Journal of Applied Animal Research

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/taar20

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To cite this article: Cecilia Dauber, Tatiana Carreras, Gabriela Casarotto Daniel, Fabiana Cabrera, Adriana Liscano, Gabriela Vicente, Alejandro Britos, Silvana Carro, Cecilia Cajarville, Adriana Gámbaro & Ignacio Vieitez (2022) Adding sunflower or soybean oil to goat's pasture-based diet improves the lipid profile without changing the sensory characteristics of milk, Journal of Applied Animal Research, 50:1, 204-212, DOI: 10.1080/09712119.2022.2056464

To link to this article: https://doi.org/10.1080/09712119.2022.2056464

Published online: 28 Mar 2022.

JOURNAL OF APPLIED ANIMAL RESEARCH
2022, VOL. 50, NO. 1, 204–212
https://doi.org/10.1080/09712119.2022.2056464

Adding sunflower or soybean oil to goat's pasture-based diet improves the lipid profile without changing the sensory characteristics of milk

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ABSTRACT

The lipid profile of milk from grazing goats supplemented with vegetable oils was evaluated. Twenty-seven Saanen goats consuming pasture were grouped and supplemented with 3 concentrates: without added oil (control, C) and with added sunflower (SFO) or soybean oil (SBO) until 6% ether extract (diet basis). Fat content and sensory profile of milk were not modified. Vaccenic acid increased for SBO and SFO (1.5% vs. 2.6% and 2.7% respectively; $p < 0.01$), and cis-9, trans-11 conjugated linoleic acid from 0.6% to 0.8% for treated groups ($p < 0.01$). Oil supplementation resulted effective to decrease the saturated/unsaturated ratio of grazing goat's milk.

ARTICLE HISTORY
Received 7 April 2021
Accepted 17 March 2022

KEYWORDS
Goat milk; conjugated linoleic acid; vaccenic acid; oil supplementation; sensory profile

1. Introduction

The lipid composition of milk, particularly the fatty acids (FA), is involved in the production and quality of dairy products and directly affects their sensory characteristics (Medeiros et al. 2014). Some unsaturated fatty acids (UFA) in milk are associated with positive effects on human health (e.g. anticarcinogenic, antiatherogenic, and immune modulators). Among them, the conjugated linoleic acid (CLA), a family of geometric and positional isomers of conjugated dienes of linoleic acid (C18:2) produced by partial biohydrogenation of dietary UFA in the rumen, and the trans-11 C18:1 (vaccenic acid, TVA), a precursor of cis-9, trans-11 CLA, both UFA have potentially healthy properties and are present in dairy products in different amounts (Ferlay et al. 2017).

Therefore, the study of practical alternatives to increase the UFA in milk in a natural way, which can be used in the production system, as the addition of unsaturated lipids to ruminants' diet, are of current interest worldwide.

Studies concluded that it is possible to modify the fatty acid composition of ruminant products by manipulating their diet with appropriate dietary fat sources (Martínez Marín et al. 2012). An interesting characteristic of goats is the fact that they are more resistant than cows to milk fat depression after fat addition to the diet (Chilliard et al. 2007). Mele et al. (2008) and Bouattour et al. (2008) studied the inclusion of soybean oil in goat's diets and observed an increase of CLA and TVA. Meanwhile, Medeiros et al. (2014) observed an increase of CLA when sesame and faveleira oils were included in goat diets, but this effect was not observed after the inclusion of castor oil. These previous studies indicate that some vegetable oils as dietary supplements in goats are a promising alternative for increasing UFA in milk. However, there are not enough comparing common fat sources. Sunflower is one of the most used oilseeds in the world, while soybean oil is the lowest-cost source in several regions (Pilorgé 2020). Some recent studies compared supplementing goats with either sunflower seeds or sunflower oil and suggested that both enhanced CLA content in milk without detrimental effects on animal performance (Morsy et al. 2015). Luna et al. (2008) compared the response in milk yield and composition supplementing with linseed or sunflower oil for 90 days and observed an increase in CLA content that persisted during the whole period. Martínez Marín et al. (2013) compared the supplementation of goats with different oil sources and observed that the more unsaturated the oil, the better was the fatty acid profile of milk from a health point of view. Meanwhile, Ollier et al. (2009) studied the response in milk composition of goats that received either a high or low ratio forage/concentrate diets, supplemented with oils, and observed that sunflower oil increased CLA concentrations in diets with a high level of concentrates. All these studies used diets based on hay, cereals, and dried by-products. Meanwhile, the information existing on pasture-based systems is scarce, although a wide world region produces milk on pasture-based systems. Recently, Tudisco et al. (2019) found higher total CLAs in milk of grazing goats when diet was supplemented with linseed mainly due to the increase of CLA cis-9 trans-11. Working with cows, Mendoza et al. (2016) observed CLA improvements and, in general, beneficial properties of milk, in cows consuming fresh pastures, even with a low

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level of pasture inclusion in the diet. It is reasonable to question if the benefits of adding vegetable oils to the diet of goats persist in pasture-based systems, when it is supposed that animals are already producing a 'more healthy' milk. Indeed, working on grazing conditions, Eknæs et al. (2009) observed that supplementing with saturated fatty acids reduced tart and rancid flavours in the milk of goats under grazing conditions, respect to supplementing with sunflower oil.

Sensory characteristics of goat milk products are another challenge for production and industry. Goat milk has caproic (C6:0), caprylic (C8:0), and capric (C10:0) acids in a higher proportion than milk produced by other ruminants (Chilliard et al. 2003), which are responsible for its characteristic flavour when this volatile fatty acids are released by hydrolysis or lipolysis (Luna et al. 2008). Flavour and aroma are key to describe goats' milk sensory profile, but as far as we could find, there is little background in the literature on the description of a complete sensory profile of goat milk. For instance, the study reported by Eknæs et al. (2009) examined the effect of different fat sources in grazing goats on sensory properties. This study shown that feeding concentrate with a high fat supplement, consisting mostly of C16:0 and C18:0 (saturated long chain fatty acids), increased the content of C16:0 in the milk but reduced the perception of rancid and tart flavour of milk.

Thus, this study aimed to compare the changes in the lipid profile of goat's milk on a pasture-based feeding system through the inclusion of two of the most used vegetable oils rich in polyunsaturated fatty acids (PUFA): soybean and sunflower oil. The main interest was to increase CLA and TVA contents, with a decrease in the proportion of saturated fat. Additionally, it was also studied if these changes in the milk led to any modification from the sensory point of view. The particularity of this study is based on comparing two of the most used oilseeds in the world (but not the most studied ones) under pasture-based conditions.

2. Materials and methods

2.1. Animals, experimental design and diets

The experiments were carried out on the premises of a commercial goat farm in Uruguay (34°S and 56°W). In a randomized complete block design, twenty-seven multiparous Saanen goats were selected and blocked by days in milk (DIM) to deal with this nuisance variable, separated into three equal groups ($n = 9$), arranged in trios inside the group, and ultimately trios were randomly assigned to treatments. Thus, each group of three goats was considered as the experimental unit and each goat was the sampling unit. Each group was supplemented for 50 days with 750 g/d of 3 concentrates: (1) without added oil (control diet, C), (2) with added sunflower oil (SFO) or (3) with added soybean oil (SBO).

The goats were under the typical management of a commercial dairy farm in Uruguay, a semi-extensive rearing system with direct grazing of pastures (mixture of implanted grasses and legumes) and nocturnal stabling with a supply of whole plant corn silage or prairie hay. Before the beginning of the experiment, the concentrate used as supplement (wheat bran, corn grain and soybean meal), was provided outside the parlour, collectively.

All experimental diets were formulated using the software package Capricorn 2010 Demo Version (UC Davis, EEUU) to meet the nutrient requirements of an average lactating goat weighing 55 kg of live weight (LW), with 51 days of lactation, and daily production of 3.5 kg of milk with a fat content of 3.5%. Total dry matter intake (TDMI) was estimated by the software as 3.6 of the LW. Considering the data provided by the software, the pasture available in the farm at the beginning of the experiment, and the characteristics needed for the concentrate to meet the experimental amounts of oil (see below), the whole diet had a ratio forage to concentrate of 2/1, being the forage provided mainly by grazing pasture (approximately 80%). Due to the grazing management of the farm, the direct determination of pasture intake was not possible, and then was estimated as the difference between the TDMI and the amount of concentrate offered. After this estimation, the final diet was composed by 0.675 kg dry matter (DM) of concentrate and 1.31 kg DM of forage (approximately 1.050 kg from pasture and 0.260 kg from silage or hay).

The oils were incorporated into the concentrate to reach 10% of EE (DM basis) for SFO and SBO treatments, taking care that the percentage of EE in the total diet did not exceed 6% of EE (DM basis). Therefore, the oils were incorporated to the concentrate at 7.6% of DM, and this resulted in a 2.6% of oil added to the TDMI. This level of EE was previously tested using the same concentrates and alfalfa hay (35:65 ratio) in a previous *in vitro* experiment using a RUSITEC system (Casarotto et al. 2020) in which two levels of sunflower and soybean oil addition to reach 6.0 and 7.5% of EE of dry matter (DM) in the whole diet were evaluated. In this study, we observed an increase in the concentration of TVA (C18:1 t11) and a decrease in the concentration of saturated acids (mainly C16:0). In the light of the results obtained, and considering economic concerns for practical uses (cost of the concentrate), the lowest oil content was used in the following experiments.

Goats were milked twice daily and the concentrates (C, SFO, and SBO) were offered individually in the milking parlour feeders in 2 equal portions of 375 g while being milked. The concentrates (Table 1) contained ground corn grain, wheat bran, soybean meal, calcium carbonate, sodium chloride, monocalcium phosphate, sodium bicarbonate, magnesium oxide, vitamins, and minerals premix. The diet of the goats previously at the beginning of the study was a pasture-based feeding system. Goats were adapted to the diets and management for 10 days before beginning the measurement period.

2.2. Measurement and sampling

Milk samples were collected at the beginning of the experiment (day 0) and then on days 7, 18, 25, 34, and 46, individually, using specific milk metres for goats (Tru-Test, Datamars Livestock), during the morning milking. Milk yield was registered at each sampling period. Then, individual samples were pooled (proportionally to the individual milk production), to make a single composite sample for the experimental unit (group of 3 goats). The composite samples were immediately

Table 1. Chemical composition and percentage of fatty acid profile of the concentrates.

	Treatment		
Nutrient	Control	SFO	SBO
DM (%)	90.0	90.0	90.0
Organic Matter (OM, % DM)	90.7	90.5	90.5
Crude Protein (CP, % DM)	17.0	15.5	15.5
Neutral detergent fibre (NDF % DM)	9.1	9.0	9.0
EE (% DM)	2.7	10.0	10.0
Metabolizable energy (EM, Mcal/kg DM)	2.7	2.9	2.9
C16:0 (% DM)	0.72	1.08	1.66
	(26.8)	(10.8)	(16.6)
C18:0 (% DM)	0.09	0.43	0.55
	(3.4)	(4.3)	(5.5)
C18:1 c9 (% DM)	0.80	4.37	3.32
	(29.6)	(43.7)	(33.2)
C18:2 c9,c12 (% DM)	0.89	3.85	3.39
	(32.9)	(38.5)	(39.9)
C18:3 c9, c12, c15 (% DM)	0.10	0.11	0.34
	(3.8)	(1.1)	(3.4)
C20:1 c9 (% DM)	0.02	0.03	0.04
	(0.6)	(0.3)	(0.4)

SFO supplemented diet with sunflower oil.
SBO supplemented diet with soybean oil.
Values between brackets are fatty acid concentrations expressed as % of total fatty acids.

cooled upon collection to be transferred to the laboratory where a sub-sample was separated for the analysis of the fatty acid profile and another sub-sample for the analysis of the composition. They were immediately frozen (−18°C) until analysis.

2.3. Chemical analysis

2.3.1. Milk composition analysis

The determination of protein and lactose content in raw milk was carried out by the ultrasonic technique using a Lactoscan SP in mode goat milk (Milkotronic Ltd., Nova Zagora, Bulgaria). For each sterilized milk sample (see 2.5), the protein content was measured in triplicate according to the Kjeldahl method (AOAC 2007).

2.3.2. Fat extraction

The fat was extracted from milk samples (3 g) of each diet treatment, according to the Röse-Gottlieb technique (AOAC 2001). Analyses were carried out in triplicate.

2.3.3. Determination of fatty acid profile

Fatty acid methyl esters were prepared by base-catalyzed methanolysis of the glycerides according to IUPAC 2.301 protocol (IUPAC 1987) with a methanol solution of KOH 2 N, and analyzed by gas chromatography [according to AOCS Ce 1c-89, AOCS Ce 1f-96 (AOCS 1990)] using Shimadzu (Kyoto, Japan) model 14B equipped with a Supelco (Bellefonte, PA) SP 2560 (100 m × 0.25 mm × 0.2 mm) capillary column and a flame ionization detector (FID). The temperature program used was the following: initial temperature 90°C for 2 min, then increasing to 175°C at 20°C/min and maintained for 35 min, then increasing to 240°C at 15°C/min and maintained for 25 min. Peak identification was accomplished through the analysis of authentic standards (F.A.M.E. Mix, C4-C24 and linoleic acid conjugated). Standards and reagents used for the analysis were supplied by Sigma–Aldrich (United States). Finally, cis-9, trans-11 CLA coeluted with other minor isomers.

2.4. Sensory analysis

Milk from the fifth sampling day (40 days after feeding started) was thermally treated in plastic bottles and stored for sensory evaluation. Sterilization of bottled milk was done in a batch system reaching 120°C as maximum temperature and a total time of 90 min considering the whole temperature ramp.

The sensory panel consisted of eleven assessors (six females and five males), aged 25–55 years, who were members of the Panel of Judges of the School of Chemistry at the Universidad de la República (UdelaR). Assessors were selected following the guidelines of the ISO 8586-1 standard (ISO 2007). They all had a minimum of 200 h of experience in discrimination and descriptive tests of different foods, and particularly more than 50 h of experience in the evaluation of milk. Sensory analysis of the goat milk samples was performed by a quantitative descriptive analysis technique (Stone and Sidel 1993).

Initially, the assessors described the sensory characteristics of the milk samples. During this phase, reviewed all samples, agreed with suitable descriptive terms for the flavour, and then defined the intensity for each of these descriptors. For each sample, the assessors evaluated the following attributes: white colour, creaminess, sourness, bitterness, sweetness, goat flavour, dairy flavour, strange flavour, oil flavour, persistent flavour, rancid flavour, soft flavour, saltiness, and intense flavour. Unstructured 10-cm-long scales anchored with 'nil' and 'high' were used to describe the attribute intensity.

All milk samples were stored under refrigeration and brought to room temperature (22 ± 2°C) 2 h before testing by the panel. Twenty mL of milk samples were supplied in plastic glasses coded with three-digit random numbers. Samples were presented in random balanced order and duplicate evaluations were performed for each sample of milk. Sensory testing sessions were held in a standard evaluation room, as described in ISO 8589 (ISO 2007). Drinking water at room temperature and salt-free crackers were used for mouth-rinsing between samples. Three codified samples were presented each session: Control, SFO, and SBO. The test was held in duplicate for every sampling period. The assessors evaluated the samples at 1 (T0), 30 (T1), 60 (T2), and 90 (T3) days of storage.

2.5. Microbiological analyses

The sterilized milk used for sensory evaluation was tested for microbiological quality to confirm it was safe for consumer intake. The total count of mesophilic aerobic microorganisms was determined according to APHA (2001) using the standard plate count agar (PCA) for 24 h.

2.6. Statistical analysis

Data from milk yield, composition, fat content and fat profile were analyzed by PROC MIXED of SAS® (SAS Institute Inc.,

Cary, NC) using the following statistical model:

$$y_{ijk} = \mu + T_i + M_j + B_k + (T \times M)_{ij} + e_{ijk}$$

where y_{ijk} is the dependent variable, μ is the overall mean, T_i is the fixed effect of the oil treatment i ($n = 3$; without oil, with SFO or with SBO), M_j is the fixed effect of the sampling period j ($n = 5$), B_k is the random effect of the block k ($n = 3$), $T \times M$ is the effect of an interaction of oil supplementation by sampling period and e_{ijk} is the residual error. Data obtained in the day 0 were used as covariates. Each goat was considered as the sampling unit, whereas each group of three goats was the experimental unit. Thus, the structure of repeated measures used the individual goat as the subject of repetition, which leads with the fact that, for a specific animal, one measure is linked with another one. A first-order autoregressive covariance structure was used. Treatment means were compared using the least-squares means procedure (LSMEANS) of SAS® with the PDIFF option. Significant differences were considered when $p < 0.05$ and $0.05 < p < 0.10$ were considered a tendency.

All data provided by the panel of assessors were subject to an ANOVA, using 'assessor', 'time', and 'sample' as fixed factors. Mean ratings and honestly significant differences were determined, based on Tukey's test ($p < 0.05$).

3. Results and discussion

3.1. Dairy performance

The average fat percentage values (Table 2) were within the range expected for goat milk according to bibliographic references (Kholif et al. 2018). The supplementation with sunflower oil showed a trend of 1.3% in milk yield related to the control diet and 7.6% to soybean oil supplementation (Table 2). No differences in milk fat content were observed ($p > 0.05$). A decrease in total milk production from 1.9 to 1.2 L/milking ($p < 0.001$) was observed in the whole herd throughout the experimental periods of the study, as well as a decreasing trend in milk protein ($p = 0.080$) and lactose ($p = 0.079$) content, which were expected as a natural variation of lactation stage. This effect cannot be attributed to the diets provided since the interaction between treatment and day was not significant and a similar downward in production was observed in the rest of the herd. The fact that the milk yield decreased gradually during lactation agrees with other studies (Luna et al. 2008). It is known that in goats, the response of raw milk yield to lipid supplementation is different during early and mid-lactation (Chilliard et al. 2003). While in early-lactation, lipid supplementation tended to increase milk yield (Mele et al. 2008), in mid or late-lactation feeding with lipid supplemented diets did not modify milk yield (Chilliard et al. 2003; Bouattour et al. 2008; Ferlay et al. 2017).

Milk fat content was similar between treatments and did not differ between sampling dates ($p > 0.05$). Several authors observed similar results (Luna et al. 2008; Eknæs et al. 2009; Martínez Marín et al. 2012; Medeiros et al. 2014). For instance, Medeiros et al. (2014), concluded that supplementation with 4.0% of vegetable oil (sesame or castor) in dairy goat diets did not promote an increase in the percentage of total fat in the milk. However, there are also studies reporting that milk fat content was improved when feeding diets supplemented with vegetable oils to dairy goats (Silva et al. 2020).

One problem encountered with lipid supplementation in dairy cows is that the milk protein content is generally reduced (Ferlay and Chilliard 2020), altering coagulation properties. This negative effect of dietary fat on milk protein content seems to be unusual in dairy goats (Bouattour et al. 2008; Mele et al. 2008), as observed in the present study.

In some studies reported in the literature, lipid supplementation increased lactose concentration (Bernard et al. 2009; Kholif et al. 2018), but many other studies reported that dietary supplementation with vegetable oils did not affect milk lactose content (Eknæs et al. 2009; Martínez Marín et al. 2012; Prieto-Manrique et al. 2018), as seen in our study.

3.2. Milk fatty acid profile in raw milk

Despite differences in the quantitative responses (milk yield), the measured milk FA composition was remarkably similar with both oils used (SBO and SFO) (Table 3). Nevertheless, it is necessary to point out that there are FA being probably affected, which were not measured in the present study (e.g. branched-chain FA or some other 18:1 and 18:2 isomers).

The saturated FA content was reduced progressively by adding SBO and SFO to diets ($p = 0.006$), which can be explained by the inhibitory effect of long-chain PUFA on ruminal biohydrogenation, and because de novo synthesis would have also been affected by oil supplementation, as described by Silva et al. (2020). Meanwhile, the concentration of polyunsaturated FA increased with the inclusion of oils ($p = 0.0401$). This is a frequent observation in goat experiments as reported by other authors (Sanz Sampelayo et al. 2007; Bernard et al. 2009).

Table 2. Milk yield and composition (wt %) of dairy goats according to the different diets.

	Treatment				*P*-value		
Variable	Control	SFO	SBO	SEM	Treat	Day	Treat × Day
Individual production (L/milking)	1.54 (±0.17)$^{+}$	1.56 (±0.25)$^{+}$	1.45 (±0.24)$^{+}$	0.042	0.158	<.001	0.279
Protein (wt %)	3.02	2.99	3.06	0.150	0.909	0.080	0.385
Lactose (wt %)	4.39	4.36	4.46	0.220	0.912	0.079	0.378
Lipid (wt %)	3.96	4.02	3.89	0.090	0.591	0.976	0.770

SFO supplemented diet with sunflower oil.
SBO supplemented diet with soybean oil.
SEM standard error of the mean.
$^{+}$Range between days.

Table 3. Fatty acid profiles of fluid milk (g/100 g fat) from goats fed control (C), SFO, and SBO diets.

	Treatment				*P*-value		
Variable	Control	SFO	SBO	SEM	Treat	Day	Treat × Day
C4:0 (g/100 g fatty acids)	1.5	2.2	1.7	0.054	<.001	<.001	<0.001
C6:0 (g/100 g fatty acids)	2.3	2.7	2.2	0.071	<.001	<.001	<0.001
C8:0 (g/100 g fatty acids)	3.0	3.0	2.8	0.114	0.177	<.001	0.019
C10:0 (g/100 g fatty acids)	11.1	10.2	10.3	0.382	0.064	0.031	0.118
C11:0 (g/100 g fatty acids)	0.21	0.31	0.20	0.078	0.387	0.398	0.522
C12:0 (g/100 g fatty acids)	4.3[a]	3.7[b]	3.8[b]	0.160	0.012	0.001	0.580
C14:0 (g/100 g fatty acids)	10.8[a]	9.7[b]	10.0[b]	0.244	<.001	0.010	0.887
C15:0 (g/100 g fatty acids)	0.9	0.9	0.8	0.031	0.361	0.069	0.447
C16:0 (g/100 g fatty acids)	26.0[a]	23.7[c]	24.9[b]	0.438	0.005	<.001	0.139
C16:1 *c*9 (g/100 g fatty acids)	0.3	0.3	0.3	0.019	0.766	0.014	0.773
C17:0 (g/100 g fatty acids)	0.6	0.6	0.6	0.014	0.813	0.281	0.264
C18:0 (g/100 g fatty acids)	11.4[b]	13.0[a]	12.7[a]	0.295	0.018	<.001	0.388
C18:1 *c*9 (g/100 g fatty acids)	18.0	18.7	17.9	0.675	0.396	0.009	0.561
C18:1 *t*9 (g/100 g fatty acids)	0.4	0.4	0.4	0.026	0.638	0.005	0.191
C18:1 *t*11 (TVA) (g/100 g fatty acids)	1.7[b]	2.7[a]	2.8[a]	0.080	<.001	0.008	0.172
C18:2 *c*9, *c*12 (g/100 g fatty acids)	2.0	2.2	2.4	0.075	0.064	0.089	0.234
Σ 18:2 trans (g/100 g fatty acids)	0.7[b]	0.7[b]	0.9[a]	0.045	0.003	0.043	0.168
C18:2 *c*9, *t*11 (CLA) (g/100 g fatty acids)	0.7[b]	0.8[a]	0.9[a]	0.025	<.001	0.7094	0.223
C18:3 *c*9, *c*12, *c*15 (g/100 g fatty acids)	0.7	0.8	0.8	0.081	0.938	0.009	0.365
Saturated (g/100 g fatty acids)	72.39[a]	70.4[b]	70.1[b]	0.737	0.006	0.089	0.411
Mono-unsaturated (g/100 g fatty acids)	18.3	19.0	18.2	0.677	0.415	0.010	0.563

SFO diet supplemented with sunflower oil.
SBO diet supplemented with soybean oil.
SEM standard error of the means.
In different letters, significant differences were considered when $p < 0.05$.

Interactions between treatment and sampling date were observed for butyric (C4:0), caproic (C6:0), and Caprylic (C8:0).

Sunflower oil supplementation led to higher contents of butyric acid (C4:0) and caproic acid (C6:0) on days 25 and 46 compared to other treatments ($p < 0.001$, data not shown in Table 3). The content of butyric acid and caproic acid in supplemented and non-supplemented diets did not differ on the rest of the experimental days. Likewise, soybean oil supplementation led to a higher content of butyric acid compared to the control diet on day 25. The decrease in the content of short- and medium-chain SFA (C4:0-C10:0) observed with supplemented diets could be a consequence of the negative effects of oils on the de novo synthesis of these FA. It is known, that the increase of preformed FA flow and the presence of biohydrogenation isomers (especially trans-10, cis-12 C18:2) in the mammary gland reduces short and medium-chain SFA by reducing the acetyl-CoA carboxylase activity among other enzymes (Bernard et al. 2017; Silva et al. 2020).

Besides, higher contents of lauric (C12:0) and myristic (C14:0) acids were observed for animals fed with the control diet ($p <$ 0.001), with no differences between sunflower or soybean oil supplementation.

The lowest content of palmitic acid (C16:0) was observed for animals supplemented with sunflower oil and was 5.1 and 9.7% higher in animals supplemented with soybean oil and fed the control diet, respectively.

The content of CLA and TVA were higher in the milk from goats fed with the two supplemented diets (SBO and SFO) compared to the control diet (C). According to Tudisco et al. (2012), the increase of milk CLA could be due to the increase of SCD activity in mammary gland, which can be measured by comparing the product:substrate ratios of certain fatty acids. In fact, in the present trial C16:1/C16:0 ratio was higher in both treated compared to control group (0.0115 vs. 0.0127 vs. 0.0120 for group Control, SFO and SBO, respectively). It should be noted that the increase in the content of these fatty acids occurred from the beginning of the study (sampling day 7) but then, the values remained stable in time (Figures 1 and 2). Throughout the whole feeding trial, the composition of the diets had a marked positive effect on TVA and CLA levels of the milk fat produced. The oil-supplemented diets led to higher TVA concentration in milk ($p < 0.001$), compared to milk from goats fed the control diet (Figure 1). The levels of CLA were higher when the goats were fed soybean and sunflower oil diets ($p <$ 0.05), but in sampling days 18 and 25 this concentration did not differ from the control treatment (Figure 2).

The saturated/unsaturated ratio was lower for milk derived from goats fed SFO, followed by those fed SBO and finally those fed the control diet, indicating that either of these two enriched diets would be a good alternative to improve the lipid profile of goat milk from the standpoint of health benefits.

3.3. Sterilized milk

3.3.1. Chemical analysis (composition and fatty acid profile)

Milk fat and protein content were not affected by thermic treatment (Table 4), and no differences were observed for protein and fat contents between control and supplemented diets.

Percentages of FA were also like raw milk (Table 5). The slight reductions of some poly-unsaturated FA are logical as they are labile compounds. There was an apparent increase in some saturated ones (like C16:0), which is consistent since FA were expressed as percentage of fat. Also, the effect of the treatments was revealed in sterilized milk in a similar way as in raw milk, with differences mainly observed between the control and the other two treatments, and similar profiles for soybean and sunflower diets.

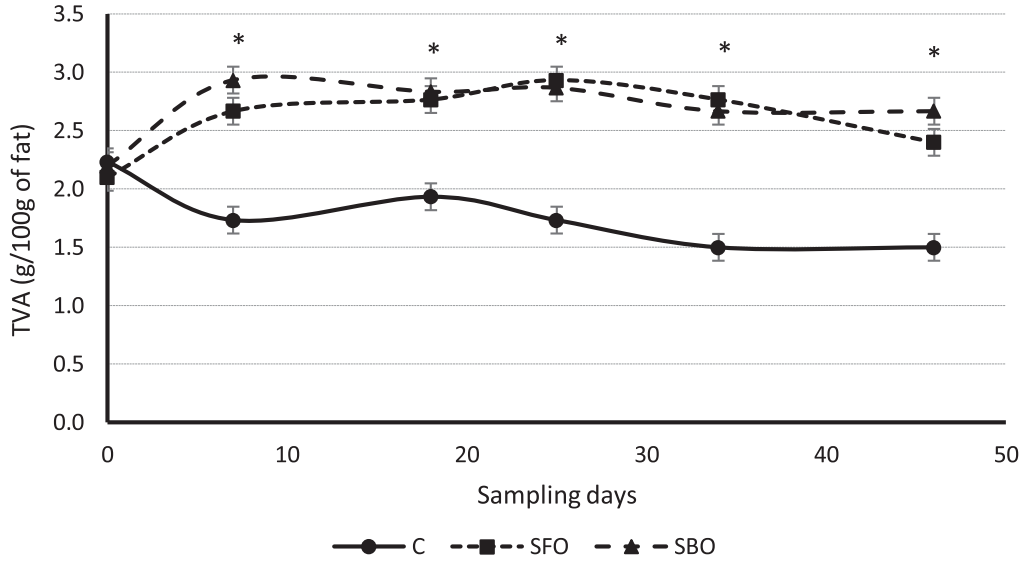

Figure 1. Evolution of TVA in 100 g of fluid milk fat during the sampling period.

Note: *C control diet
*SFO diet supplemented with sunflower oil
*SBO diet supplemented with soybean oil

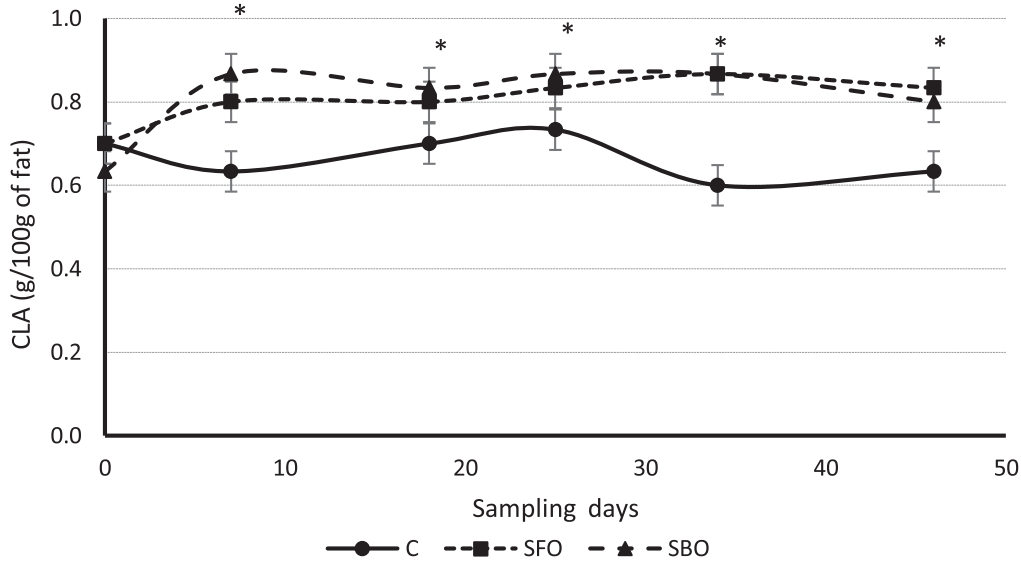

Figure 2. Evolution of CLA in 100 g of fluid milk fat during the sampling period.

Note: *C control diet
*SFO diet supplemented with sunflower oil
*SBO diet supplemented with soybean oil

Similarly to raw milk, a slight decrease in the content of short- and medium-chain SFA (C4:0-C10:0) was found in the sterilized milk (Table 5) for soybean and sunflower diets respect to the control. The higher volatility and water solubility of short- and medium-chain fatty acids, compared with long-chain fatty acids, explains their considerable effect on the sensory properties of cheese, despite being less abundant than long-chain fatty acids (Vieitez et al. 2016; Gámbaro et al. 2017). The reduction in the concentration of C4:0 to C10:0 is of interest to the dairy industry since those FAs confer odour and flavour of the goat milk that are commonly not appreciated by a certain range of consumers (Chilliard et al. 2003; Silva et al. 2020). Yet, caproic (6:0) and caprylic (8:0) acids related to the 'goaty' flavour intensity of caprine milk are believed to have a positive contribution to the sensory properties of derived dairy products (Gómez-Cortés et al. 2019).

Table 4. Milk fat and protein contents of sterilized milk of dairy goats fed control (C), SBO, and SFO diets.

	Treatment			
Variable	Control	SFO	SBO	*P*-value
Protein/100 g milk	3.06 ± 0.06	3.02 ± 0.03	3.04 ± 0.03	0.149
Fat/100 g milk	3.87 ± 0.08	3.91 ± 0.07	3.81 ± 0.08	0.491

SFO diet supplemented with sunflower oil.
SBO diet supplemented with soybean oil.

Table 5. Fatty acid profile of sterilized milk of dairy goats fed control (C), SFO, and SBO diets.

	Treatment				
FA (g/100 g fatty acids)	Control	SFO	SBO	SEM	*P*-value
C4:0	3.3[b]	2.6[a]	2.6[a]	0.067	0.001
C6:0	3.2	3.0	2.7	0.217	0.463
C8:0	3.4	3.2	3.0	0.137	0.463
C10:0	11.2	10.2	10.1	0.741	0.296
C11:0	0.2	0.2	0.2	0.054	>0.999
C12:0	4.0[b]	3.6[a]	3.6[a]	0.017	0.014
C14:0	10.6[b]	9.9[a]	9.8[a]	0.029	0.002
C15:0	0.8	0.8	0.8	0.067	>0.999
C16:0	25.5[b]	23.8[a]	25.3[b]	0.141	0.003
C16:1 n-7	0.3	0.3	0.4	0.067	0.296
C17:0	0.6	0.6	0.6	0.033	>0.999
C18:0	10.9[a]	12.9[b]	12.2[a,b]	0.377	0.019
trans-9 C18:1	0.3	0.3	0.3	0.067	>0.999
trans-11 C18:1 (TVA)	1.5[a]	2.6[b]	2.7[b]	0.013	<0.001
cis-9 C18:1	17.8[a]	18.6[b]	18.3[a,b]	0.101	0.045
Σ 18:2 trans	0.7	0.7	0.7	0.067	>0.999
cis-9, *cis*-12 C18:2	1.9[a]	2.0[a,b]	2.2[b]	0.067	0.011
cis-9, *cis*-12, *cis*-15 C18:3	0.6[a]	0.5[a]	0.7[b]	0.022	0.011
cis-9, *trans*-11 C18:2 (CLA)	0.6[a]	0.8[b]	0.8[b]	0.017	<0.001
Σ saturated	73.7[b]	70.8[a]	70.9[a]	0.542	0.002
Σ unsaturated	23.7[a]	25.8[b]	26.0[b]	0.137	0.010

SFO diet supplemented with sunflower oil.
SBO diet supplemented with soybean oil.
SEM standard error of the means.
In different letters, significant differences were considered when $p < 0.05$.e

It is important to note, that TVA and CLA concentrations seem to have been unaffected by this thermic treatment employed and the positive impact of using soybean and sunflower in the diets was similar for raw and sterilized milk. These findings are important from producers' and consumers' points of view, as the inclusion of oils improves the production of healthier milk for direct consumption, which usually undergoes pasteurization heat treatment.

Similar behaviour with the raw milk was found in sterilized milk content of lauric (C12:0) and myristic (C14:0) acids were reduced by both oil-supplemented diets ($p < 0.05$). Also, feeding SFO reduced milk concentration of palmitic acid (C16:0) in sterilized milk ($p < 0.05$), this behaviour is different than in the raw milk. The decrease in the concentration of C12:0, C14:0, and C16:0 is positive since the excessive consumption of these FA promotes the increase of plasma cholesterol and cholesterol associated with low lipoproteins (LDL). High concentrations of LDL are associated with a greater predisposition to cardiovascular diseases (CVD), especially C14:0 (Silva et al. 2020).

In the raw milk, the concentration of polyunsaturated FA increased with the inclusion of oils ($p = 0.0401$). The same behaviour was observed for the sterilized milk ($p < 0.01$). In the sterilized milk, the most important increase was observed for TVA, which increased from 1.5 to 2.6 and 2.7% for SBO and SFO respectively ($p < 0.0001$). Besides, CLA content presented an increase from 0.6 to 0.8% for both supplemented diets ($p < 0.0001$). As CLA is also originated from the ruminal biohydrogenation of linoleic acid, an increase in its concentration via a diet enriched with linoleic acid source is expected (Kholif et al. 2018). Therefore, the treatments affected similarly raw and sterilized milk and this is the most important fact.

Table 6. Sensory profile of sterilized goat milk at time 0 (1 day of storage).

	Treatment			
Attribute	Control	SFO	SBO	*P*-value
White colour	5.0	5.3	5.3	0.237
Creaminess	1.7	1.8	1.7	0.991
Sourness	1.6	1.6	1.6	0.997
Bitterness	0.3	0.6	0.5	0.606
Sweetness	3.4	3.3	3.5	0.402
Goat flavour	3.7	3.5	4.3	0.963
Dairy flavour	4.5	4.4	4.5	0.769
Strange flavour	1.0	1.2	1.8	0.561
Oil flavour	1.9	1.1	1.1	0.462
Persistent flavour	3.5	3.1	3.9	0.607
Rancid flavour	0.4	0.3	0.8	0.458
Saltiness	2.7	3.1	2.6	0.845
Flavour intensity	5.2	5.6	4.8	0.721

SFO diet supplemented with sunflower oil.
SBO diet supplemented with soybean oil.

3.3.2. Microbiological analyses

The efficiency of the thermic treatment was determined by counting total mesophilic aerobic microorganisms. A result of <10 UFC/mL in the three samples analyzed was obtained, which meets the quality standards of sterilized milk according to the National Regulations for this kind of product.

3.3.3. Sensory analysis

No differences ($p > 0.05$) were found between control and supplemented diets' milk for any of the attributes evaluated (Table 6) being sensory characteristics of the samples very similar at the beginning of the storage period in terms of their sensory descriptors. All milk samples presented medium intensities of white colour, sweetness, goat flavour, dairy flavour, persistent flavour, and flavour intensity, with values between 3.3 and 5.6 on an unstructured 10-cm-long scale.

There were no major changes in the sensory profile during the storage time of 90 days. Neither time nor feeding significantly affected ($p > 0.05$) the sensory profile of the samples.

All the samples evaluated throughout the storage time presented low values of creaminess (1.7–1.8), sourness (0.8–1.6), bitterness (0.3–0.5), strange flavour (1.0–1.8), oil flavour (1.1–1.9), and rancid flavour (0.3–0.8), on a 10.0 cm scale. Likewise, all the samples evaluated presented higher intensities of white colour (5.0–5.3), sweetness (3.3–3.5), goat flavour (3.5–4.3), salty (2, 6–3.1), dairy flavour (4.3–4.6), persistent flavour (1.1–3.5) and flavour intensity (4.8–5.6), on a scale of 10.0 cm.

Only a significant decrease in sourness ($p = 0.0002$) was found between time 0 (1.6) and the other storage times, with values of 1.0 (T1, 30 days of storage), 0.9 (T2, 60 days of storage), and 0.8 (T3, 90 days of storage). The same behaviour was observed with persistent flavour, with a significant difference ($p < 0.0001$) between time 0 (3.5) and the other storage times, with values of 1.5 (T1), 1.2 (T2), and 1.1 (T3).

In general, the inclusion of vegetable oils rich in PUFA in the diet was well tolerated by goats, improved the content of TVA and CLA, and did not substantially change the sensory characteristics of milk. These changes represent an improvement in the production of healthier milk for direct consumption and deliver a better raw material for the elaboration of dairy products (e.g. cheese). The slight differences observed in short- and medium-chain SFA (main responsible for the sensory characteristics of milk products, as mentioned before), can explain the absence of significant sensory changes in the milk

produced. Finally, it should be said that the impact of these changes on human health will depend on the consumption rate of goat's milk by the population.

4. Conclusions

In this study, it was possible to modify the lipid profile of goats' milk in a grazing system, by including vegetable oils rich in PUFA in their diet. Feeding both soybean oil and sunflower oil to dairy goats led to a noticeable increase of TVA and CLA, a decrease in the saturated/unsaturated ratio. Goats seem to tolerate the addition of unsaturated fat well, without detrimental effects on animal performance. On the other hand, total milk fat and protein content, microbiological and sensory profile of goat milk were not affected by the diets. This could lead to an improvement in the production of healthier milk for direct consumption, and/or elaboration of different derived dairy products. It is noteworthy that, the impact of these changes on human health will depend on the consumption rate of goat's milk by population, which is very variable worldwide. However, this kind of study will help goat's milk producers to reach other consumer sectors. For future studies, it would be of interest to perform measurements that allow to go deeper on some FA that would change with different oils as branched-chain FA (e.g. iso and anteiso 15:0 or 17:0), or separate some isomers (e.g. trans-11 and trans-10 18:1).

Acknowledgements

All experimental procedures were approved by the ethical committee guidelines of the Honorary Commission of Animal Experimentation (CHEA) from UdelaR, following guidelines from the Ethical Commission for the Use of Animals (CEUA, Faculty of Veterinary, protocol number 652).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This study was funded by Comisión Sectorial de Investigación Científica (CSIC; Uruguay) with financial support and Programa de Desarrollo de las Ciencias Básicas (PEDECIBA)-Química programs (Uruguay).

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