Time-dependent variations in milk fatty acid content of goats fed 3 different plant oils

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ABSTRACT

The effect of sampling time on milk fatty acid (FA) composition after separately adding 3 plant oils to an oil-free control diet (67% cereal-soybean-based concentrate and 33% alfalfa hay) was studied in 12 Malagueña goats. Individual animals were randomly allocated to 1 of the 4 treatments: control, 48 g/d of added high oleic (OSO) or regular (RSO) sunflower oil, or linseed oil (LO). Individual milk samples were taken at 0 (covariate), 1, 12, 24, 72, 120, 192, 312, and 504 h after the beginning of the experiment. Milk FA contents (g/100 g of total FA methyl esters) were analyzed in a completely randomized design with repeated measures using PROC MIXED of SAS (SAS Institute Inc., Cary, NC). Comparing results of 15 chosen FA (for example, medium-chain saturated FA *trans*-11 C18:1, *cis*-9,*trans*-11 C18:2, *trans*-10 C18:1, and C18:3n-3) indicated that throughout the duration of the experiment, feeding the control diet had little influence on the concentrations of most FA in milk. Most changes in milk FA composition due to oil supplementation had occurred within 192 h since the beginning of the experiment. However, the concentrations of 2 FA (*trans*-10 C18:1 in RSO and C18:3n-3 in LO treatments) continued to change until 504 h. By comparing FA values in milk fat from oil treatments with those of the control at the same sampling times, typical value differences for the 3 supplementary oils found at 504 h (21 d) were also observed at 312 h from the beginning of the experiment (13 d) and even earlier in some FA, such as medium-chain saturated FA at 120 h in RSO and LO and at 72 h in OSO, *cis*-9,*trans*-11 C18:2 and *trans*-10 C18:1 at 24 h in RSO, *trans*-11 C18:1 at 12 h in RSO and LO, and C18:3n-3 at 1 h in LO. In the conditions assayed in

these experiments, reliable results of milk FA changes were obtained at sampling times shorter than 21 d. Monitoring early changes in milk FA after the addition of plant oils to diets could help in the study of rumen and mammary metabolism of dietary FA.

Key words: plant oil, fatty acid, goat milk, sampling time

INTRODUCTION

There is a scarcity of information dealing with the kinetics of milk FA composition responses to plant oil inclusions in the diet of dairy ruminants. Most information corresponds to work carried out with cows (Dhiman et al., 2000; Roy et al., 2006) and ewes (Gómez-Cortés et al., 2008a,b; Hervás et al., 2008). To our knowledge, only Chilliard et al. (2005) gave data on time-related changes to *cis*-9,*trans*-11 C18:2 content after introducing sunflower or linseed oils into dairy goat diets.

In most published papers, the first milk sample was taken 2 or 7 d after the introduction of the plant oil into the diets. However, in vitro work done by Mosley et al. (2002) and Jouany et al. (2007) showed changes in the accumulation of biohydrogenation (BH) intermediates and end products as soon as 0.5 h after oil inclusion in media inoculated with mixed rumen microbes. Fievez et al. (2007) indicated that rumen microorganisms are permanently adapted to biohydrogenate unsaturated FA from plants because they are always in contact with them in most ruminant diets. Different authors (Moate et al., 2004; Harvatine and Allen, 2006) have used information from in vivo experiments to build models describing rumen BH kinetics. These models predict a fast, strong lipolysis-BH reaction, which delivers unsaturated fats into the rumen and provide estimates for FA rumen passage rates. Whereas the model by Moate et al. (2004) practically precludes C18:3n-3 from escaping the rumen unaltered by BH, the model by Harvatine and Allen (2006) allows room for this to happen.

When studying the kinetics of FA responses to the inclusion of plant oils in dairy ruminant diets, one has

Received October 26, 2012.

Accepted January 24, 2013.

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to bear in mind that the observed effects on milk FA changes also imply the time from FA leaving the rumen to their secretion as milk triacylglycerols. Furthermore, although several authors have studied the response of milk FA composition to abomasal/duodenal infusions of long-chain FA (Drackley et al., 2007; Khas-Erdene et al., 2010), their studies show changes occurring in the milk fat FA profile at 5 d from the beginning of the infusions, at the earliest. The aim of this work was to obtain information about the timing of changes in FA contents in goat milk fat from 1 to 504 h (21 d) after introducing 3 different plant oils into the diet.

MATERIALS AND METHODS

The experiments were carried out on the premises of the Animal Production Department of Córdoba University (Córdoba, Spain). Animals were kept in accordance with Spanish regulations relative to the treatment of experimental animals. Twelve Malagueña goats were used (45 ± 5 DIM, 47 ± 4.2 kg live weight, and $2,287 \pm 512$ g of milk production/d at the beginning of the ex-

periment). They were placed in individual cages of 1.0×1.4 m with slatted floors equipped with water and feeding troughs. All goats were fed a general-purpose diet without added fat (maize, oats, horsebeans, and alfalfa hay) from kidding until the beginning of the experiment.

Goats were randomly assigned to 1 of 4 treatments (3 goats per treatment): a basal control diet (67% concentrate and 33% alfalfa hay) with no added oil or a basal diet supplemented with 48 g/d of either high oleic sunflower oil (**OSO**), regular sunflower oil (**RSO**), or linseed oil (**LO**) as shown in Table 1. The experiments lasted 21 d. Milk samples were taken from milkings at 0 h (before oil supplementation) and 1, 12, 24, 72, 120, 192, 312, and 504 h after the addition of the corresponding oil. Milkings at 0 (covariate), 1, and 12 h were stripped out by hand after giving an i.v. dose of 2 to 3 IU of oxytocin to the goats. Daily DMI, BW changes, milk production and sampling, and diet analysis were carried out as in Martínez Marín et al. (2012).

Milk fats were extracted as described by Gómez-Cortés et al. (2008a). Fatty acid methyl esters (**FAME**)

Table 1. Ingredients, chemical composition, and nutritive value of the experimental diets

Item	Treatment ¹			
	Control ²	OSO	RSO	LO
Diet (g/d)				
Alfalfa hay	600	600	600	600
Concentrate ³	1,200	1,200	1,200	1,200
OSO ⁴	—	48	—	—
RSO ⁴	—	—	48	—
LO ⁴	—	—	—	48
Chemical composition				
DM (%)	90.6	90.5	91.0	91.2
CP (% of DM)	17.0	16.4	16.4	16.5
NDF (% of DM)	28.2	27.5	27.0	26.9
AHEE ⁵ (% of DM)	2.4	5.6	5.5	5.8
Ash (% of DM)	7.6	7.5	7.5	7.5
Nutritive value ⁶				
ME (Mcal/kg of DM)	2.67	2.77	2.77	2.77
MP (g/kg of DM)	123	119	119	119
FA from oil (g/d)				
C16:0	—	1.8	2.9	2.6
C18:0	—	1.4	2.0	1.8
<i>cis</i> -9 C18:1	—	41.0	14.2	10.0
C18:2n-6	—	2.7	27.9	8.0
C18:3n-3	—	—	—	23.9

¹Control = basal diet with no added oil; OSO, RSO, and LO = diets enriched with 48 g/d of high-oleic sunflower oil, regular sunflower oil, and linseed oil, respectively.

²Control diet supplied 5.1, 0.8, 6.9, 18.9, and 6.5 g/d of C16:0, C18:0, *cis*-9 C18:1, *cis*-9,*cis*-12 C18:2, and C18:3n-3, respectively; calculated according to INRA (2002).

³Composition (g/kg, as fed): maize, 375; barley, 374.9; soybean meal, 200; vitamin and mineral premix (Maxi Nutral Ovejas; Nutral SA, Madrid, Spain), 30; binder (Exal; Tolsa S.A., Madrid, Spain), 20; antioxidant (Luctanox; Lucta S.A., Barcelona, Spain), 0.1.

⁴Included in the respective concentrates. High-oleic sunflower oil and RSO were purchased from Carrefour S.A. (Madrid, Spain). Linseed oil was supplied by Gustav Heess S. L. (Barcelona, Spain).

⁵Acid hydrolysis ether extract.

⁶Calculated from NRC (2007).

Figure 1. Time-dependent changes of *trans*-11 C18:1 and *cis*-9,*trans*-11 C18:2 in milk fat of goats fed an unsupplemented diet (control) or diets enriched with high oleic sunflower oil (OSO), regular sunflower oil (RSO), or linseed oil (LO). FAME = FA methyl esters.

were prepared by base-catalyzed methanolysis of the glycerides (ISO-IDF, 2000a). Analysis of FAME was performed on a gas-liquid chromatograph (Agilent 6890 N Network System; Agilent Technologies Inc., Santa Clara, CA) onto a CP-Sil 88 fused silica capillary column (100 m $\times$ 0.25 mm; Varian BV, Middelburg, the Netherlands) under similar conditions to those reported by Luna et al. (2008). Individual FAME quantification was performed according to ISO-IDF (2002b) using a milk fat with known composition (CRM 164; European Community Bureau of Reference, Brussels, Belgium). Individual FA were identified by comparison with stan-

dards distributed by Nu-Chek Prep Inc. (Elysian, MN), whereas *trans*-11,*cis*-15 C18:2, *trans*-11,*trans*-15 C18:2, *cis*-9,*trans*-11,*cis*-15 C18:3, and *cis*-9,*trans*-11,*trans*-15 C18:3 had previously been identified by gas chromatography-tandem mass spectrometry (Gómez-Cortés et al., 2009).

Data of milk fat FA content were analyzed by repeated measurement analysis (Littell et al., 2006) using PROC MIXED of SAS (SAS Institute, 2004). The statistical model included the fixed effects of diet, time, their interaction, the covariate, and the random effect of goat nested within treatment. For each FA, the

covariance structure of goat nested within treatment [compound symmetry, ANTE(1) or spatial power] was chosen on the basis of the Schwarz Bayesian information model fit criteria. Least squares means (adjusted by the covariate) of the diet $\times$ time interaction were compared using the CONTRAST statement in PROC MIXED. Within treatments, the least squares means were compared with their respective 504-h values. Least squares means from samples of goats fed with added oil were also compared, by sampling times, with the respective control mean. Statistical differences were declared at $P < 0.05$.

RESULTS AND DISCUSSION

To study the effect of time after introducing the oils into the diets, 15 FA were selected (Table 2) on the basis of their significant differences in diet $\times$ time interaction and relevance in current knowledge of rumen and mammary metabolism as well as in human nutrition.

Comparing Respective 504-h Values

In the control treatment, sampling time did not affect the proportion of any FA in Table 2 [i.e., for a given FA, the values obtained at any sampling time were no different from the corresponding 504-h value (21 d)]. This provided a proper reference for comparing the effects of sampling time on the 3 oil treatments.

In the OSO treatment, only 4 FA out of the 15 presented in Table 2 showed differences due to sampling time compared with the corresponding value obtained at 504 h: medium-chain SFA (MCSFA), C18:0, *cis*-9 C18:1, and *trans*-15(+*cis*-11) C18:1. No significant differences were observed in the percentages of MCSFA and C18:0 relative to the final samples collected after 1 and 3 d, respectively. The effect of OSO on MCSFA content in milk fat may be mediated by 2 different causes, which are not mutually exclusive: one is the negative effect of oil on VFA produced in rumen fermentation, and the other is the direct effect of long-chain FA absorbed in the small intestine on de novo FA synthesis in the mammary gland. According to Martínez Marín et al. (2012), who used the same diets in their experiments as those in the current work, the likelier cause is the second because the short-chain SFA (SCSFA; C4:0 to C8:0) showed no negative, or even positive, responses to oil supplementation (Table 2). The effect of OSO on C18:0 and *cis*-9 C18:1 milk fat content probably reflected its high level of *cis*-9 C18:1 and the particular rumen BH-mammary desaturation cycle of these FA.

Five FA in the RSO treatment showed values statistically different from their corresponding 504-h values, which did not differ significantly at 72 h (MCSFA and

cis-9,*cis*-12 C18:2), at 120 h (*trans*-11 C18:1 and *cis*-9,*trans*-11 C18:2; Figure 1) or at 192 h (SCSFA; i.e., between 3 and 8 d; Table 2). Roy et al. (2006) and Shingfield et al. (2006) observed in cows and Gómez-Cortés et al. (2008a, 2011) in ewes, that the contents of *trans*-11 C18:1 and *cis*-9,*trans*-11 C18:2 in milk fat reached maximum values between 6 and 7 d after introducing linoleic acid-rich oils into the diet, but then decreased and leveled off to values higher than those of the control diet. In the current research, the highest milk fat content values of these 2 FA were reached at 8 d, but rather than subsequently decreasing, they leveled off at these highest values. On the other hand, the sampling time values of *trans*-10 C18:1 were all different from the corresponding 504-h value, which was higher than the apparent plateau reached between 120 and 312 h (Figure 2). This type of response was not observed in cows [Roy et al. (2006), with forage:concentrate ratios of 27:73 and 48:52; or by Shingfield et al. (2006), with a forage:concentrate ratio of 60:40]. Both sets of authors reported a plateau of *trans*-10 C18:1 content in milk fat around 10 to 12 d, up to 20 and 28 d, respectively. However, Gómez-Cortés et al. (2008a) found the highest value of *trans*-10 C18:1 on the last sampling day of their experiment (21 d) with a 20:80 forage:concentrate diet supplemented with 6% of soybean oil. Gómez-Cortés et al. (2011) also found the same type of result at 28 d when including 2% of sunflower oil in a 30:70 forage:concentrate diet. All of this suggests that temporal changes in *trans*-10 C18:1 milk fat content observed in cows could be different from those in ewes and goats. In these species, at least with high-concentrate diets, the potential maximum value of *trans*-10 C18:1 content in milk fat does not seem to have been reached at 21 or 28 d after introducing the dietary oil.

Nine of the 15 FA listed in Table 2 that showed statistically significant differences between their first sampling time values and those of the corresponding 504-h sampling in the LO treatment did not differ significantly at 24 h [MCSFA, *trans*-11 C18:1, *trans*-15(+*cis*-11) C18:1, *cis*-9,*cis*-12 C18:2, *cis*-9,*trans*-11 C18:2, and *cis*-9,*trans*-11,*cis*-15 C18:3], at 120 h (*cis*-15 C18:1), or at 192 h (*trans*-11,*cis*-15 C18:2 and *cis*-9,*trans*-11,*trans*-15 C18:3). The content of C18:3n-3 showed numerically increasing values with time, which were all lower than the 504-h value (Table 2), suggesting that the potential maximum content of C18:3n-3 in milk fat was not reached before or even at 504 h (21 d) after the introduction of LO in the dairy goat diets (Figure 2). A similar response was observed by Luna et al. (2005) working with ewes fed linseed for 6 wk.

In the current study, the final values of *trans*-11 C18:1 and *cis*-9,*trans*-11 C18:2 were 58 and 42% higher, respectively, in the RSO than in the LO treatment.

Table 2. Fatty acid content (g/100 g of FA methyl esters) at different sampling times in milk fat from goats fed control (basal diet with no added oil) or oil-supplemented diets

FA ¹	Treatment	Hour								SEM
		1	12	24	72	120	192	312	504	
SCSFA	Control	10.00	9.62	9.84	9.44	9.62	9.53	8.98	8.95	0.118
	OSO	9.95	9.31	9.54	7.66 ^a	8.67	9.00	9.43	8.99	0.191
	RSO	9.64 ^A	9.57 ^A	9.51 ^A	9.37 ^A	9.50 ^A	10.32	10.13 ^a	10.97 ^a	0.169
	LO	9.62	9.43	10.02	10.50	10.65	10.50	10.52 ^a	9.81	0.163
	SEM	0.172	0.146	0.119	0.391	0.301	0.256	0.246	0.384	
MCSFA	Control	44.84	45.00	43.03	41.73	43.27	45.47	46.83	46.47	0.672
	OSO	45.42 ^A	45.50 ^A	40.14	32.11 ^a	37.63 ^a	38.04 ^a	39.24 ^a	36.73 ^a	1.272
	RSO	45.08 ^A	45.69 ^A	40.06 ^A	36.76	34.75 ^a	34.70 ^a	34.96 ^a	33.40 ^a	1.015
	LO	45.85 ^{A,a}	45.48 ^A	40.46	36.04	34.68 ^a	33.34 ^a	35.66 ^a	36.71 ^a	1.336
	SEM	1.030	1.160	0.974	1.161	1.392	2.011	1.892	2.180	
C18:0	Control	7.88	8.57	8.67	9.11	8.23	7.95	7.83	7.178	0.143
	OSO	7.58 ^A	8.22 ^A	10.47 ^{A,a}	13.72 ^a	10.54	10.91	11.00 ^a	13.88 ^a	0.583
	RSO	7.99	8.61	10.67 ^a	11.40	10.29	9.09	9.76	8.78	0.391
	LO	7.63	7.59	8.75	11.10	11.06	11.83 ^A	10.14	8.220	0.499
	SEM	0.288	0.273	0.380	0.673	0.724	0.696	0.531	0.953	
<i>cis</i> -9 C18:1	Control	15.20	16.30	17.23	19.35	18.27	16.10	15.86	15.31	0.516
	OSO	14.82 ^{A,a}	15.12 ^A	18.45 ^A	27.29	21.44	20.28	18.07 ^A	21.94 ^a	1.139
	RSO	15.15	14.19	17.15	18.67	18.66	16.35	17.14	16.24	0.488
	LO	14.79 ^a	13.68	14.23	16.88	17.20	17.90	15.33	14.98	0.510
	SEM	0.474	0.690	0.634	1.710	0.864	1.216	0.522	0.840	
<i>trans</i> -10 C18:1	Control	0.19	0.13	0.15	0.13	0.15	0.16	0.20	0.36	0.027
	OSO	0.19	0.24	0.32	0.30	0.29	0.29	0.28	0.22	0.018
	RSO	0.18 ^A	0.24 ^A	0.40 ^{A,a}	0.44 ^{A,a}	0.69 ^{A,a}	0.78 ^{A,a}	0.72 ^{A,a}	1.33 ^a	0.088
	LO	0.17 ^a	0.26	0.43 ^a	0.25	0.19	0.20	0.24	0.33	0.035
	SEM	0.040	0.035	0.049	0.032	0.076	0.078	0.063	0.162	
<i>trans</i> -11 C18:1	Control	0.78	0.61	0.69	0.72	0.73	0.69	0.64	0.89	0.050
	OSO	0.81	0.87	1.16	1.39	1.39	1.34	1.29	1.46	0.129
	RSO	0.81 ^A	1.14 ^{A,a}	1.87 ^{A,a}	3.18 ^{A,a}	4.32 ^a	5.15 ^a	4.95 ^a	5.51 ^a	0.467
	LO	0.78 ^A	1.65 ^{A,a}	3.06 ^a	3.28 ^a	3.65 ^a	3.64 ^a	3.46 ^a	3.49 ^a	0.312
	SEM	0.129	0.147	0.299	0.429	0.584	0.654	0.550	0.680	
<i>trans</i> -15 (+ <i>cis</i> -11) C18:1	Control	0.30	0.30	0.31	0.32	0.27	0.24	0.27	0.25	0.012
	OSO	0.31	0.32	0.34	0.40 ^A	0.34	0.34	0.27	0.27	0.015
	RSO	0.32	0.32	0.40 ^a	0.38	0.37	0.38	0.33	0.34	0.014
	LO	0.30 ^A	0.33 ^A	0.49 ^a	0.53 ^a	0.55 ^a	0.55 ^a	0.54 ^{A,a}	0.61 ^a	0.048
	SEM	0.028	0.026	0.033	0.034	0.038	0.041	0.045	0.061	
<i>cis</i> -15 C18:1	Control	0.05	0.06	0.07	0.04	0.05	0.04	0.04	0.05	0.002
	OSO	0.04	0.03 ^a	0.05	0.05	0.05	0.04	0.05	0.03	0.002
	RSO	0.04 ^A	0.04 ^A	0.07	0.06 ^A	0.07	0.07	0.07 ^A	0.10	0.005
	LO	0.05 ^A	0.10 ^{A,a}	0.21 ^{A,a}	0.23 ^{A,a}	0.31 ^a	0.29 ^a	0.30 ^a	0.30 ^a	0.034
	SEM	0.003	0.008	0.019	0.024	0.036	0.036	0.035	0.038	
<i>trans</i> -11, <i>trans</i> -15 C18:2	Control	0.01	0.01	0.03	0.01	0.01	0.01	0.010	0.01	0.001
	OSO	0.01 ^a	0.01	0.01 ^a	0.02	0.02 ^a	0.02	0.01	0.02	0.001
	RSO	0.01 ^a	0.01	0.02	0.01	0.01	0.02 ^a	0.02 ^a	0.02	0.001
	LO	0.01	0.01 ^A	0.01 ^a	0.01	0.01	0.01	0.01	0.03	0.002
	SEM	0.001	0.001	0.003	0.001	0.001	0.001	0.001	0.004	
<i>trans</i> -11, <i>cis</i> -15 C18:2	Control	0.03	0.02	0.04	0.04	0.03	0.03	0.03	0.03	0.002
	OSO	0.03	0.03	0.04	0.05	0.05	0.04	0.04	0.03	0.003
	RSO	0.02	0.02	0.04	0.06 ^A	0.08	0.08	0.07	0.13	0.009
	LO	0.04 ^A	0.34 ^{A,a}	0.57 ^{A,a}	0.54 ^{A,a}	0.66 ^{A,a}	0.76 ^a	0.73 ^a	0.87 ^a	0.094
	SEM	0.003	0.037	0.064	0.067	0.084	0.103	0.101	0.120	
<i>cis</i> -9, <i>cis</i> -12 C18:2	Control	1.42	1.46	1.55	1.76	1.85	1.80	1.85	1.72	0.047
	OSO	1.33 ^a	1.28	1.36	1.58	1.60	1.42	1.32	1.35	0.036
	RSO	1.40 ^A	1.51 ^{A,a}	1.97 ^{A,a}	2.27	2.62 ^a	2.71 ^a	2.58 ^a	2.82 ^a	1.129
	LO	1.38 ^A	1.50 ^A	1.68	1.80	1.82	2.02	2.06	2.33	0.119
	SEM	0.051	0.062	0.110	0.132	0.172	0.195	0.194	0.244	
<i>cis</i> -9, <i>trans</i> -11 C18:2	Control	0.39	0.30	0.36	0.34	0.39	0.33	0.31	0.46	0.027
	OSO	0.38	0.37	0.43	0.49	0.51	0.47	0.43	0.60	0.034
	RSO	0.42 ^A	0.44 ^A	0.79 ^{A,a}	1.19 ^{A,a}	1.71 ^a	2.09 ^a	1.99 ^a	2.27 ^a	0.201
	LO	0.39 ^A	0.60 ^{A,a}	0.97 ^a	0.94 ^a	1.20 ^a	1.21 ^a	1.24 ^a	1.60 ^a	0.115
	SEM	0.055	0.058	0.103	0.161	0.229	0.267	0.231	0.294	
C18:3n-3	Control	0.13	0.13	0.15	0.17	0.18	0.16	0.17	0.15	0.007
	OSO	0.12	0.12	0.13	0.17	0.17	0.14	0.13	0.16	0.008

Continued

Table 2 (Continued). Fatty acid content (g/100 g of FA methyl esters) at different sampling times in milk fat from goats fed control (basal diet with no added oil) or oil-supplemented diets

FA ¹	Treatment	Hour								SEM
		1	12	24	72	120	192	312	504	
<i>cis</i> -9, <i>trans</i> -11, <i>trans</i> -15 C18:3	RSO	0.15	0.12	0.18	0.15	0.17	0.14	0.14 ^A	0.18	0.006
	LO	0.18 ^{A,a}	0.34 ^{A,a}	0.50 ^{A,a}	0.54 ^{A,a}	0.61 ^{A,a}	0.65 ^{A,a}	0.73 ^{A,a}	0.83 ^a	0.068
	SEM	0.007	0.025	0.041	0.044	0.051	0.062	0.078	0.112	
	Control	Tr ²	Tr	Tr	Tr	Tr	Tr	Tr	Tr	0.000
	OSO	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	0.000
	RSO	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	0.000
<i>cis</i> -9, <i>trans</i> -11, <i>cis</i> -15 C18:3	LO	0.01 ^A	0.01 ^A	0.02 ^A	0.03 ^A	0.03 ^A	0.04	0.04	0.04	0.004
	SEM	0.000	0.001	0.002	0.003	0.004	0.005	0.004	0.006	
	Control	0.05	0.06 ^A	0.05 ^A	0.05 ^A	0.04	0.04 ^A	0.04	0.03	0.005
	OSO	0.04	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.002
	RSO	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.001
	LO	0.03 ^A	0.07 ^A	0.09 ^a	0.09 ^b	0.09 ^a	0.11 ^a	0.14 ^{A,a}	0.10 ^a	0.012
	SEM	0.005	0.007	0.008	0.008	0.008	0.011	0.017	0.013	

^AWithin an FA, the means in a treatment with superscript "A" differ significantly ($P < 0.05$) from the 504-h mean in the same treatment.

^aWithin an FA, the means in OSO, RSO, or LO (diets enriched with 48 g/d of high oleic sunflower oil, regular sunflower oil, or linseed oil, respectively) treatments with superscript "a" differ significantly ($P < 0.05$) from the same mean in the control treatment.

¹Short-chain SFA (SCSFA) = sum of C4:0, C6:0, and C8:0; medium-chain SFA (MCSFA) = sum of C12:0, C14:0, and C16:0.

²Tr = concentrations below 0.01 g/100 g of FA methyl esters.

These results indicate that the response of *trans*-11 C18:1 and *cis*-9,*trans*-11 C18:2 to diets supplemented with LO was faster but weaker than with RSO. Bernard et al. (2009) also found higher *trans*-11 C18:1 and *cis*-9,*trans*-11 C18:2 contents in goat milk fat when the basal diet was supplemented with sunflower oil instead of LO.

In the LO treatment, the contents of *trans*-11 C18:1 and *cis*-9,*trans*-11 C18:2 were not different from their respective 504-h values at 24 h (i.e., a plateau was reached up to the final sampling time), but in the RSO treatment, the plateau started later (120 h; Figure 1 and Table 2). Work in vitro by Jouany et al. (2007) with a mixed rumen microbial population indicated that BH of C18:3n-3 was faster, reaching a maximum at 5 h, whereas, in the case of *cis*-9,*cis*-12 C18:2, BH was still important between 5 and 24 h. According to Jouany et al. (2007), the reason for the delayed BH of *cis*-9,*cis*-12 C18:2 could be due to the preferential uptake of 18:3n-3 by bacteria, or differences in microbial isomerase or saturase affinity between the 2 FA. Work with dairy goats by Chilliard et al. (2005) indicated that the *cis*-9,*trans*-11 C18:2 increase in milk fat of goats fed sunflower and linseed oils, which was observed at 7 d, lasted up to the end of the experiment (35 d). Luna et al. (2008), also working with goats supplemented with whole linseed and sunflower oil, found that the maximum values in milk fat of *trans*-11 C18:1 and *cis*-9,*trans*-11 C18:2 were at 15 d. Unfortunately, no data was reported for the week before supplementation in those experiments.

Comparing Oil Treatments with the Control

Comparison of FA contents from oil treatments with the corresponding values in the control treatment at the different sampling times are shown in Table 2. Of the 45 possible comparisons (i.e., 15 selected FA and 3 oil treatments), 28 (7, 9, and 12 in OSO, RSO, and LO treatments, respectively) had significantly different values from the corresponding values in the control at 1 or more sampling times. Out of these 28 comparisons, 16 showed differences of the same algebraic sign (positive or negative) to their corresponding 312- and 504-h values in the control treatment. All 3 oils lowered the MCSFA content in milk fat, whereas increases in *trans*-11 C18:1 and *cis*-9,*trans*-11 C18:2 content were common to RSO and LO treatments. Specific for each oil were the increases in C18:0 in the OSO treatment; SCSFA, *trans*-10 C18:1, and *cis*-9,*cis*-12 C18:2 in the RSO treatment; and *trans*-15(+*cis*-11) C18:1, *cis*-15 C18:1, *trans*-11,*cis*-15 C18:2, C18:3n-3, and *cis*-9,*trans*-11,*cis*-15 C18:3 in the LO treatment.

Some of the changes observed when comparing oil-supplemented diets with the control diet at 312 and 504 h were also detected at shorter time periods. For example, the MCSFA content in milk fat of goats fed oil-supplemented diets had the same response observed at 312 and 504 h and as soon as 120 h; that response was already present at 72 h in the OSO treatment. Other FA responded faster: *cis*-9,*trans*-11 C18:2 and *trans*-10 C18:1 contents in milk fat of RSO-supplemented goats and *cis*-9,*trans*-11,*cis*-15 C18:3 in milk fat of LO-supplemented goats were already different from the

Figure 2. Time-dependent changes of *trans*-10 C18:1 and C18:3n-3 in milk fat of goats fed an unsupplemented diet (control) or diets enriched with high oleic sunflower oil (OSO), regular sunflower oil (RSO), or linseed oil (LO). FAME = FA methyl esters.

control at 24 h. Differences observed with the control treatment appeared at 12 h for *trans*-11 C18:1 in both RSO and LO treatments, for *cis*-9,*cis*-12 C18:2 in the RSO treatment, and for *cis*-15 C18:1, *cis*-9,*trans*-11 C18:2, and *trans*-11,*cis*-15 C18:2 in the LO treatment. Furthermore, only 1 h was necessary to obtain a significant increase in C18:3n-3 in the LO treatment. All the responses mentioned in the paragraph above were consistent in that the differences with control values were statistically significant at all sampling times after the earlier one observed. In contrast, other FA comparisons failed to give a continuous significant response after the first difference with the control was seen (Table 2).

The fact that the milk FA profile can be changed shortly after dietary lipid introduction had already been observed by Scott et al. (1971) and Gulati et al.

(1997). Those authors introduced fat into diets and observed clear changes in milk fat FA composition at the first milk sampling at 36 h in cows and 96 h in goats. It can be argued that those authors used protected oils or oilseeds, but the relevant fact is the short time required to obtain clear results. This is not surprising, in view of the results obtained by Li et al. (2009). Those authors observed increased *cis*-9,*trans*-11 C18:2 in the rumen fluid of dairy goats fed twice daily a diet supplemented with 4% soybean oil at 1, 2, and 6 h after the morning feeding.

The observed evolution of FA contents determined in the present work could not be necessarily identical for other types of diets (i.e., when lipid supplementation is accompanied by other changes, such as the dietary forage-to-concentrate ratio). However, a shortening of

the period for assessing changes in milk fat following the introduction of dietary lipid supplements may be possible. Although the data suggest that longer periods after lipid supplementation would be required for an accurate assessment of some FA (mainly *trans*-10 C18:1), a stable milk fat general profile could be achieved at shorter times than 21 d.

CONCLUSIONS

In summary, compared with their respective 504-h values, most FA responding to the addition of any of the 3 plant oils used in this study reached a value that did not differ greatly between 24 and 192 h (i.e., between 1 and 8 d). That means that for most of the FA studied, the time from introducing the plant oil into the diet up to having a milk fat response not different from that obtained at 21 d was 8 d. Results obtained under the conditions described in this paper show that typical changes in milk fat FA content by separately adding 3 different plant oils (OSO, RSO, or LO) to the diet of dairy goats, compared with a control diet without added fat, can be obtained as soon as 13 d after introducing the oils into the diet for most FA (earlier for many of them), although the maximum attainable values for some FA may require a longer time.

ACKNOWLEDGMENTS

This work was financed by the Ministerio de Ciencia e Innovación (MICINN, Madrid, Spain; AGL2008-04805 and the Consolider Ingenio 2010 Programme; FUN-FOOD CSD2007-063) and the Comunidad Autónoma de Madrid (Spain; 2009-AGR-1469). The authors thank A. Jiménez Secilla and B. Garfia Catalán of Laboratorio Agropecuario Regional of Córdoba (Spain) for their help with milk composition analysis. We are also grateful to I. Andújar-Ramírez (Universidad de Córdoba, Córdoba, Spain) and M. V. Rodríguez-Pino [Consejo Superior de Investigaciones Científicas (CSIC), Madrid, Spain] for their technical assistance in processing milk samples and J. J. Pérez-Hernández (Universidad de Córdoba) for his assistance in animal feeding and management.

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