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Using safflower supplementation to improve the fatty acid profile in milk of dairy goat

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ABSTRACT

Although supplementation effects of safflower seed oil (SSO) on dairy cattle have been extensively studied, little information exists on the effective use of SSO in lactating dairy goat. Thus, this study investigated the effects of SSO supplementation on feed intake, yield, composition and fatty acid profile of milk of lactating dairy goat. Fifteen multiparous *Xinong Saanen* dairy goats (63 ± 2 DIM) were assigned to a 3×3 Latin square for periods of 21-d. They were randomly allocated to three treatments: (A) unsupplemented (control), (B) supplemented with 10 g SSO (low dose, SSO-1), and (C) supplemented with 30 g SSO (high dose, SSO-2) per kilogram diet dry matter (DM) of total ration. Feeding SSO resulted in a significant increase of DM intake compared with the control ($P < 0.01$). Ruminal pH values in SSO-1 were increased in comparison with the control ($P < 0.05$). SSO supplementation increased the content of low density lipoprotein cholesterol (LDL-C) in serum ($P < 0.01$). Yield and ratio of mike fat with SSO supplementation decreased significantly compared with the control ($P < 0.01$). SSO supplementation decreased the ratios of short- and medium-chain fatty acids ($C \leq 16$) but significantly increased the ratios of long-chain fatty acids ($C > 16$) in milk fat. Furthermore, SSO supplementation increased *cis*-9, *trans*-11 CLA contents from 0.49 g/day of the control to 0.68 and 1.18 g/day for SSO-1 and SSO-2, respectively ($P < 0.01$). This study demonstrated that SSO supplementation improved milk fat composition of dairy goat.

1. Introduction

Safflower (*Carthamus tinctorius* L.) is a highly branched, herbaceous, and thistle-like annual, and its seed oil containing carthamine is known for a long time. The main components of safflower seed oil (SSO) are linoleic acids, *i.e.*, *cis*-9, *cis*-12 18:2 and *cis*-9, *trans*-11 CLA (McLennan et al., 1985; Kim et al., 2000). These unsaturated fatty acids such as *cis*-9, *trans*-11 CLA are potent anti-atherogenic, hypolipidemic, and able to clear the lining of blood vessels and down-regulate blood pressure (Pariza et al., 2001; Corl et al., 2003; Tricon et al., 2004).

At present, in over 60 countries, safflower seeds are used as a feed for ruminants (Alizadeh et al., 2012). Many reports have demonstrated that SSO improved the content of health promoting fatty acids in ruminant body and milk. For example, the content of CLA in bovine milk fat was significantly improved in rations supplemented with safflower oil (Griinari and Bauman, 1999; Chilliard et al., 2000). The contents of unsaturated fatty acids in cattle body were greatly increased by feeding formaldehyde-treated casein–safflower oil or infusing safflower oil into abomasums (Dinius et al., 1974, 1975). For lambs, feeding safflower seeds increased the content of unsaturated fatty acids such as *cis*-9, *trans*-11 CLA in muscle tissues (Kott et al., 2003).

Although the effects of CLA supplementation on the yield and quality of goat milk have been studied (Erasmus

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Table 1
Ingredient and chemical composition of experimental diets in g/kg of diet dry matter (DM).

	C[c]	SSO-1[a]	SSO-2[b]
Alfalfa hay	211	211	211
Maize silage	319	319	319
Concentrate mixture			
Maize grain	286	276	256
Wheat bran	67	67	67
Soybean meal	62	62	62
Rapeseed meal	42	42	42
Mineral and vitamins supplement[d]	6	6	6
Calcium hydrogen phosphate	5	5	5
Salt	2	2	2
Safflower seed oil (SSO)	–	10	30
Chemical composition			
Crude protein (CP)	113	113	111
Crude fiber (CF)	122	122	121
Ether extract (EE)	23	32	48
Nitrogen free extract (NFE)	373	366	351
Ca	10	10	10
P	5	5	5
NE_L (MJ/kg DM)	4.89	4.91	4.98

[a] First group of safflower seed oil. The same below.
[b] Second group of safflower seed oil. The same below.
[c] Control (C); 10 g and 30 g SSO per kilogram of dietary DM.
[d] Contained 30 g Ca, 0.7 g P, 12 mg Cu, 60 mg Fe, 150 mg Zn, 60 mg Mn, 1.5 mg Se and 4000 IU of vitamin A, 1000 IU of vitamin D3 and 150 mg of vitamin E/kg.

et al., 2004; Lock and Bauman, 2004; Lock et al., 2008), information on the effectiveness of SSO as a dietary source of unsaturated fatty acids to dairy goat is still lacking. This study was conducted to investigate the effects of SSO supplementation on milk fatty acid profile in lactating *Xinong Saanen* dairy goat.

2. Materials and methods

2.1. Animal and experimental design

The experiment was conducted with the approval of Animal Use and Care Committee of Northwest A&F University. Fifteen multiparous lactating *Xinong Saanen* dairy goats (63 ± 2 days in milk (DIM)) from the Dairy Goat Research Center of Northwest A&F University were used. These goats were divided into three subgroups, five in each group, according to body weight and milk yield. The experiment was designed as a 3 × 3 Latin square with 14-d treatment periods separated by 7-d washout intervals. After adaptation period of 10 d, dietary treatments were assigned to the experimental groups as follows: (A) control (*C*); (B) 10 g SSO (low dose, SSO-1) and (C) 30 g SSO (high dose, SSO-2) per kilogram of dietary DM. The body weight (BW) of goat at the start of experiment was 53 ± 6.2 kg and body conditioning score (BCS) was 2.4 (evaluated at a 1–5 scales by 0.5 increments). BW and BCS were measured at the beginning and end of each 14-d treatment period. During the experiment, the goats were housed according to the subgroups from April to June, with room temperature about ~25 °C.

Goats were offered a total mixed ration (TMR) twice per day at 07:30 am and 16:00 pm, respectively. The ingredients and chemical composition of the experimental diets are shown in Table 1. SSO were provided by Safflower Sci-Technology Co., Ltd. (Tacheng, Xinjiang, China) with the fatty acid composition of 79.45% c18:2 (*cis*-9, *trans*-11 CLA in which is 3.48%), 11.69% c18:1, 5.55% c16:0, 2.63% c18:0, 0.34% c20:0 and 0.2% c14:0. The individually daily amount of dry matter (DM) initially offered was approximately 2 kg (~3.5% of BW) and was then adjusted daily for an *ad libitum* intake. Fresh water was freely available at all time.

2.2. DM intake detection

The TMR were offered to allow for 5–10% daily refusals. Samples of TMR and orts were collected during days 10–14 of each period. Feed samples were stored at −20 °C until analysis for DM intake. After thawing at room temperature, samples were dried at 65 °C for 12 h, placed in dried bottle for 24 h, and again dried at 105 °C for 3 h before analyzing DM content.

2.3. pH of ruminal fluid

On the last day of each 14-d treatment period, ruminal fluid of goats was collected with needle by puncturing the rumen wall. The puncturing site, on the horizontal line, which connects the pregenual skin fold with the last rib, was clipped and disinfected. Then, abdominal and ruminal walls were punctured with a 90 mm-long 1.5 mm gauge epidural needle with mandrin and ruminal fluid was taken for pH analysis using Sartorius pB-10 pH meter (Sartorius, Germany).

2.4. Biochemical makers of lipid metabolisin in the serum

On the last day of each period, blood samples were collected through venipuncture at 2 h after the morning feeding and let to be clogged for 1 h at room temperature. The serum was separated by centrifugation at 3200 × *g* for 10 min. Total cholesterol (TC), low density lipoprotein cholesterol (LDL-C), high density lipoprotein cholesterol (HDL-C) and triglyceride (TG) in serum were determined using XD-811 biochemical analyzer with commercial kits (BioSino Bio-Technology and Science Inc., Beijing, China).

2.5. Milk sample collection and analysis

Experimental goats were milked twice per day at 07:00 am and 16:00 pm, respectively. The amount of milk produced by each goat each time was measured by the automated Westfalia milking system (Westfalia Systemat, Elk Grove Village, IL, USA). On the last 2 days of each period, the contents of fat, protein and lactose in milk samples from all goats were measured using a Milkoscan™ FT120 (Foss Electric, Hillerød, Denmark).

In addition, milk samples from two consecutive milkings on the final day of each treatment period were collected and stored at −20 °C for fatty acid analysis at the end of experiment. The refrigerated milk samples were tempered at 20 °C for 20 min before being centrifuged at 17,800 × *g* for 30 min at 4 °C. The fat layer was removed, transferred to microtubes, and centrifuged at 19,300 × *g* again at room temperature. After the second centrifugation, the top layer was removed for analysis. Fatty acid methyl esters were prepared by base-catalyzed ($KOCH_3$) trans methylation as described in a previous work (Luna et al., 2005). The fatty acid methyl esters were then transferred to 1.5 ml vials and determined by gas chromatography (GC, Agilent Technologies 7890A, California, USA) with a 100 m (0.25 mm ID) column (SP-2560). Nitrogen was the carrier gas, and initial and final temperatures were set at 50 and 230 °C, respectively, with detector and injector temperatures set 300 and 280 °C, respectively. Fatty acid standards were from Sigma–Aldrich (St. Louis, MO, USA).

2.6. Statistical analysis

Data from the experiment were analyzed using the ANOVA model (SAS, 1994). Results were presented as treatment mean values with a standard error of the mean (SEM). Significance of difference ($P < 0.05$) between treatments was determined by multiple comparisons using the Tukey *t*-test (Samuels, 1989).

3. Results

3.1. Performance

BW and BCS were unaffected by SSO supplementation with averages of 54 ± 4.1 kg and 2.5 ± 0.3 (mean ± SE), respectively for all treatments. Similarly, milk yield was not affected by SSO treatments (Table 2). However, DM intakes in SSO-1 and SSO-2 (10.70 and 10.67 kg/d) were higher than that in the control (10.30 kg, $P < 0.01$; Table 2). Milk lactose