaba.

RUSSELL, J. B. and WALLACE, R. J. 1997. Energy yielding and energy consuming reactions. In: The rumen microbial ecosystem. 2th.ed. Robson, P. N. e Stewart, C. S., ed. London: Blackie Academic and Professional.

SANTOS, F. L.; LANA, R. P.; SILVA, M. T. C.; BRANDÃO, S. C. C. and VARGAS, L. H. 2001. Milk Production and Composition in Dairy Cows Receiving Diets with Different Levels and Sources of Lipids Supplementation. Revista Brasileira de Zootecnia 30: 1376-1380. https://doi.org/10.1590/S1516-35982001000500034

SANZ SAMPELAYO, M. R. S.; CHILLIARD, Y.; SCHMIDELY, P. H. and BOZA, J. 2007. Influence of type of diet on the fat constituents of goat and sheep milk. Small Ruminant Research, 68:42-63. https://doi.org/10.1016/j.smallrumres.2006.09.017

SILVA, M. M. C.; RODRIGUES, M. T.; RODRIGUES, F. C. A.; BRANCO, R. H.; LEÃO, M. I.; MAGALHÃES, A. C. M. and MATOS, R. S. 2007. Effect of lipid supplementation on digestibility and ruminal metabolism in dairy goats. Revista Brasileira de Zootecnia 36:246-256. https://doi.org/10.1590/S1516-35982007000100029

SILVA, R. L. N. V.; OLIVEIRA, R. L.; CARVALHO, G. G. P.; RIBEIRO, O. L.; LEÃO, A. G.; FARIA, M. M. S. and LEDO, S. C. A. 2012. Ruminal degradability and energy balance in dairy cows on pasture supplemented with palm kernel cake. Revista Brasileira de Saúde e Produção Animal 13:503-515. https://doi.org/10.1590/S1519-99402012000200018

SIMON, J. W. 2008. Avaliação microbiológica e sensorial do guacamole conservado pelo frio. Dissertação (M.SC.) Universidade Estadual Paulista, Botucatu.

SOLLENBERGER, L. E. AND CHERNEY, D. J. R. 1995. Evaluating forage production and quality. The Science of Grassland Agriculture. Iowa State University Press.

VALADARES FILHO, S. C. AND PINA, D. S. 2006. Fermentação Ruminal. p.151-179. In: Nutrição de ruminantes. Berchieli, T. T.; Pires, A. V.; Oliveira, S. G., ed. Jaboticabal, Funep.

VAN SOEST, P. J.; ROBERTSON, J. B. AND LEWIS, B. A. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science 74:3583-3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

VARGAS, L.H.; LANA, R. P.; JHAM, G. N.; SANTOS, F. L.; QUEIROZ, A. C. and MANCIO, A. B. 2002. Lipids in the Ration of Dairy Cows: Ruminal Fermentation Parameters, Milk Production and Composition. Revista Brasileira de Zootecnia 31:522-529. https://doi.org/10.1590/S1516-35982002000200029