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Production, composition, and fatty acid profile of milk from anglo-nubian goats fed avocado (*Persea americana* Mill.) pulp and oil

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Abstract: The aim of this study was to examine the effect of including avocado oil in goat diets, because it was the fastest strategy to change the milk fatty acid profile to benefit the health of consumers is increasing the conjugated linoleic acid (CLA), where evaluated intake and milk yield, composition and fatty acid profile. Six lactating Anglo-Nubian goats were evaluated in two 3 × 3 balanced Latin squares. The diet containing avocado pulp reduced DM intake, whereas the oil-supplemented diet increased it, compared to control diet, and the same trend was observed for the other nutrients except Ether Extract, whose intake was higher in the goats fed avocado pulp diet compared to control diet. Milk total solids and fat contents were higher in the group fed the diet with avocado oil than in the control group, which in turn did not differ from the group fed avocado pulp. The other milk components and milk yield were not influenced by the diets. Short-chain fatty acid contents in the milk of the goats supplemented with a lipid source decreased in comparison to control group, whereas the CLA level rose by 56.88 and 66.10% in the milk of the goats fed the pulp- and oil-supplemented diets, respectively. Supplementing unsaturated fatty acids via avocado oil or avocado pulp elevates the CLA concentrations and reduces the short-chain fatty acid content in milk, improving its nutraceutical properties and ultimately benefitting the health of consumers.
Keywords: conjugated linoleic acid, feed evaluation, lipids, small ruminants

Introduction

Fresh goat's milk is a highly digestible product. Compared to milk, it is more alkaline and has a higher buffering capacity. For these reasons, it is considered a functional food and is used mostly in the diet of children with some intolerance to cow milk proteins (Fisberg et al., 1999; Azambuja; Souza, 2001; Martínez, 2013).

Intolerance to milk of other animal species in children is related to the β-lactoglobulin and αS1-casein proteins, whose contents are low in goat's milk. Goat's milk can also be consumed by the elderly and the sick, as it is more digestible by virtue of the smaller fat globules and low contents of the agglutinin protein, which groups the fat globules to form larger structures. At lower concentrations, the molecules are better dispersed and more easily attacked by digestive enzymes (Chacón, 2005).

However, like all other milks, it has been subject to consumption restrictions due to elevated concentrations of saturated fatty acids, ω6/ω3 ratio and cholesterolemic fatty acids (C12 + C14 + C16), which have been related to increased serum cholesterol levels and risk of cardiovascular disease. On the other hand, milk and its derivatives represent around 75% of the conjugated linoleic acid (CLA) consumed by humans (Bauman et al., 2006), with rumenic acid (C18:2 c9, t11) accounting for 75% of the CLA present in those products (Sieber et al., 2004).

The most commonly used and studied strategy to improve the fatty acid profile of cow's or goat's milk is supplementing the animal diet with

lipid sources (oils and fats). Additionally, lipids can increase the energy concentration of the diet and reduce methane production (Abdalla et al., 2008).

Most studies show that lipid supplementation to goat diets via oil addition results in increased fat contents (Bernard et al., 2005; Fernandes et al., 2008; R. P. L. Lana et al., 2005; Queiroga et al., 2010) or no effects at all (Fábio José; Maia et al., 2006; Martínez Marín et al., 2012; Razzaghi et al., 2015), as opposed to what is observed in cows. In cows, lipid supplementation elevates the concentration of an isomer, C18:2 t10, c12 – CLA, during the biohydrogenation of linoleic acid, which is pointed as a depressant of milk fat (Bauman et al., 2006). In goat's milk, this isomer is found at low concentrations, thus not reducing the milk fat content (Ribeiro et al., 2011). Furthermore, no correlation has been found between the concentration of this isomer and lipid supplementation (Martínez Marín et al., 2012).

Additional effects of lipid supplementation on goat's milk fat include: decreased percentage of short- and medium-chain fatty acids and saturated fatty acids and increased percentage of long-chain fatty acids (Bouattour et al., 2008; Razzaghi et al., 2015); increased levels of unsaturated fatty acids and C18:2 c9,t11 isomer (Almeida et al., 2013; Bouattour et al., 2008); and decreased atherogenicity index and related fatty acids (C12 + C14 + C16) (Bernard et al., 2005; Martínez Marín et al., 2012).

Despite the beneficial impact of vegetable oil supplementation on the yield, fat content and fatty acid profile of milk, this practice has the drawback of raising the cost of milk production and thus reducing revenues to the producer, who is not yet remunerated for improving the nutraceutical characteristics of milk. Another problem is that supplementing goat diets with vegetable oils at levels higher than 7% may cause the animals to reduce their dry matter intake (Maia et al., 2006).

The avocado fruit (*Persea americana* Mill.) has a high oil content (18 to 30%) and is well adapted to the soil-climatic conditions found in Brazil. Most avocado varieties grown in the Brazilian territory have their production concentrated in the second semester of the year, which coincides with the period of natural kidding, in goats. In addition to its excellent yield potential, the crop does not require sophisticated cultivation practices and can be grown in nurseries to be fed to animals as a low-cost method to improve the nutraceutical properties of their milk.

The present study proposes to examine the effects of supplementing the diet of Anglo-Nubian goats with a commercial oil of avocado and avocado fruit pulp (at double the concentration of the oil) on feed intake and on the yield, components and fatty acid profile of their milk.

Methods

Ethical principles and good practices in experimentation

The project was developed in the experimental area located at 22°53'42"S and 48°26'42"W, 840 m altitude. According to the Köppen (1948) classification, the region has a Cwa climate type, with an average temperature of 22 ºC. All procedures undertaken in this project were approved by the ethics committee of the above-mentioned institution (approval no. 31/2012-CEUA).

This experiment was carried out involving six Anglo-Nubian goats at 47.5 ± 13.5 days in milk, with an average body weight of 58 ± 17.63 kg and a milk yield of 1.67 kg/day. The animals were reared in a semi-confined regime in which they were grazed from 07h30 to 11h00 and then housed from 11h00 to 07h00 of the next day in individual 3.5-m^2 stalls equipped with water, salt and feed troughs inside a covered shed with slated floors.

The rotational grazing method with variable stocking rate was adopted. Additional animals were used to maintain paddock uniformity ('put-and-take' technique) (Mott and Lucas, 1952). The grazing area consisted of eleven 500-m^2 paddocks of *Panicum maximum* cv. Tobiatã. The animals grazed for three days, which were followed by 30 days of rest. Paddocks were fenced with regular wire and electric wire and equipped with individual drinkers.

Goats were milked manually, at 07h00 and 16h00, in a milking room with a pit and waterproof floor. The animals were pre-dipped with water and soap and an iodinated solution, dried with paper towel and tested for mastitis by the strip-cup method. After milking, a glycerin iodine solution was used for post-dipping. The milk was collected in jars and weighed on a 5-g-precision digital scale.

The experiment was designed as two 3×3 balanced Latin squares. Each experimental period lasted 14 days, which consisted of nine days of adaptation and adjustment of voluntary consumption of the diets followed by five days of data collection. This experimental design was adopted because there were not enough animals under the same conditions for another design.

The evaluated diets differed in terms of lipid source and concentration, as follows: control diet [3% ether extract (EE) on a dry matter (DM) basis] containing corn, soybean meal, wheat bran; diet containing pulp of avocado variety Brenda (16.5% EE, DM basis); and diet with oil of avocado variety Hass (8% EE, DM basis) (Table 1). Both diets were balanced so as to meet the requirements of goats with a live weight of 50 kg and a milk yield between 2.06 and 3.22 L, with 4.0% fat (NRC, 2007).

The concentrate feed was supplied twice daily at the rate of 1 kg of DM/goat/day, with half of the portion given at 11h00, when the goats would return from grazing, and the other half at 16h30, after the afternoon milking. The avocado pulp and oil were added at the time of supply to prevent rancidification issues. Before the concentrate was supplied, orts were collected and weighed to calculate feed intake.

Prior to its use, the avocado was stored at room temperature until ripening, which was defined

based on pulp softening, by palpation. Once ripe, the avocado was washed with water and soap, the pulp was removed and the fruit was packed in plastic bags (1 kg per bag) which were then frozen, following the methodology of Simon and Vieittes (2010). The amount required for supplementation was removed from the freezer one day before, for thawing.

The avocado oil used in the experiment was the Azeite Hass brand (avocado variety Hass), which was purchased from Jaguacy farm in Bauru - SP, Brazil.

A program of gradual adaptation to the diet was employed. By this strategy, 30% of the new diet would be introduced in the first and second days; 70% on the third and fourth days; and 100% from the fifth day onward.

The concentrate feed was sampled on the last five days of each period, while the pasture was sampled upon paddock rotation. Samples were kept frozen until analysis to determine the concentrations of DM (method 930.15; AOAC, 2000), crude protein (CP; N × 6.25; method 984.13; AOAC, 2000), mineral matter (MM; method 942.05; AOAC, 2000) and ether extract (EE; method 920.39; AOAC, 2000); and crude fiber (CF), neutral detergent fiber (NDF) and acid detergent fiber (ADF) by the method proposed by Van Soest (1994).

Total digestible nutrients (TDN) were calculated by the following equation, developed by Kearl (1982): TDN = 40.2625 + 0.1969 %CP + 0.4228 %NFE + 1.1903 %EE – 0.1379 %CF, where NFE: nitrogen-free extract. The nitrogen-free extract was determined by the following formula, as proposed by Sniffen et al. (1992): NFE (%) = 100 – (%CP + %EE + %CF + %MM).

To determine forage intake, chromium oxide (Cr_2O_3) was used as an external marker that was administered orally, in gelatin capsules. The animals were given 2.5 g of Cr_2O_3 once daily at 17h00, during the last 10 days of the period. The first five days were used as a period of stabilization of the Cr_2O_3 concentration in the feces, and the last five days were used to collect feces directly from the animals' rectum, at 08h00 and 17h00. This material was frozen and processed at the Laboratory of Food Chemical Analysis by the methodology of Neto et al. (2005).

Milk yield was estimated as the average of the last five days of each period. On the 14th day, individual milk samples were collected from the morning and afternoon milking sessions proportionally to their respective production and placed in 30-mL bottles containing the preservative bronopol (2-bromo-2-nitropropane – 1,3 diol). These were then sent to the Milk Clinic for determination of the concentrations of protein, fat, lactose, total solids, solids non-fat, somatic cell count and urea nitrogen by the infrared absorption method, using a Bentley 2000® instrument. Somatic cell count was determined by flow cytometry.

The following formulae, described in NRC (2001), were used to correct milk yield for 3.5% and 4% fat: 3.5%FMY = [(0.4255 × Milk yield (kg)] + [16.425 × (% fat/100) × Milk yield (kg)]; and 4%FMY = 0.4 × milk (kg/day) + 15 × Fat yield (kg/day). Milk yield was also corrected for total solids as proposed by Tyrrell and Reid (1965), as follows: TSMY = [(12.3 × Fat yield (kg)] + [(6.56 × Solids-not-fat yield (g)] – [(0.0752 × Milk yield (kg)]. Somatic cell count was converted to natural logarithm.

During the sampling of milk for the analysis of its components, individual 80-mL samples were also collected to determine the fatty acid profile. These were frozen and sent to the Laboratory of Animal Nutrition and Growth, where they were analyzed by gas chromatography. Fatty acid levels in the forage, concentrate and supplements were also analyzed at the same laboratory.

Milk samples were thawed and centrifuged at 9,000 rpm for 30 min to separate the fat. To determine the fatty acid profile of the milk fat, the lipids were first extracted through an hexol:isopropanol organic solvent mixture (3:2), following the methodology described by Hara and Radin (1978), and the lipid fraction was esterified using a basic solution of sodium methoxide, in accordance with Christie (1982). Once esterified, the sample was injected into the chromatograph and the fatty acids were identified using Chromquest 4.1 software (Thermo Electron, Italy). Fatty acid results were expressed as area percentage (%).

The concentrations of omega 3 (ω3), omega 6 (ω6), conjugated linoleic acid (CLA), saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) and ω6/ω3, MUFA/SFA and PUFA/SFA ratios were obtained based on the fatty acid profile. The nutritional quality indices of the lipid fraction were also obtained, namely atherogenicity index (AI = C12:0 + (4 * C14:0) + C16:0)] / (MUFA + ω3 + ω6)) and thrombogenicity index (TI = [(C14:0 + C16:0 + C18:0) / [(0.5 + MUFA) + (0.5 * ω6) + (3 * ω3) + (ω3 * ω6)]), as proposed by Ulbricht and Southgate (1991). The ratio between hypocholesterolemic and hypercholesterolemic fatty acids (H:H) was determined by the following formula suggested by Santos-Silva et al. (2002): HH = [(C18:1cis9 + C18:2ω6 + C20:4ω6 + C18:3ω3 + C20:5ω3 + C22:6ω3) / (C14:0 + C16:0)].

Statistical analysis

The data were subjected to analysis of variance using the System for Statistical and Genetic Analysis (SAEG) version 9.0 (UFV – 2000). Mean contrasts were achieved by Tukey's test, adopting the significance level of 5% for procedures.

The traits pertaining to the chemical composition and fatty acid profile of milk were analyzed as split plots, with the main plots being the treatments and the subplots the collection days.

Results and discussion

Dry matter intake was highest ($P<0.005$) in the group supplemented with avocado oil (Table 4),

which was likely due to some factor that enhanced the palatability of the oil-containing concentrate.

Ether extract intake (g/day; Table 4) did not differ between the treatments with pulp (157.0 g/day) and oil (145.0 g/day), which may suggest that goats are able to ingest around 145 to 157 g/day, and upon reaching this EE level they cease to eat.

Dry matter intake was highest in the group fed the diet with avocado oil, followed by control group. Accordingly, the intakes of nutrients were influenced in a similar manner (Table 4).

The treatments influenced DM intake, altering the weight gain of the animals in all treatment groups. Weight gain decreased in the goats supplemented with avocado pulp and oil ($P<0.005$), at an overall mean of –34.80 g/day, which may be related to the mobilization of body reserves caused by maximum milk yield being close to peak milk yield (Table 5).

Milk yield, 3.5%FMY, 4%FMY, TSMY, SNF, protein, lactose, urea nitrogen and somatic cell count logarithm were not influenced by the treatments ($P>0.005$) (Table 5).

The percentage of total solids in milk was higher in the group fed the diet with avocado oil in relation to control group, which in turn did not differ from the group supplemented with avocado pulp. Those differences were due to the milk fat percentage, which showed the same behavior and ended up influencing the percentage of total solids, since the other components did not differ across the treatments (Table 5).

In the present study, the SCFA (C4 – C10) content in the goat's milk decreased by 21.20 and 27.28% in the groups fed the diets with avocado pulp and oil, in relation to control diet. However, the concentration of isomer C18:2 t10, c12 was not influenced by the treatments (Table 6), indicating the existence of some mechanism impeding its synthesis or that its action in inhibiting fat synthesis in the mammary gland is reduced in goats, with another mechanism being involved in the reduction of SCFA in milk.

Among the long-chain MUFA, there was an increase in C18:1 acid (c15, t10 – t12 and t16) in the milk of the goats fed the oil diet compared to control treatment. The group fed avocado pulp was in an intermediate position for this variable, not differing from the two other groups.

Among the PUFA, there was a considerable increase of 55.95 and 65.86% in C18:2 c9, t11 CLA in the milk of the goats fed the pulp and oil diets, respectively, compared to control diet.

No differences were detected between the diets for the concentrations of ω-3, ω-6, SFA, MUFA, PUFA, their ratios, or the AI, TI and HH indices ($P>0.005$; Table 7). However, the CLA level was 56.88 and 66.10% in the groups fed avocado pulp and oil, respectively, compared to control group ($P<0.005$).

Although there was no difference in the total sums of saturated and unsaturated fatty acids, differences were detected in the concentrations of some fatty acids when analyzed separately (Table 6). The levels of SCFA and MCFA (C8 – C15) in the diets with pulp and oil decreased, compared to control. The main reductions were seen in caprylic (C8:0), lauric (C12:0), pentadecanoic (C15:0), capric (C10:0) and myristic (C14:0) acids, the last two of which differed only in the oil-supplemented diet ($P<0.005$). The milk of the animals fed the avocado pulp and oil diets had 25 to 33% and 29 to 40% less SCFA, respectively, than the milk of the goats fed control diet (Table 6). The reduction in the concentration of those fatty acids contributed to the same differences being observed between the treatments for the SCFA, which decreased by 21.19 and 27.27% in the diets supplemented with pulp and oil, respectively.

In the present study, the higher CLA levels in the milk of the goats fed the diets with avocado pulp and oil compared to control group was an effect caused by rumenic acid (C18:2 c9, t11), since C18:2 t10, c12 was found at low contents and was not influenced by the diets (Table 7).

Dry matter intake was highest ($P<0.005$) in the group supplemented with avocado oil. This occurrence is a consequence of the higher concentrate intake shown by the animals fed the diet supplemented with oil in relation to control diet, considering that there was no difference in roughage intake (Table 4), which was likely due to some factor that enhanced the palatability of the oil-containing concentrate.

The higher intake of control diet in relation to the avocado pulp diet indicates that the diet containing avocado pulp reduced roughage intake and that the amount of EE in that diet is responsible for the decline in DM intake from the roughage portion.

Almeida et al. (2013) found DM intake by goats to decrease linearly as soybean oil was added (0, 30, 60 and 90 g/day), the last level of which corresponded to an EE intake of 161 g/day, considering the basal diet and supplementation. The EE intake range between 145 and 157 g/day observed in the present study, obtained from high-UFA sources, which are able to reduce DM intake, is close to the 3.6 g/kg LW of goats described by Teh et al. (1994), and because of that Ether Extract intake did not differ ($P>0.05$) between the treatments.

In several experiments, dietary inclusion of vegetable oil did not influence DM intake (Almeida et al., 2013; R. P. Lana et al., 2005; Martínez Marín et al., 2012; Razzaghi et al., 2015). However, none of those studies tested EE levels greater than 160 g/day.

The reduction in DM intake observed when the animals reached an EE intake of 157 g may be explained as a mechanism protecting the rumen microorganisms, since UFA have an inhibitory effect on the Gram-positive bacterial population (Nagaraja et al., 1997); a toxic effect on cellulolytic bacteria (Palmquist, 1989); and also a toxic effect on the bacteria which participate in biohydrogenation, e.g.

Butyrivibrio fibrisolvens, the main responsible for this process.

Due to the milk fat percentage of total solids, this result corroborates those reported by Chilliard et al. (2003), who observed that the main effect of adding lipids to goat diets was an increase in milk fat content.

The majority of studies have demonstrated that vegetable-oil supplementation to goat diets increases (Bernard et al., 2005; R. P. L. Lana et al., 2005; Queiroga et al., 2010) or has no effect (Fábio José; Maia et al., 2006; Martínez Marín et al., 2012; Razzaghi et al., 2015) on milk fat percentage.

Most studies with cows revealed the opposite effect, with a reduction in milk fat percentage occurring when the diet was supplemented with vegetable oils. This reduction is caused by an isomer formed in the rumen during the biohydrogenation of linoleic (18:2 c9, c12) to stearic acid (C18:0), or C18:2 t10, c12 (CLA). In the opinion of Bauman and Griinari (2003), the decreasing milk fat percentage caused by this isomer is the result of inhibition of synthesis in the mammary gland, which reduces the concentrations of short- (SCFA) and medium-chain (MCFA) fatty acids in milk and also the capture of fatty acids in arterial blood. According to Andrade (2011), this reduction may be related to inhibited activity of the lipogenic enzymes acetyl-CoA carboxylase and fatty acid synthase, in the mammary gland.

The lack of differences for isomer production may be due to the smaller amount of its main precursor, linoleic acid, which is present in lower proportions in avocado oil (Table 3) compared to the oils normally used for animal supplementation such as canola, rice, soybean, cottonseed, sunflower and flaxseed oils, whose content is between 24.48% and 65.18% (Gulati et al., 1999; Kalscheur et al., 1997; Fábio José; Maia et al., 2006; Masiha et al., 2013). Alternatively, this lack of differences may be because, in goats, linoleic acid preferably leads to the formation of rumenic acid (C18:2 c9, t11 CLA)—which was present in larger proportions in the diets with avocado pulp and oil compared to control (Table 6)—over C18:2 t10, c12. The higher fat content in the goat's milk may be explained by the saturation of biohydrogenation caused by the high levels of oleic acid present in avocado and its oil, considering the higher concentration of C18:1 isomers observed in the milk of the goats in those treatment groups (Table 6).

Another explanation for the lack of depression in fat content in the milk of the goats supplemented with avocado oil lies in the fact that MUFA are less toxic to cellulolytic bacteria than PUFA (Maia et al., 2006). This toxic effect reduces the acetate:propionate ratio and, consequently, the supply of acetic acid, a direct precursor of 50% of the milk fat (Palmquist, 1989), mainly through the synthesis of SCFA and MCFA in milk (Schmidely and Andrade, 2011).

The reduction of SCFA, especially C6:0 (caproic), C8:0 (caprylic) and C10:0 (capric) in free form, may be considered a beneficial fact, since these are responsible for the characteristic flavor of goat's milk, which is considered the main factor causing resistance to consumption of goat's milk and its derivatives by humans (Chilliard et al., 2003). Likewise, the reduction in the levels of MCFA C:12 – C:16 can also be considered a positive finding, since they are part of the group of compounds responsible for the development of cardiovascular diseases.

Reduced SCFA and MCFA contents and increased C18:1 and C18:2 c9, t11 CLA levels in the milk of goats fed lipid-supplemented diets were also reported in most studies (Bernard et al., 2005; Bouattour et al., 2008; Fernandes et al., 2008; Fábio José; Maia et al., 2006; Martínez Marín et al., 2012; Razzaghi et al., 2015), with slight divergences regarding the fatty acids and their contents.

As stated by Razzaghi et al. (2015), the reduction of saturated SCFA and MCFA in the milk of goats supplemented with lipid sources is a consequence of the reduced *de novo* synthesis in the mammary gland, which is offset by an increase in the levels of C18 fatty acids in the milk fat.

The reduction presented int his study by SCFA is greater in cows, reaching 69% (Roy et al., 2006), which may explain the reduced fat content in the milk of these animals when their diet is supplemented with lipid sources.

The increased concentration of the C18:1 family in the group fed the oil diet may be a consequence of the greater incorporation of available sources in the diet or the action of the Δ^9 desaturase enzyme on the C18:0 in the tissues of the mammary gland (Gómez-Cortés et al., 2011). Another possible explanation for the increase in C18:1 is a reduction in the *trans-10* pathway during biohydrogenation in the rumen, which would limit the synthesis of C18:2 t10, c12 CLA, considered an inhibitor of Δ^9 desaturase, or even a lower sensitivity of this enzyme for LCFA in goats (Bernard et al., 2010). These arguments can also be used to explain the low contents and lack of effects of the diet on the C18:2 t10, c12 CLA contents observed in the current study.

Increasing CLA levels in the milk of goats supplemented with lipid sources of vegetable origin are a well-established fact in the literature (Bernard et al., 2005; Bouattour et al., 2008; Fábio José; Maia et al., 2006; Martínez Marín et al., 2012; Razzaghi et al., 2015).

The latter acid may have two origins: the first, in a smaller quantity, is linoleic acid, considering that a small portion of CLA is formed during biohydrogenation in the rumen. Secondly, in a larger quantity, from the increased synthesis of vaccenic acid (C18:1 t11) during the biohydrogenation of linoleic and linolenic acids, which are carried by the bloodstream to the mammary gland in the desaturation process through the Δ^9 desaturase enzyme (Chilliard et al., 2007; Santos et al., 2011). This explains the increased concentrations of vaccenic acid C18:1 (t10-t12) observed in the avocado-oil diet compared to control

diet, which did not differ from the pulp diet. However, the proportional increase was sufficient to elevate CLA production (Table 7).

According to Bomfim et al. (2011) and Santos-Zago et al. (2008), the increase in the CLA profile is very important, since this class of linoleic acid (C18:2) isomers is recognized today as having anticarcinogenic, antiatherogenic, antidiabetic, antioxidant, immunomodulatory and hypocholesterolemic properties, as shown in studies with animals.

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

	Concentrate		
Ingredients	Control	Pulp	Oil
Soybean meal	100.00	147.60	112.4
Ground corn	560.00	382.40	182.6
Wheat	300.00	-	533.7
Limestone	10.00	10.70	14.1
Dicalcium phosphate	10.00	10.70	14.1
Mineral supplement[1]	20.00	23.10	28.1
Avocado pulp[2]	-	377.10	-
Avocado oil[3]	-	-	115.0
Chemical composition, expressed as estimated (g/kg DM)			
Nutrient			
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 detergent fiber	196.90	238.90	250.50
Acid detergent fiber	56.70	95.90	74.70
Chemical composition of the diets expressed as (g/kg DM[4)]			
Mineral matter	79.20	76.50	92.20
Crude protein	158.40	170.70	167.40
Ether extract	28.90	165.00	80.00
Crude fiber	194.70	128.70	207.10
Total digestible nutrients	668.50	808.70	693.90
Neutral detergent fiber	455.00	365.50	458.80
Acid detergent fiber	201.50	162.50	197.10

[1]Provides per kilogram of product: Ca 150 g, P 80 g, Na 110 g, S 40 g, Zn 2700 mg, Cu 300 mg, Mn 810 mg, I 62 mg, Co 64 mg, Se mg. [2]The variety used was Breda, [3] The variety used was Hass. [4]Based on the nutritional composition of the concentrates, chemical composition of *Panicum maximun* cv. Tobiatã (Table 2) and DM intake (Table 4).

Table 2. Chemical composition (g/kg DM) of forage and avocado pulp used in goat feeding

Nutrient	*Panicum maximum* cv. Tobiatã	Avocado variety Breda
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 detergent fiber	696.00	381.20
Acid detergent fiber	336.40	268.60

Table 3. Fatty acid profile (g/100 g of fat) of *Panicum maximum* cv. Tobiatã, concentrates and supplements

Fatty acids	Grass	Control concentrate	Concentrate without pulp	Pulp	Concentrate without oil	Oil
Saturated						
C16:0	30.29	16.37	16.05	22.65	18.74	23.71
C18:0	2.62	1.93	2.71	1.19	1.75	0.49
C18:1n c9	3.26	23.20	25.49	36.62	19.81	35.29
C18:1n c11	0.48	1.95	1.48	4.45	1.36	6.98
Others	0.61	1.53	1.47	3.33	1.20	4.54
C18:1						
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
SFA[1]	40.37	18.91	19.38	26.36	21.17	24.31
UFA[2]	55.38	80.57	79.92	68.36	78.02	74.04
MUFA[3]	8.94	27.64	29.23	50.48	23.56	60.83
PUFA[4]	46.44	52.93	50.69	17.88	54.46	13.21
MUFA/SFA[5]	0.22	1.46	1.51	1.91	1.11	2.50
PUFA/SFA[6]	1.15	2.80	2.62	0.68	2.57	0.54

[1]Saturated fatty acids, [2]Total unsaturated fatty acids, [3]Monounsaturated fatty acids, [4]Polyunsaturated fatty acids, [5]Total monounsaturated/total saturated fatty acid ratio, [6]Total polyunsaturated/total saturated fatty acid ratio.

Table 4. Average daily nutrient intakes according to the experimental treatments

Nutrient (1)	Treatment			SEM
	Control	Pulp	Oil	
		Total diet intake		
DM (g/day)	1357[b]	953[c]	1802[a]	89.19
CP (g/day)	214[b]	163[c]	301[a]	14.94
EE (g/day)	39[b]	157[a]	145[ab]	17.62
MIN (g/day)	107	73	166	9.63
TDN (g/day)	908[b]	778[b]	1251[a]	56.28
NDF (g/day)	618[b]	347[c]	827[a]	49.41
ADF (g/day)	274[b]	152[c]	355[a]	21.26
		Roughage intake		
DM (g/day)	702[a]	264[b]	842[a]	62.13
		Concentrate intake		
DM (g/day)	655[b]	689[ab]	959[a]	43.49
R:C[1]	51.73/48.27	27.70/72.30	46.73/53.27	

*Means followed by common letters in the row do not differ according to Tukey's test (P > 0.05).
[1]Roughage-to-concentrate ratio according to intake.
SEM: standard error of the mean.

Table 5. Composition and yield of milk from goats fed experimental diets

Variable	Treatment			SEM	Probability
	Control	Pulp	Oil		
Weight gain in the period (g/day)	40.47[b]	-73.45[a]	-71.43[a]	35.42	
Milk yield (kg/day)	1.84	1.46	1.67	0.12	0.2157
3.5%FMY(kg/day)[1]	2.14	1.77	2.06	0.14	0.1077
4.0%FMY (kg/day)[2]	1.98	1.63	1.90	0.14	0.1068
TSMY (kg/day)[3]	1.89	1.55	1.80	0.12	0.0873
Fat (%)	4.31[b]	4.68[ab]	4.94[a]	0.11	0.0203
Protein (%)	3.23	3.27	3.25	0.11	****
Lactose (%)	4.18	4.13	4.20	0.07	0.1958
Total solids (%)	12.67[b]	13.06[ab]	13.39[a]	0.15	0.0256
SNF (%)[4]	8.36	8.38	8.45	0.11	0.2178
LSCC (cells/mL)[5]	2.80	2.76	2.88	0.14	****
Urea nitrogen (mg/dL)	23.07	23.60	23.32	1.31	****

[1]3.5% fat-corrected milk yield, [2]4% fat-corrected milk yield, [3]Total solids-corrected milk yield, [4]Solids-not-fat, [5]Natural logarithm of somatic cell count.
SE: standard error. Means followed by common letters in the row do not differ according to Tukey's test (P > 0.05).

Table 6. Fatty acid profile of the milk (g/100 g fat) from cows fed control diet, a diet with avocado pulp and a diet with avocado oil

Variable	Treatment			SEM	Probability
	Control	Pulp	Oil		
Saturated					
C4:0	1.76	2.13	1.95	0.09	0.0946
C6:0	2.40	2.20	2.11	0.07	0.1163
C8:0	2.88[a]	2.16[b]	2.021[b]	0.14	0.0190
C10:0	10.23[a]	7.19[ab]	6.51[b]	0.62	0.0257
C11:0	0.11	0.045	0.064	0.01	0.0113
C12:0	4.40[a]	3.015[b]	2.61[b]	0.32	0.0608
C13:0	0.11	0.074	0.071	0.01	0.1084
C14:0	9.71[a]	7.79[ab]	6.32[b]	0.56	0.0199
C15:0	0.86[a]	0.58[b]	0.56[b]	0.05	0.0077
C16:0	24.85	26.00	29.71	0.84	0.0853
C17:0	0.66	0.72	0.53	0.03	0.0926
C18:0	13.17	14.41	14.54	0.74	****
C20:0	0.081	0.057	0.056	0.00	0.1053
Monounsaturated					
C14:1	0.14[a]	0.088[b]	0.082[b]	0.01	0.0062
C16:1	1.11[b]	1.25[b]	1.67[a]	0.07	0.0022
C17:1	0.22	0.34	0.20	0.03	0.3129
C18:1n c9	18.39	22.33	20.73	0.99	0.1080
C18:1n c11	1.23	1.61	1.47	0.10	****
C18:1n c12	0.69	0.89	0.82	0.06	****
C18:1n c13	0.37	0.46	0.45	0.03	****
C18:1n c15	0.027[b]	0.041[ab]	0.060[a]	0.00	0.0402
C18:1n (t6-t9)	0.28	0.37	0.66	0.06	0.1483
C18:1n (t10-t12)	0.77[b]	1.26[ab]	1.60[a]	0.11	0.0334
C18:1n t16	0.076[b]	0.12[ab]	0.16[a]	0.01	0.0156
Polyunsaturated					
C18:2n c9t11	0.29[b]	0.45[a]	0.48[a]	0.03	0.0170
C18:2n c9c12	2.051	1.60	1.68	0.08	0.0820
C18:2n t10c12	0.00	0.0027	0.0006	0.00	0.2427
C18:3n 3	0.12	0.098	0.087	0.01	****
C18:3n 6	0.068[a]	0.045[b]	0.053[b]	0.00	0.0086
C20:3n 3	0.0007	0.0028	0.0005	0.00	0.3858
C20:3n 6	0.0005	0.0002	0.0005	0.00	****
C20:4n 6	0.12	0.078	0.094	0.01	0.2648
C20:5	0.0028[b]	0.0035[ab]	0.0075[a]	0.00	0.0371
Chain					
Short	17.54[b]	13.82[a]	12.75[a]	0.77	
Medium	41.19	38.28	40.078	1.20	
Long	40.34	46.79	46.10	1.78	

SEM: standard error of the mean. Means followed by common letters in the row do not differ according to Tukey's test (P > 0.05).

Table 7. Percentage values of milk fatty acids (g/100 g of fat)

Variable	Treatment			Mean ± SE	P value
	Control	Pulp	Oil		
CLA[1]	0.29[b]	0.45[a]	0.48[a]	0.41 ± 0.03	0.0172
ω-3	0.19	0.15	0.14	0.16 ± 0.01	0.4060
ω-6	2.24	1.72	1.83	1.93 ± 0.09	0.0826
SFA[2]	72.77	67.62	68.38	69.59 ± 1.22	0.1436
MUFA[3]	23.57	28.95	28.10	26.87 ± 1.18	0.0884
PUFA[4]	2.72	2.33	2.45	2.50 ± 0.10	0.2865
MUFA/SFA[5]	0.32	0.44	0.41	0.39 ± 0.02	0.0945
PUFA/SFA[6]	0.037	0.035	0.035	0.036 ± 0.00	****
ω-6/ω-3[7]	12.44	11.90	14.033	12.79 ± 0.55	****
AI[8]	2.66	2.21	1.97	2.28 ± 0.19	0.1775
TI[9]	3.56	3.25	3.37	3.39 ± 0.17	****
HH[10]	0.60	0.75	0.63	0.66 ± 0.04	0.1983

[1]conjugated linoleic acid, [2]Saturated fatty acids, [3]Monounsaturated fatty acids, [4]Polyunsaturated fatty acids, [5]Total monounsaturated/total saturated fatty acid ratio, [6]Total polyunsaturated/Total saturated fatty acid ratio, [7]Omega 6/Omega 3 fatty acid ratio, [8]Atherogenicity index, [9]Thrombogenicity index, [10]Hypocholesterolemic/Hypercholesterolemic.
SE: standard error. Means followed by common letters in the row do not differ according to Tukey's test (P > 0.05).

Conclusion

Inclusion of commercial oil of avocado (8% EE, DM basis) in the diet of lactating goats increases DM intake, whereas avocado pulp (16.5% EE, DM basis) reduces DM intake, compared to control diet (3% EE, DM basis).

Milk yield is not influenced by the inclusion of avocado pulp or commercial oil, at the tested levels. However, the milk total solids and fat contents increase with supplementation of commercial oil.

Supplementing goat diets with unsaturated fatty acids via commercial oil of avocado and avocado pulp increases the CLA concentration and reduces the levels of short-chain fatty acids in the milk produced by those animals, improving its nutraceutical properties and consequently benefiting the health of consumers.

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