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Influence of supplemental canola or soybean oil on milk yield, fatty acid profile and postpartum weight changes in grazing dairy goats

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Objective: This experiment was designed to evaluate the effect of supplementation with soybean or canola oil on milk production and the composition of long chain fatty acids as well as weight changes in the goats and their kids.
Methods: Thirty nine mulitparous crossed Alpine×Nubian goats (initial body weight [BW] 43.5±1.7 kg) from the day of parturition were assigned to the treatments: grazing control (n = 15); grazing plus 20 mL/goat/d of supplemental soybean oil (n = 12); and grazing plus 20 mL/goat/d of supplemental canola oil (n = 12) from November 26, 2014 to March 7, 2015. The planned contrasts were: CI (control vs supplemented with oils); CII (soybean vs canola oil) to compare the treatment effects.
Results: The vegetable oil supplementation reduced weight losses in lactating goats (CI: –0.060 vs 0.090 kg/d; p = 0.03) but did not improve milk production or affect kids' growth. The content of C4, C6, C8, C10, C11, C14, and C18:1n9t in the milk was increased (p<0.05) with respect to control. However, C12, C14, C16, C18, C18:1n9c, C18:2n6c, and C18:3n3 were reduced (p<0.05) in supplemented goats. Conjugated linoleic acid (CLA) was increased (p<0.05) in goats supplemented with oils compared to the control group.
Conclusion: Supplementation with 20 mL/d of soybean or canola oil did not affect milk production or kids' performance; however, it increased CLA concentration and reduced the reduced weight losses in lactating goats.

Keywords: Fatty Acids; Goats; Milk Yield; Soybean Oil; Canola Oil

INTRODUCTION

Goat production in México since their introduction has been associated with poverty because only low income families who live in rural areas raised goats for profit or food (meat, milk, skins, etc.). Eighty percent of the goats in the world inhabit subtropical semi-arid regions [1], where the availability of good quality forage is limited throughout the year [2]. Eighty percent of parturitions occur during the dry season (between November and February) when forage is scarce, reducing colostrum and milk production and therefore affecting neonates' health and survival [3]. Kid mortality can reach up to 51%, associated with under-nutrition of the does [4].

Fat supplements are used in animal diets not only because they supply essential fatty acids and fat-soluble vitamins, but also because they provide more energy, approximately twice that of carbohydrates, for milk production. The actual choice of fat or oil and the form by which it is included in the feed is decided by a number of factors. These include, the cost and availability of the raw material, both locally and globally, the impact of fat or oil form (oilseed or extracted oil) and its fatty acid composition on feed digestibility [5]. Energy is critical for milk production [6] and the addition of lipids to ruminant feed is a strategy to increase the energy density of the diet without increasing the proportion of grains [7], preventing ruminal acidosis and low fat yield, [8] while

providing essential fatty acids. Palm oil, canola oil, soybean oil, and sunflower oil are the most common sources of lipids used in animal feeding and provide polyunsaturated fatty acids [9]. Their inclusion may alter the composition of the goat milk fat [10], with some potential benefits for the goats' kids or people consuming the milk. Therefore, this experiment of evaluated the effects of soybean and canola oil supplementation on milk production, changes in long-chain fatty acid milk composition, and changes in goat kid live weight.

MATERIALS AND METHODS

Animal care

All animal care and management procedures involving goats were conducted according to the guidelines approved by Mexican Official Norms (NOM-051-ZOO-1995: Humanitarian care of animals during mobilization; NOM-033-ZOO-1995: Slaughter of domestic and wild animals).

Locale

The study was conducted in the Altiplano Potosino region in the northern part of subtropical Mexico (22° 23′ 24″ N). This region possesses a semi-arid climate where the mean annual rainfall is 492 mm from June to September. The dry season is characterized by a dramatic decrease in food availability [11]. In this region, goats are fed only by grazing the natural rangeland daily from 0700 to 1700 h. During the night they are kept in rural shelters. The vegetative species available are shrubs (Prosopis leavigata, Acacia farneciana, Atriplex acantocarpa, Agave scabra, Mimosa biuncifera, Celtis pallida, Condalia lycioides, and Castella texana), herbaceous (Heliantus ciliaris, Salsola kali, and Solanum elaeagnilolium) and grasses (Bouteloua radicosa, Bouchloe dactyloides, Setarias spp, and Cencchrus ciliaris L.). The goats' diet throughout the year in the region consists of 82% shrubs, 12% herbaceous plants and 6% grasses [2].

Animals, experimental treatments, and management

Thirty nine mulitparous crossed Alpine×Nubian goats, 3 years old (initial body weight [BW] 43.5±1.7 kg) from the day of parturition were assigned to one of the following treatments: i) grazing control (n = 15); ii) grazing plus 20 mL/goat/d of supplemental soybean oil (n = 12); and iii) grazing plus 20 mL/goat/d of supplemental canola oil (n = 12). During the day, all goats grazed the rangeland and returned at 17:00 hour to pens. Supplemental oil was dosed individually using a 20 mL syringe every day at 07:00 h, before grazing. The goat kids were weighed each 7 days to estimate daily gain. They were slaughtered on day 35 and hot carcass weight was recorded. Does were weighted at the day of parturition and on day 35. To estimate the feed intake the equation of AFRC [12] was used as:

$$\text{Lactating goats dry matter intake} = (119.6 \times BW^{0.75})/1{,}000$$

Where $BW^{0.75}$ is metabolic body weight, kg.

Milk production

Milk production was measured each 7 days as described by Reynolds et al [13]. Goats were separated from their kids at 07:00 h and were immediately milked by hand after an injection of oxytocin (20 IU) into the jugular vein. This milk was offered to the goat kids. After 3 h, the goats were milked again using oxytocin and the yield was recorded. Milk samples were frozen at 4°C until further analysis. Samples which were mixed, homogenized in a water bath for 1 min (40°C) until the temperature reached 29°C and analysed (fat and protein) with a Lactoscan Ultrasonic milk analyzer (Milkotronic, Nova Zagora, Bulgaria).

Fatty acid composition of milk fat

Lipids for fatty acid analysis were extracted from the milk and analyzed using 2:1 (vol/vol) chloroform-methanol [14]. A total of 10 to 20 mg of extracted lipid was derivatized using 1:4 (vol/vol) tetramethylguanidine and methanol [15] after including heptadecanoic acid (17:0) as an internal standard. Fatty acid profiles were determined by chromatography on a Supelco-2560, 100 m× 0.25 mm×0.20 μm column (Sigma Aldrich Canada, Oakville, ON, Canada) installed in a gas chromatograph (Agilent 6890, Santa Clara, CA, USA) by flame ionization detection and splitless injection using conventional standards (Sigma Aldrich Canada, Canada).

Statistical analyses

Results were analyzed as a Completely Randomized Design and means were compared with those of the planned contrasts: CI, control vs supplemented with oils; CII, soybean vs canola oil. Means were also compared via Tukey test [16]. Data were analyzed with the JMP7 software [17].

RESULTS

Performance of goats

The soybean and canola oil supplementation reduced weight losses in the lactating goats (CI: –0.060 vs 0.090 kg/d; $p = 0.03$) but did not improve milk production or affect the growth of the kids (Table 1).

Fatty acid composition of milk fat in goats

The milk fat and protein content did not show differences ($p<0.05$) between treatments. Milk fatty acids, although no differences were detected in the planned contrasts, the Tukey test showed some differences (Table 2). Vegetable oil supplementation reduced linoleic acid to 76%, palmitoleic 23%, and heptadecanoic 35% compared to unsupplemented control group (Table 2), although there was an increase in undecylic, myristoleic, and conjugated linoleic acids (CLA) up to 70% respect the fat milk content (Table 2). Soybean oil increased the concentrations of butyric, caproic,

Table 1. Effects of supplementation with soybean and canola oil on does and kid performance in goats

	Grazing	Soybean oil	Canola oil	CI[1)]	CII[1)]	SEM
Lactating goat						
Initial weight (kg)	44.32	43.39	42.92	0.47	0.91	1.73
Final weight (kg)	41.02	40.85	40.93	0.94	0.79	1.77
Difference (kg)	–3.30[a]	–2.53[ab]	–1.98[b]	0.03	0.22	0.51
LW changes (kg/d)	0.09[a]	0.07[ab]	0.05b	0.03	0.22	0.07
Initial feed intake (kg)	2.05	2.02	2.00	0.56	0.19	0.73
Final feed intake (kg)	1.93	1.93	1.93	0.49	0.97	0.15
Milk production (kg/d)	1.05	1.08	1.03	0.76	0.32	0.30
Fat (%)	3.82	4.12	4.07	0.21	0.79	0.19
Protein (%)	3.20	3.33	3.28	0.84	0.35	0.53
Goat kid						
Initial weight (kg)	3.41	3.36	3.38	0.60	0.49	0.08
Final weight (kg)	8.65	8.58	8.80	0.82	0.24	0.15
Difference (kg)	5.23	5.22	5.42	0.60	0.25	0.11
ADG (g/d)	149	147	155	0.60	0.25	1.17
Carcass weight (kg)	4.65	4.55	4.92	0.72	0.67	0.25

SEM, standard error of the mean; LW, live weight; ADG, average daily gain.
[1)] p-value for CI, control vs oil supplements; CII, soybean vs canola oil.

capric and oleic acid and canola oil increased the concentrations of stearic and trans oleic acid. Heptadecanoic, alpha linolenic and linoleic acids all showed higher concentrations in the control group of grazing goats.

DISCUSSION

Oil supplementation could prevent weight loss during lactation and reduce the impact of the negative energy balance. Some authors [5] did not find a response in terms of live weight changes in Red Sokoto goats during the first 17 weeks of lactation when supplemented with palm oil at doses of 0, 16, 32, 48, and 64 g/d, but milk production was increased by 16 g/d. However, there has not been a clear trend concerning the effect of early fat supplementation on body weight changes in goats [18].

Since there were no changes in milk production, the growth of the kids was not modified. Changes in body weight in goat kids reflect the efficiency of converting suckled milk into body weight during the suckling period [19] and differences in milk yield as well as in milk fat and protein levels in the milk can be significant [20]. In this study, goat kids were fed exclusively on maternal milk.

Milk fatty acids have a dual origin; they are either taken up from plasma lipoproteins (composed of mobilized fat and dietary fat), or synthesized de novo in the mammary gland [21]. During early lactation, goats are normally in negative energy balance and mobilize extensively from their body fat stores, mainly in the form of non-esterified fatty acids [22]. The enzyme fatty acid synthase is involved in de novo fatty acid synthesis in mammary tissue and is responsible for the synthesis of short and medium chain fatty acids (C4 to C16) in the mammary gland during lactation [23], indicating a reduction in de novo synthesis [24]. In this study, the fatty acid composition of milk lipids was influenced by oil supplementation. Changes in milk composition and production have been observed with higher levels of lipids or sunflower seed oil [25] or on linseed oil in diets based on grass hay [26].

The higher secretion of C18:1n9t and 18:1n9c with soybean

Table 2. Effects of soybean and canola oil on fatty acid composition (g/100 g) of milk fat in goats

Fatty acid	Only grazing	Soybean	Canola	CI[1)]	CII[1)]	SEM
C4:0; butyric	2.13[b]	4.76[b]	3.15[ab]	0.24	0.66	0.63
C6:0; caproic	3.14[a]	5.54[b]	3.81[a]	0.59	0.84	0.36
C8:0; caprylic	3.88[a]	6.23[b]	4.67[a]	0.80	0.93	0.40
C10:0; capric	11.98[b]	16.79[a]	13.68[ab]	0.87	0.91	1.02
C11:0 undecylic	0.29[b]	0.64[a]	0.48[ab]	0.80	0.93	0.07
C12:0; lauric	5.28[a]	5.40[a]	4.81[a]	0.76	0.81	0.33
C14:0; myristic	10.82[a]	10.21[a]	9.86[a]	0.70	0.41	0.42
C14:1 myristoleic	0.31[b]	0.52[a]	0.43[ab]	0.54	0.30	0.04
C15:0 pentadecylic	1.0[a]	1.16[a]	1.15[a]	0.91	0.94	0.04
C16:0; palmitic	22.73[a]	19.60[b]	20.52[ab]	0.59	0.72	0.64
C16:1 palmitoleic	1.22[a]	1.06[a]	1.07[a]	0.48	0.71	0.04
C17:0 heptadecanoic	1.18[a]	1.02[b]	0.87[c]	0.77	0.72	0.03
C17:1 cis-heptadecenoic	0.61[a]	0.33[b]	0.39[b]	0.78	0.57	0.02
C18:0; stearic	11.47[a]	8.13[b]	11.25[ab]	0.83	0.47	0.79
C18:1 trans oleic	1.83[b]	3.77[a]	4.23[a]	0.80	0.69	0.21
C18:1 cis-9; oleic	16.11[ab]	18.92[a]	12.16[b]	0.42	0.71	1.43
C18:2 cis-9, cis-12; linoleic	2.24[a]	1.43[b]	1.74[b]	0.44	0.68	0.10
C18:3 cis-9, cis-12, cis-15; α-inolenic	0.77[a]	0.45[b]	0.58[b]	0.46	0.61	0.03
C18:2 cis-9, trans-11; CLA	0.47[a]	0.82[b]	0.85[b]	0.57	0.71	0.06

SEM, standard error of the mean; CLA, conjugated linoleic acid.
[1)] p-value for CI, control vs oil supplements; CII, soybean vs canola oil.
[a,b,c] Different letters differ by Tukey test ($p < 0.05$).

and canola oil could be due to partial biohydrogenation of dietary cis-9 C18:1 to C18:0 followed by its desaturation by mammary stearoyl-CoA desaturase, and by partial protection of soybean oil cis-9 C18:1 from ruminal biohydrogenation. In contrast to published observations in ewes and goats fed supplemental oils, a decreased proportion of C18 unsaturated fatty acids in milk lipids was noted in our study, which is inconsistent with its reported increase in goats' milk [27,28]. Banskalieva et al [29] indicated that the major fatty acids in body fat stores of goats are C18:1-n9t, C16:0, and C18:0, which are incorporated into milk fat during mobilization [30]. Increments in the ratio of USFA to saturated fatty acids in milk lipids in response to oil supplementation have been reported in goats fed hay-based diets supplemented with plant oils or oilseeds [25]. Agreement with our results Collomb et al [31], Rego et al [32] and Stergiadis et al [33] found decreased concentrations in milk of C18:1 cis-9, C18:2 cis-9, cis-12, and C18:3 cis-9, cis-12, cis-15 from animals given an oil supplementation in contrast with basal diets. This could be explained because unsaturated trans FA as vaccenic and rumenic acids increase in grassland cows [34]. Rumenic acid is the primary octadecadienoic acid isomer (cis-9, trans- 11-octadecadienoic acid), which accounts for more than 82% of the total in dairy products [35]. Rumenic acid in milk is mainly formed from linoleic acid, which is transformed in the rumen forming vaccenic acid (trans-11-octadecenoic acid) by means of *Butyrivibrio fibrisolves* (biohydrogenation). Vaccenic acid can pass into milk directly or after transformation to rumenic acid by the action of Δ-9 desaturase in the epithelium of the mammary gland [36]. This metabolism could be accelerated by a higher amount of fresh grass in the diet [37].

The increase in milk cis-9, trans-11 CLA concentration seen with the soybean and canola oil was expected. Bauman et al [38] mentioned cis-9, trans-11 CLA in milk originates from either ruminal biohydrogenation of linoleic acid as an intermediate product or from endogenous synthesis in mammary gland from vaccenic acid, which could explain the decreased C18:2nc6 and C18:3n3 if they were used for the formation of CLA. The endogenous synthesis of cis-9, trans-11 CLA from vaccenic acid has been proposed as the major pathway of cis-9, trans-11 CLA synthesis in lactating cows, accounting for an estimated 0.90 of the cis-9, trans-11 CLA in milk fat [39].

Dietary manipulation of goat milk by feeding goats plant oils rich in either linoleic acid (C18:2, LA) or α-linolenic acid (C18:3) has been shown to increase the CLA content in goat milk fat [10]. CLA has been identified as an anti-mutagenic substance [40] and a potent anti-carcinogen in several cell culture and animal models [41]. Other benefits attributed to CLA consumption include effects on the immune system, atherosclerosis and bone health [42].

CONCLUSION

Supplementation with 20 mL/d of soybean or canola oil to grazing goats did not affect milk production or the performance of the goats' kids; however, it increased CLA levels and reduced weight losses in lactating goats.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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