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EFFECT OF SUNFLOWER OIL SUPPLEMENTATION ON NUTRIENTS DIGESTIBILITY AND CLA CONTENT OF DROMEDARY MILK

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ABSTRACT

Three experiments were carried out to investigate the effect of sunflower oil (SFO) supplementation on; 1) nutrients digestibility (Exp.1), 2) *in vitro* degradation kinetics of organic matter and fibre fractions (Exp. 2); and 3) milk composition and fatty acids profile in milk fat of dairy camels (Exp.3). Experimental diets were basal diet (SF-0), basal diet with 2% SFO (SF-2) and basal diet with 4% SFO (SF-4). In the digestibility trial (Exp.1), dry matter intake (DMI) and digestibility of NDF, ADF and N decreased ($P < 0.05$) in camel fed SF-4, but not with SF-2. Adding SFO at the level of 4% of DM negatively affected ($P < 0.05$) ruminally degradable fraction and degradation rate of OM, NDF and ADF of the experimental diets. No significant differences were detected on DMI and milk composition for either SF-2 or SF-4 (Exp.3). The provision of SF-2 and SF-4 to dairy camel had no effect ($P > 0.05$) on the concentrations of capric acid (C10:0) and lauric acid (C12:0) of milk fat. Myristic (C14:0) and palmitic acid (C16:0) contents of milk fat of animals fed added-oil diets (i.e., SF-2 and SF-4) were lower ($P < 0.05$) compared with control diet. The concentrations of total short and medium chain (i.e. C10:0 to C16:0) FA were reduced compared with control by 16% and 27% with SF-2 and SF-4, respectively. A positive response was observed for cis-9, trans-11 conjugated linoleic acid (CLA) content in milk fat, which increased ($P < 0.05$) by about 5 folds in animals fed SF-2 compared to SF-0. However, no difference was found between SF-0 and SF-4 in this respect. Total CLA isomers of milk fat were higher ($P < 0.05$) in SF-2 than in other treatments, since the values were 0.94, 3.80 and 0.60 g/100 g fat for, SF-0, SF-2 and SF-4, respectively. In conclusion, CLA content of dairy camel's milk could be increased by the addition of SFO at the level of 2% of DM of the diet with no negative effect on nutrients digestibility and daily milk production.

Key words: CLA, dairy camel, sunflower oil

Conjugated linoleic acid (CLA) represents a mixture of positional and geometric isomers of octadecadienoic acid with conjugated double bonds. The CLA are effective as anticarcinogenic, antidiabetic, and antilipogenic agents in the diet of laboratory animals (Pariza *et al,* 2001). Milk fat-derived cis-9, trans-11 C18:2 prevented growth of human mammary cancer cells more effectively than did synthetic trans-10, cis-12 C18:2 (O'Shea *et al,* 2000). Ruminant meat and milk are the predominant natural sources of the cis-9, trans-11 CLA, that accounts for nearly 90% of total CLA in milk fat from cows fed typical diets (Bauman *et al,* 1999). The cis-9, trans-11 CLA can be formed as a result of incomplete biohydrogenation of dietary fatty acids (FA) and by desaturase action on trans-11 C18:1 (another intermediate of biohydrogenation) in the rumen. Also, it can arise from isomerisation via cis-12, trans-11 isomerase produced by rumen bacteria (Kepler and Tove, 1967). In the bovine mammary gland (Bauman *et al,* 1999) or human tissues (Pariza *et al,* 2001), trans-11 C18:1 can be a source for endogenous synthesis of cis-9, trans-11 CLA via Δ9-desaturase. The substantial variation in content of CLA in milk fat between herds suggests that diet has a major influence. Kelly *et al* (1998) demonstrated that dietary supplementation of vegetable oils high in linoleic acid gave the greatest response and there is a clear dose-dependent increase in milk fat content of CLA. Cruz-Hernandez *et al* (2007) found that the addition of sunflower oil (i.e. 1.5%, 3.0% and 4.5% DM) to the diet in the presence of 0.5% of fish oil had no significant effect on milk production, but there was linear decrease in all short- and medium chain saturated FA and a linear increase in total trans- 18-1 and total CLA.

Compared to cow milk, milk from camels contains lower fat and lactose and greater potassium and vitamin C (Farah, 1993; Mehaia, 1995). Therefore, this study was aimed to evaluate the effect of

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supplementing camels diets with sunflower oil (SFO) rich in unsaturated fatty acids (UFA) on nutrients digestibility and FA profile of milk in order to increase its nutritive quality for consumers.

Materials and Methods

Experimental location and diets. This study was carried out at the Agricultural Research Station, Qasssim University. Basal diet was formulated by Arabian Agricultural Services Company (ARASCO), Riyadh, Saudi Arabia. Basal diet contained 92.3, 14.1, 32.6, 12.9 and 2.1%; organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and ether extract (EE), respectively. Sunflower oil (SFO) was purchased from the local supermarket. Experimental diets were basal diet (SF-0) which served as a control diet and basal diet with 2% SFO (SF-2) and basal diet with 4% SFO (SF-4).

Metabolism trial (Experiment 1). Nine mature male camels (*Camelus dromedarius*) with body weight of 225±11.3 kg, (mean±SD) were used and randomly assigned into three treatments (n=3/treatment). Each animal was kept in an individual metabolic cage having a tray for quantitative collection of faeces. The initial 21 days were used as an adaptation period and the collection period of samples was carried out during the subsequent 7 days. During the collection period, daily feed intake and faeces were individually recorded. Sub-samples of feed and faeces were collected every morning and dried at 60°C for 48 h, then were ground to pass through a 1 mm sieve and preserved for further chemical analyses.

***In vitro* rumen degradation of OM, NDF and ADF (Experiment 2).** By the end of the metabolism trial, 3 animals were slaughtered (one animal per each diet) to obtain rumen contents to carry out an *in vitro* experiment. Rumen content of each camel was squeezed through four layers of cheese cloth into pre-warmed flasks to separate the liquid from solid fractions. An automatic incubator (Daisyll incubator; ANKOM Technology, NY-USA) with 3-glass bottles was used for the *in vitro* study. To begin the *in vitro* experiment, each glass was filled with 360 ml of rumen fluid and 1440 ml artificial saliva (Hungate, 1966) and was kept in an incubator adjusted at 39°C. Six bags (pore size of 45 µm, Swiss Nylon Monofilament, Luzern- Switzerland) were used for each treatment; bags of each treatment were incubated with rumen fluid obtained from the animal fed the same diet. One bag was removed at intervals of 3, 6, 12, 24, 48 or 72h. After the incubation, bags and residues were washed by running tap water until the water became clear, then they were squeezed gently. Microorganisms attached to the residual samples were eliminated by freezing-rethawing technique as described by Kamel *et al* (1995). Residuals of OM, NDF and ADF were determined in each bag. Degradability coefficients were calculated by fitting the data for OM, NDF and ADF disappearance to model of Ørskov and McDonald (1979), as following:

$$P = a + b\,(1-e^{-ct})$$

where P is the cumulative amounts of OM, NDF and ADF degraded at time t, a is the readily degraded fraction, b is the fraction potentially degraded in the rumen, c is a rate constant of degradation of b and t is the incubation time in hours. The *in vitro* study was repeated 3 times per each treatment.

Feed intake and milk yield measurements (Experiment 3). Twelve multiparous she-camels (90±30 days postpartum; mean ± SD) were used to determine feed intake and milk yield as influenced by different levels of SFO supplementation. Each female was housed with its calf in an individual pen. The duration of milking trial was 8 wks (0, 1, 2, 3, 4, 5, 6 and 7). One day before the end of each week of lactation, calves were separated in the evening from their mothers and the mothers were machine-milked for the remaining milk after calve suckling. Calves were kept near to their dams to stimulate milk secretion at both milking times (i.e. 06:00 and 18:00 h). On the last day of each week (milking and sampling day), animals were totally machine-milked in the morning and evening, then milk yield was recorded and sampled for each female. Milk samples (100 mL from each) were divided into 2 equal subsamples of 50 mL each (with and without potassium dichromate preservative) and stored for further analysis. Milk samples, with preservative, were kept at 4°C for further analysis of fat, N and lactose. Milk samples without preservative were kept frozen at -20°C for FA determination. Also, on the last day of each week of lactation trial, diets were offered at 105% of the previous day's intake. The amount of feed offered and orts were recorded and sampled according to treatment. Samples of feed offered and orts were dried at 60°C for 48 h and kept individually to determine dry matter intake.

Laboratory analysis. Dry matter (DM), OM, EE and N of feed and faeces samples were determined according to AOAC (1990), while NDF and ADF were determined as described by Van Soest *et al* (1991). Fat, N and lactose contents in milk samples were

determined using LactoStar (Funke-Gerber, Berlin-Germany).

Fatty acids analysis. Fat was extracted from 5 ml milk using a mixture of chloroform and methanol (2:1, v/v) as described by Folch *et al* (1957). The FA of milk fat were transmethylated using sodium methoxide. Fatty acids methyl esters (FAME) were separated on a Shimadzu (2010A) gas chromatograph equipped with a FID detector, and a fused silica capillary column of 100 m × 0.25 mm (i.d.); 0.2 µm phase film (SP 2380; Supelco, Inc., Bellefonte, PA). The split ratio in the injector port was 50:1 with a linear velocity of 25 cm/sec of He. Oven temperature was adjusted at 60°C for 5 min, then increased from 60°C to 170°C at 3°C/min, held at 170°C for 10 min, ramped to 230°C at 5 °C/min, then hold for 20 min. Injector and detector temperatures were 250°C. The FA of milk fat were identified by comparison of their retention times with standard mixture of FAME (Cat.# O5632, Sigma-Germany & Cat.# 47885-U, Supelco, Bellefonte, PA).

Statistical analysis

Data for *in vitro* trial were analysed using the following model:

$$Y_{ij} = \mu + T_i + e_{ij}$$

where Y_{ij} = observation, μ = overall mean, T_i = treatment (i = 1, 2 and 3), and e_{ij}= residual error.

Data for metabolism trial, milk production, composition and FA content were statistically analysed by the Proc. MIXED for repeated measure (weeks) using procedure of SAS (SAS Inst., Inc., Cary, NC). Model that included the fixed effect of sunflower oil levels in the diet (SFO, 0, 2 and 4% of DM), animal was the term of the random statement. In lactation trial, data at week 0 were included as covariate term. Differences were considered significant at $P < 0.05$. When the differences were significant ($P < 0.05$), least square means were separated by the Duncan's, multiple range tests.

Results

Significant differences were not detected for the time (week), therefore results will focus on the effects of SFO level in the diet.

Ingredients and chemical composition of the three diets are presented in Table 1. Experimental diets contained similar concentrations of CP and metabolisable energy (ME). The EE has been increased in linear manner as a result of oil supplementation and the values were 2.1, 4.1 and 6.2% for SF-0, SF-2 and SF-4, respectively.

In the digestibility trial (Exp.1), the addition of sunflower oil to the basal diet decreased dry matter intake at SF-2 ($P > 0.05$) and SF-4 ($P < 0.05$) than SF-0, and the changed was -5% and -15% compared to SF-0 (Table 2). Non-significant negative effects ($P > 0.05$) were noticed for SF-2 on digestibility coefficient of DM, NDF, ADF and N compared to control diet. On the contrary, SFO supplementation at the level of 4% reduced ($P < 0.05$) the digestibility of DM, NDF, ADF and N than at control (Table 2).

Degradation parameters of OM, NDF and ADF of tested diets were presented in table 3. The rapidly degradable fraction (a) of OM was not affected by the SFO supplementation. Potentially degraded fraction (b) was decreased ($P > 0.05$) for SF-2 and SF-4 ($P < 0.05$) compared with the control diet. Degradation rate (c, % per h) of OM in SF-2 enhanced ($P > 0.05$) by 10% compared to SF-0. However, addition of SFO to the diet at 4% of DM reduced ($P < 0.05$) the c fraction

Table 1. Ingredients and chemical composition of experimental diets supplemented with different levels of sunflower oil (SFO).

Parameter	Level of sunflower oil		
	SF-0*	SF-2	SF-4
	% of DM		
Ingredient composition			
Alfalfa hay	26.0	24.0	22.0
Barley	26.0	26.0	24.0
Wheat straw	14.0	16.0	18.0
Corn, grain	10.0	10.0	10.0
Wheat bran	9.0	7.0	6.0
Soybean meal	9.0	10.0	11.0
Molasses	3.0	2.0	2.0
Sunflower oil	-	2.0	4.0
Sodium chloride	0.9	0.9	0.9
Dicalcium phosphate	0.6	0.6	0.6
Minerals, salts and vitamins	1.5	1.5	1.5
Chemical composition (%, DM basis)			
Organic matter	92.3	92.4	93.1
Crude protein	14.1	14.0	13.9
Neutral detergent fibre	32.9	33.0	33.4
Acid detergent fibre	12.9	13.7	14.2
Ether extract	2.1	4.1	6.2
ME**, (MJ/Kg)	10.1	10.4	10.7

*Basal diet + 0% of sunflower oil (SF-0), Basal diet + 2 % of sunflower oil (SF-2), Basal diet + 4 % of sunflower oil (SF-4).

**Calculated metabolisable energy.

Sunflower oil contained (% total FA methyl esters) C16:0 (7.5), C18:0 (4.3), C18:1 (26.3), and C18:2 (60.5).

compared with control (Table 3). The b fraction of NDF was not affected at SF-2, however, this value was lower (P < 0.05) at 4% SFO than in control (Table 3). A non-significant inhibitory effect after addition of SF-2 was noticed on b fraction and c of ADF, however the decreases in these two values (b and c) were significant (P < 0.05) at SF-4.

Results of milk composition as affected by different levels of oil supplementation are presented in table 4. Milk fat content increased (P > 0.05) by 7% in SF-2 compared to basal diet, although this increase was not significant.

Table 2. Effect of different levels of sunflower oil on dry matter intake and nutrients digestibility in she-camel (Exp.1)

Parameter	Level of sunflower			
	SF-0[1]	SF-2	SF-4	SEM[2]
Dry matter intake (kg)	4.9[a]	4.7[ab]	4.2[b]	0.17
Digestibility coefficient (%)				
DM	81.1[a]	76.7[a]	70.3[b]	1.62
NDF	64.6[ab]	66.5[a]	58.6[b]	2.51
ADF	57.9[a]	59.2[a]	49.2[b]	2.34
N	73.4[ab]	77.5[a]	70.9[b]	1.76

[1]Diet + 0% sunflower oil (SF-0), Diet + 2 % sunflower oil (SF-2), Diet + 4% sunflower oil (SF-4).

[2]SEM= standard error of the means.

[a,b]Means in the same row with different letters in their superscripts differ significantly (P < 0.05).

Table 3. *In vitro*, degradation kinetics of organic matter (OM), neutral detergent fibre (NDF) and acid detergent fibre (ADF) of diets supplemented with different levels of sunflower oil (Exp. 2).

Parameter	Level of sunflower oil			
	SF-0[1]	SF-2	SF-4	SEM
OM				
a[2]	26.4	25.9	24.6	1.65
b[2]	56.3[a]	54.3[ab]	49.3[b]	1.48
c[2]	0.108[ab]	0.119[a]	0.094[b]	0.007
NDF				
b	55.1[a]	54.3[ab]	47.6[b]	2.36
c	0.062	0.059	0.052	0.006
ADF				
b	43.3[a]	41.9[a]	32.1[b]	1.98
c	0.041[a]	0.039[a]	0.031[b]	0.002

[1]Basal diet + 0% sunflower oil (SF-0), basal diet + 2% sunflower oil (SF-2), basal diet + 4% sunflower oil (SF-4).

[2]a, b and c are constants predicted by the exponential equation as proposed by Ørskov and McDonald (1979).

[a,b]Means in the same row with different letters in their superscripts differ significantly (P < 0.05).

Higher milk yield (data are not presented) and fat content at SF-2 than SF-0 and SF-4 leaded to a higher (P>0.05) fat yield by about 14% in SF-2 than in control diet. Contents of milk protein and lactose remained unaffected (P > 0.05) for all SFO levels (Table 4).

The FA concentrations (g/100 g FA) of milk fat are presented in table 5. The provision of SF-2 and SF-4 to dairy camel exhibited no significant effects on the concentrations of capric acid (C10:0) and lauric acid (C12:0) of milk fat. Contrarily, myristic (C14:0) and palmitic acids (C16:0) contents of milk fat were significantly (P < 0.05) lower in SF-2 and SF-4 than in SF-0 milk (Table 5). Compared with control, total short and medium chains FA (i.e. C10:0 to C16:0) were reduced by 16% and 27% at SF-2 and SF-4, respectively. An increased (P < 0.05) response was observed in the concentration of C18:0 at SF-4 compared with SF-0. Oleic acid increased (P < 0.05) by about 21% at SF-4 than at control. The linoleic acid content (C18:2) in the milk fat did not differ (P > 0.05) due to SFO supplementation (Table 5).

Surprisingly, sharp positive response was observed for the cis-9, trans-11 conjugated linoleic acid (CLA) content in milk fat, which increased (P < 0.05) by about 5 folds in fat for animals fed SF-2 compared to these fed SF-0. However, no significant difference was found between SF-0 and SF-4 in this respect. Similar response was found for trans-10, cis-12 CLA contents in milk fat of animals fed SF-2 and the increment was significantly higher than SF-0 (about three folds increase). Total CLA isomers of milk fat were higher (P < 0.05) in SF-2 than other treatments, since the values were 0.94, 3.80 and 0.60 g/100 g FAME at SF-0, SF-2 and SF-4, respectively. The ratio between saturated FA to unsaturated FA (SFA/USFA) of milk fat was decreased (P < 0.05) by supplementation of SFO, which reflect the significant reduction of SFA in fat as a result of the added SFO to the diet. Meanwhile, the sum of USFA has been increased (P < 0.05) at SF-2 and SF-4 compared to SF-0, with values of 36.3, 41.8 and 44.6 mg/ 100 g FA of milk fat for SF-0, SF-2 and SF-4, respectively (Table 5).

Discussion

Diets were formulated on the basis of chemical analysis of initial samples of ingredients; consequently we anticipated that keeping the forage to concentrate ratio and similar energy level between various diets tested.

Low digestibility of DM at SF-4 (Table 2) could partially explain the reduction of DM intake that

might be due to decreasing turnover of the digesta to post-ruminal tract. Sekine *et al* (2003) reported that the capacity of the rumen to accommodate the bulky food is one of the limiting factors for DM intake. In contrary to results of current, Linseed oil (LO) at different levels (0, 2, 3and 4% of DM) reported to have no significant effects on DMI and nutrient digestibility in dairy cows (Benchaar *et al,* 2012). The effects of unsaturated fat including SFO supplementation on intake and nutrient digestibility have been variable among studies. For example, Veira *et al* (2001) found that the ruminal DM and NDF degradability of alfalfa hay were reduced by over 20% when soybean oil was added at a level of 3% to the ration of dairy cows. Ben Salem *et al* (1993) reported no effect of 7% rapeseed oil supplementation to a grass hay-based diet [60:40 forage:concentrate (F:C), dry matter basis] but rapeseed oil decreased OM and fibre digestibility in cow fed a corn silage-based diet (65:35, DM basis). In contrast, Martin *et al* (2008) found that supplementing 5.7% LO to forage-based diet (65:35 F:C, DM basis) of dairy cows decreased DMI and digestibility of DM, OM and fibre. Doreau *et al* (2009) supplemented 2.6% LO to a dairy cow diet rich in forage (75:25 F:C, DM basis) and found that LO did not depress DMI nor digestibility of DM, OM and fibre, when compared with the basal diet. Moreover, Ueda *et al* (2003) reported no differences in daily DMI in cows fed high-forage (65:35 F:C, DM basis) or high-concentrate (35:65 F:C, DM basis) diets and supplemented with 3% LO comparing with unsupplemented cows. Moreover, they found that fibre and OM digestibility increased in 3% LO supplemented dairy cows fed a high-forage diet, but digestibility of these components decreased when cows were fed a high-concentrate diet. The high-concentrate diet used by Ueda *et al* (2003) was 35: 65 F:C (DM basis) and contained 33.7% of NDF, that is similar to basal diet in the current study with 40:60 F:C and 32.9% NDF (DM basis). Several researchers found no adverse effects of supplemental fat on DM intake of ewes (Zhang *et al,* 2007), dairy cows fed canola seed (Khorasani *et al,* 1991), sunflower seed (Markus *et al,* 1996) or flaxseed (Mustafa *et al,* 2003). Taken together, these results suggested that effects of unsaturated fat supplementation, including SFO on DMI and nutrient digestibility vary with amount of fat added, form of fat added and the F:C ration of the diet.

Apparent digestibility of nitrogen was not affected by the low level of supplemental SFO (SF-2), however it was 5.5% higher ($P > 0.05$) than at SF-0 (Table 2). However, animals fed diet with 4% SFO showed a reduction ($P < 0.05$) in N digestibility. The lower digested N found in the current study could be due to the negative effect of fat on activities of rumen microorganisms, and subsequently the constant digestion rate of ruminal undegraded N in the small intestine which leads to an increased faecal N and a reduced total tract digestibility of N.

Table 4. Milk composition of dairy camels fed diets supplemented with different levels of sunflower oil (Exp.3)

Parameter	Level of sunflower oil			
	SF-0[1]	SF-2	SF-4	SEM[2]
Chemical composition of milk				
Fat, %	1.98	2.12	2.01	0.09
Fat yield (g/d)	210	239	216	10.5
Protein, %	2.52	2.66	2.70	0.08
Lactose, %	4.65	4.92	5.04	0.12

[1]Diet + 0% sunflower oil (SF-0), Diet + 2 % sunflower oil (SF-2), Diet + 4 % sunflower oil (SF-4).

[2]SEM = standard error of the means.

Means in the same row with different letters in their superscripts differ significantly ($P < 0.05$).

Table 5. Fatty acid concentrations in milk fat of dairy camels fed diets supplemented with different levels of sunflower oil.

Parameter	Levels of sunflower oil			
	SF-0[1]	SF-2	SF-4	SEM
Fatty acid (FA, g/100g) of total FA methyl esters				
Capric (10:0)	1.12	2.21	2.61	0.35
Lauric (12:0)	3.22	3.21	3.21	0.21
Myristic (14:0)	14.5^{a}	12.3^{b}	10.1^{b}	0.71
Palmitic (16:0)	26.5^{a}	20.7^{b}	17.2^{c}	0.87
Stearic (18:0)	18.3^{b}	19.8^{ab}	22.3^{a}	0.92
Oleic (18:1)	33.1^{b}	35.2^{b}	40.7^{a}	1.52
Linoleic (18:2)	2.31	2.85	3.13	0.51
CLA[2] 18:2 cis-9, trans-11	0.51^{b}	2.53^{a}	0.32^{b}	0.15
CLA 18:2 trans-10, cis-12	0.43^{b}	1.27^{a}	0.28^{b}	0.11
Total CLA	0.94^{b}	3.80^{a}	0.60^{b}	0.20
Categories of fatty acids (g/100 g FA)				
Σ saturated FA (SFA)	63.7^{a}	58.2^{b}	55.4^{b}	1.41
Σ unsaturated FA (USFA)	36.3^{b}	41.8^{a}	44.6^{a}	1.44
SFA/USFA	1.75^{a}	1.39^{b}	1.24^{b}	0.08

[1]Diet + 0% sunflower oil (SF-0), Diet + 2 % sunflower oil (SF-2), Diet + 4 % sunflower oil (SF-4).

[2]CLA = Conjugated linoleic acid

[a,b,c]Means in the same row with different letters in their superscripts differ significant ($P < 0.05$).

[3]SEM = standard error of the means.

Results of the kinetics of OM, NDF and ADF (Table 3) are in parallel with that of nutrient digestibility. The reduction of OM ruminally degraded at SF-4 was associated with a marked depression in NDF and ADF degraded in the *in vitro* study (Exp.2) and the values were lower than at SF-0 by 12% and 30%, respectively. Results of the current study are in agreement with those of Ikwuegbu and Sutton (1982) who reported that the inclusion of free oil in the diet of sheep reduced digestion of energy and OM in the rumen in a linear manner with increasing oil level added. Reduction of ruminally degradable b fractions of OM, NDF and ADF at SF-4 could be due to the adverse effect of oil supplement on rumen fermentation. Disruption of ruminal digestion by addition of fat to the diet has been documented before (Palmquist and Jenkins 1980; Zinn, 1989), while it was more pronounced when polyunsaturated FA (PUFA) were fed relative to the saturated fatty acids (Ferlay *et al,* 1991). Moreover, Ueda *et al* (2003) found an interaction between F:C and LSO supplementation for NDF ruminal degradation. Also, they found that ruminal NDF and ADF digestibility increased with LSO supplementation to the forage-rich diet whereas it decreased with supplementation to concentrate-rich diet. As for the non-significant effect of SF-2 on the ruminal b fraction of OM, NDF and ADF; and total tract digestibility of nutrients, this could be due to low level of supplemental oil added and its minor effect on ruminal fermentation. These results are consistent with Dutta *et al* (2008) who found that diet supplemented with low level of palm oil (2.5% of DM) had no effect on digestibilities of DM, OM and crude fibre, while higher level of oil supplementation to the diet had reduced those parameters.

In the current study, diets supplemented with SFO had no significant effect on milk fat content. Rations containing supplements rich in plant oils could modify the ruminal metabolism and consequently, milk production and composition (Palmquist *et al,* 2005). In cows, these strategies are known to induce a low-fat milk syndrome, which often referred to as milk fat depression (MFD). In contrast to cows, it has been demonstrated that milk fat concentration is less likely to decrease when supplementary lipids are fed to ewes (Caja and Bocquier, 2000; Pulina *et al,* 2006; Sanz-Sampelayo *et al,* 2007). Fat supplementation in animal diets affects milk fat percentage and composition by different mechanisms. First, fat feeding may have negative effects on rumen fibre digestion, thus decreasing acetic and butyric acid production which affect the de novo fat synthesis in the mammary gland (Griinari *et al,* 1998). Second, when fat is included in the ration the uptake and direct incorporation of long–chain fatty acids into triglycerides by mammary gland are increased (Palmquist and Jenkins, 1980). Therefore, milk fat content will respond to the balance between fatty acids uptake and secretion by the mammary gland, resulting in a decrease in de novo synthesis. Eventhough, supplementary SFO in the present study had shown an adverse effect on fibre digestion. Results obtained for milk fat content (%) of dairy camel fed diet supplemented with SFO are in agreement with that of ewes without MFD, which could conclude that the MFD might also be considered a function of species-dependent and a type of fat storage in animal.

Milk protein concentration in dairy camels was found not to be affected by the level of supplemental oil. Whitlock *et al* (2003) showed no difference in protein concentration or yield when cows were fed either conventional corn or high oil-corn. This is in contrast to Weiss and Wyatt (2000), who observed a decreased milk protein concentration when cows were fed high oil corn silage compared with conventional corn silage.

Overall, treatments had a negative effect on milk FA having 16 or less carbon atoms (Table 5). When supplemental fats are fed, the relative concentration of short-chain and medium-chain fatty acids decreased and that of long chain FA increased as a result of the reductions of the de novo FA synthesis and esterification in mammary tissues (Palmquist and Jenkins, 1980). It is interesting to notice that the concentration of C16:0 in milk fat of camels fed SF-0 was found to be 26.5 g/100 g FA. However, palmitic acid comprised about 35.8g/ 100g FA of milk fat of cows with a range of 25.5-46.1 g/ 100g FA of milk fat (Cruz-Hernandez *et al,* 2007; AbuGhazaleh, 2008; Murphy *et al,* 2008). Ney (1991) reported that the reduced of medium-chain fatty acids may represent an improvement in the profile of milk fat FA as these FA have been reported to constitute the hypercholesterolemic portion of milk fat.

The content of milk USFA in camels fed the basal diet was 36.3g/ 100g FA; this value was relatively similar to the average value (37.8%) with that reported by Sawaya *et al* (1984); Gorban and Izzeldin (2001) which were 45.3% and 30.5%, respectively. The modifications of the ratio between SFA and USFA could be partially attributed to an increase in the uptake of long-chain FA in

the mammary gland. In the cow and goat milk, when the bioavailability of C18 FA increases (as a result of either increased dietary intake or body lipid mobilisation), C6:0 to C16:0 FA decreased, and their concentrations diminish even more through dilution into the larger quantity of long-chain FA (Chilliard and Ferlay, 2004). This decrease could also be due to the effect of long-chain FA, which can alter the lipogenic gene networks in mammary epithelial cells. In fact, dietary polyunsaturated FA are biohydrogenated in the rumen into trans-FA, some of which are recognised as potent inhibitors of lipogenesis in the udder (Bauman *et al,* 2008; Kadegowda *et al,* 2009).

The increase in concentration of milk C18:0 with the added-oil diet (Table 5) could be the result of total rumen biohydrogenation of some of the dietary linoleic and oleic acids, whereas the greater presence of oleic acid in milk fat from sunflower oil treatments (Table 5) might be attributed to either its presence in the vegetable oil or to its synthesis capability through the action of mammary desaturase on the stearic acid taken from blood plasma (Lock and Garnsworthy, 2003).

From a nutritional point of view, the significant decrease in SFA in milk fat can be seen in a positive light, because accumulated evidence shows a strong link between the intake of some of these FA (C12:0, C14:0 and C16:0) and the incidence of cardio-vascular diseases (Hu *et al,* 2001; Mensink *et al,* 2003).

The main objective of the current study was to examine the effect of different levels of SFO supplementation to camel diets on milk fat cis-9, trans-11 CLA. In the current study, the concentrations of cis-9, trans-11 CLA and total CLA were higher by about 5 and 4 folds, respectively for dairy camels fed SF-2 compared with that fed the control diet. McGuire *et al* (1996) had suggested that the biohydrogenation sequence of linoleic acid can lead to an increase in CLA levels in milk fat. As for the effect of SFO on concentrations of cis-9, trans-11 CLA and total CLA in milk fat of camels fed SF-4, it was lower ($P > 0.05$) than in control or in SF-2 ($P < 0.05$). This finding is in agreement with that of Gervais *et al* (2005) who found a significant reduction in cis-9, trans-11 CLA content of milk fat when dairy cows received gradual levels of a rumen-inert conjugated linoleic acid supplementation. Also, Onetti *et al* (2001) reported a decline in cis-9, trans-11 CLA content of milk fat when tallow was increased from 2% to 4% of DM as a supplemental fat.

Implications

The addition of SFO at 4% of DM would negatively affect nutrients digestibilities of camel diets. However, CLA content of camel milk would be increased by the addition of SFO at a level of 2% of DM with no negative effects on nutrients digestibility and milk production. This finding confirm the safe supplementation of sunflower oil to the diets at 2% of the dry matter which resulted in an increase in the health beneficiary CLA.

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