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Dairy Science & Technology
Official journal of the Institut National de la Recherche Agronomique (INRA)Formerly 'Le Lait'

ISSN 1958-5586

Dairy Sci. & Technol.
DOI 10.1007/s13594-013-0117-6

Springer

Dairy Sci. & Technol.
DOI 10.1007/s13594-013-0117-6

ORIGINAL PAPER

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Received: 23 September 2012 / Revised: 8 February 2013 / Accepted: 8 February 2013

Abstract By-products from olive culture provided to camel could modify the fatty acid composition of its milk. The present experiment involving ten lactating she-camels divided in two groups aimed to evaluate the effect of enriched diet with crude olive cake on the milk production, milk fat excretion and fatty acid composition. The control group received diet including alfalfa, barley and concentrate. In the treated group, barley was partially substitute by olive cake (3 kg.day^{-1} as fed) for more than 3 months. There was no negative or positive impact on milk production, the fat and protein content in milk. However, a significant increase of total quantity of fat and protein excreted in milk was observed in treated group. Some changes were observed in fatty acid composition with a decrease of medium-chain fatty acids (C15:0 iso, C15:0, C16:0 iso, C17:1) but also vaccenic acid (C18:1ω-7). At reverse an increase of palmitic (C16:0) and γ-linolenic acid (C18:3ω-6) was observed after 3 months of olive cake distribution. As for other ruminants, it is possible to modulate the fatty acid composition of camel milk by the diet, but further trials for longer period and highest quantity of olive cake have to be implemented in camel.

Keywords Camel milk · Olive cake · Fatty acids · Milk fat

B. Faye · G. Konuspayeva · A. M. Musaad · H. Mehri
Camel and Range Research Center, P.O. Box 322, Al-Jouf, Sakaka, Saudi Arabia

B. Faye (✉)
CIRAD-ES, UMR SELMET Campus International de Baillarguet, TA C/112A,
34398 Montpellier, France
e-mail: faye@cirad.fr

G. Konuspayeva · M. Narmuratova
Al-Farabi Kazakh National University, 71 av. Al-Farabi, 050040 Almaty, Kazakhstan

A. Serikbaeva
Kazakh National Agrarian University, 8, Abai Av., 050013 Almaty, Kazakhstan

Published online: 07 March 2013

1 Introduction

The lipid feeding of ruminants has an impact on the milk fatty acid (FA) patterns whatever the source of lipids: linseed (Chilliard et al. 2009; Ferlay et al. 2010), sunflower seed oil (Bernard et al. 2009; Zhang et al. 2006), fish oil (Loor et al. 2005), soybean and canola oil (Matsuhita et al. 2007) or olive cake (Hadjipanayiotou 1999). In arid countries like Saudi Arabia where the olive (*Olea europaea* L.) cultivation is developing a high quantity of by-products is available, especially olive cake, which represents 55% to 80% of the total olive production after oil extraction depending on the method of extraction (Alburquerque et al. 2004; Molina-Alcaide and Yañez-Ruiz 2008). Olive cakes consist of olive pulp, skin, stone and water. In spite of its use for animal feeding in producing countries, notably for sheep, goat and cattle (Abo-Omar et al. 2012; Molina-Alcaide et al. 2008; Owaimer et al. 2004), the olive cake is rarely valorized in the camel diet. At our knowledge, the use of diet enriched in oil sources for camel is not available in published papers and the impact on FA composition of camel milk was never studied. Yet camel milk is reputed for its dietetic properties due to different factors. Its FA composition characterized by a high proportion of mono-unsaturated FA, is one of the parameter explaining its beneficial effect on the human consumers (Faye et al. 2008; Konuspayeva et al. 2008). Elsewhere, the use of olive cake could be a partial alternative to the distribution of green forages or cereals obtained by irrigation in a context of very high water constraint. Thus, the aim of the present paper is to assess the addition of olive cake in the normal diet of settled lactating camels on the milk production and FA composition of milk.

2 Materials and methods

2.1 Location and animals

This study was carried out in the camel farm of Al -Jouf "Camel & Range Research Center" located in north-west Saudi Arabia, 950 km from Riyadh. Average annual temperature was 20 °C, ranging from 12 °C to 27 °C, and average annual rainfall was 55 mm. The herd was composed by camels of four ecotype breeds (Malhah, Wadhah, Hamrah and Safrah) and their crossbreed. Camels were kept indoor throughout the year and housed in pens. Their normal diet before the experiment (expressed as fed) was composed of alfalfa (ad libitum), barley (3 $kg.day^{-1}.animal^{-1}$), salt, wheat bran (1 $kg.day^{-1}.animal^{-1}$). As the calving season occurred between December and February, all the camels were between first and third month of lactation at the beginning of the experiment. The characteristics of the experiment animals are reported in Table 1. The milk production not including part drunken by camel calves was recorded every day. After 15 days of adaptation to individual boxes, the total duration of the experiment was 101 days (21 days for progressive adaptation to olive cake distribution, then 80 days of monitoring), starting at the end of March up to June.

In spite of the heterogeneous composition of the herd, the groups' composition was comparable (no significant difference) as well for mean age (10.6±6.4 vs 8.8± 3.3 years for treated and control group, respectively) as mean parity (4.4±3.8 vs 2.8±

Table 1 Characteristics in age, parity, lactation stage, breed, weight and milk daily yield of the ten camels selected in the trial

Status	Age (years)	Parity	Lactation stage at d1 (days)	Type	Weight at d1 (kg)	Milk yield (L)
Treated	17	8	77	Malah	685	7.5±0.8
Treated	5	1	90	Malah	598	8.4±0.6
Treated	18	9	76	Hamrah	683	6.2±0.6
Treated	8	3	77	Hamrah	581	9.9±0.5
Treated	5	1	98	Safrah	630	4.6±0.6
Control	11	4	65	Wadhah	831	2.9±0.6
Control	6	1	72	Wadhah	570	3.9±0.8
Control	13	5	82	Hamrah	673	7.9±0.7
Control	5	1	19	Safrah	552	4.7±0.9
Control	9	3	20	Waddah	655	5.1±1.5

d1 first day of the experiment

1.8), mean lactation stage (83.6±9.9 vs 51.6±29.9 post-partum days) and mean weight (635±47.7 vs 656±110.8 kg). The camels were in good health all along the experiment.

2.2 Diet

For the experiment, ten adult lactating camels 5–18 years old (Table 1) only were available and divided randomly into two groups: (1) control group of five camels receiving individually current basal diet (as fed: 10 kg alfalfa, 4 kg of barley, 0.2 kg of concentrates under pellet form from market/animal); (2) treated group of five camels receiving progressively crude olive cake in substitution of barley, i.e. 0.4 kg olive cake for the first week, then 1 kg for the second week, then 1.5 kg for the third week of the trial, then finally 3 kg of olive cake per day for 80 days. In the same time, the quantity of barley distributed to the treated group decreased from 4 kg.animal^{-1} just before the trial to 3.6 kg at the first week, 3 kg the second week, 2.5 kg the third week then 1.5 kg only up to the end of the trial. Thus, the dry matter percentage being 88.5% for alfalfa and 87.2% for barley, the olive cake represented 17% of the dry matter. The olive cake was mixed with concentrate. The diet was distributed individually half in the morning and half in the evening after milking, and the refusals of all feeds were weighed daily. The animals were in good condition all along the experiment and had access daily to drinking water.

2.3 Sampling agenda and laboratory analysis

Milk yield was recorded daily. Milk was regularly sampled at the morning milking, every week for analysing the global composition. The total fat matter and protein was measured by automatic milk analyser device (lactoscan MCC) calibrated for camel milk. The analyses were achieved on aliquot of fresh milk just after milking. Fatty acid composition was determined in milk at days 7, 28, 48, 63 and 98. The milk

samples were stored at −80 °C before fat extraction. After extraction, the fat matter samples were stored at 4 °C.

The extraction of total lipids in camel milk was based on the Rose-Gottlieb method (Contarini et al. 2002) with modification by IDF 172:1995. The method applied for camel milk was described formerly by Konuspayeva et al. (2008). Fatty acids were determined after methylation by gas chromatography and were confirmed by mass spectrometry for each milk sample. A Varian 3400 gas chromatograph (Ajax, Canada) was equipped with a non polar DB-Wax capillary column (molten silica) of 60-m length, 0.32-mm diameter and 0.25-μm film thickness. All other conditions were those described by Konuspayeva et al. (2008). An Agilent 6890 Series GC System (Massy, France) was used for mass spectrometry with soft GC-MS 59. The results were expressed in gram per 100 g of methylesters).

Some saturated FA is well-known for their risk to coronary heart disease. The risk due to FA composition could be evaluated with the index of atherogenicity. The index of atherogenicity (IA) was calculated as reported formerly in Konuspayeva et al. (2008), namely:

$$\mathrm{IA} = \frac{\mathrm{aS}_{12} + \mathrm{bS}_{14} + \mathrm{cS}_{16}}{\mathrm{dP} + \mathrm{eM} + \mathrm{fM}'},$$

where, S_{12}=C12:0, S_{14}=C14:0 and S_{16}=C16:0; P=sum of ω-6 and ω-3 poly-unsaturated fatty acids (PUFA); M=oleic acid and M'=sum of other mono-unsaturated fatty acids (MUFA). *a–f* are empirical constants: b=4 and a, c, d, e and f are equal to 1. Iso fatty acids were not included in the calculation.

So, the final calculation of IA was:

$$\mathrm{IA} = \frac{\mathrm{C12:0} + (4 \times \mathrm{C14:0}) + \mathrm{C16:0}}{\mathrm{C10:1} + \mathrm{C14:1} + \mathrm{C16:1} + \mathrm{C17:1} + \mathrm{C18:1} + \mathrm{C18:2} + \mathrm{C18:3}}$$

For facilitating the interpretation, the FAs were grouped into different categories:

- According to the length of the chain by differentiating short (C4:0 to C10:0), medium (C12:0 to C14:0) and long-chain fatty acids (C15:0 and more);
- According to the saturation by differentiating saturated (Cω-0), mono-unsaturated (Cω-1) and poly-unsaturated fatty acids (Cω-2 and more).
- According to the ω-6/ω-3 ratio which is an index commonly used to evaluate the nutritional value of fat, i.e. the ratio:

(C18:2 ω-6+C18:3 ω-6) / (C18:3 ω-3+C20:5 ω-3+C22:6 ω-3).

For olive cake, the fatty acid analysis was performed in the laboratory of the FAO olive project UTF/SAU/026/SAU at Al-Jouf (Saudi-Arabia) by gas chromatography according to the method described by Browse et al. (1986).

2.4 Chemical composition of diet

The classical chemical analyses were achieved to evaluate the nutritive value of olive cake used for feeding the camels. The analyses of the dry and organic matter were based on AFNOR standard, 1982 and 1977, respectively. The total nitrogen was determined by Khjeldahl method (ISO standard 11261, 1997). The determination of the parietal components (NDF, ADF and ADL) was achieved on a Fibersac® analyser

Ankom Technology, Fairport, NY, according to Van Soest method (AFNOR standard, 1997). The brut energy expressed according to the forage unit for milk production system was assessed

2.5 Statistical analysis

The mean and standard deviation was calculated for each FA and for each group. The variance analysis (ANOVA) for time series (repeated measures procedure) was applied for each milk FA to evaluate the difference between control and treated groups all along the experiment. To identify the types of FA monthly patterns, a table (i=26; j=5) was composed. The 26 rows i corresponded to the 26 analysed FA and the 5 columns j to the time of milk sampling (days 7, 28, 48, 63 and 98). In each cell (i,j) was the mean of FA percentage for the FA i at the time j. To compare these different patterns whatever the relative importance of each FA in the milk, the values were compared by given an index 100 at each FA at the analysis achieved at day 7 of the experiment (first FA analysis achieved). This index I was calculated as follows:

$I=X_{ij}/X_{i7}$

where X_{ij} is the value (in percent) of the FA i at the time j and X_{i7}, the value of the FA i at the time 7 (analysis achieved on milk sample at day 7 of the experiment). An automatic clustering (hierarchical ascending classification) using Ward method and Chi^2 distance (Everitt et al. 2001) was applied on this table to identify the time patterns of each FA.

Non-parametric test (Mann–Whitney test) was used to compare the means of control and treated groups for unique data like IA.

The software XLSTAT (Addinsoft ©) was used for the data analysis.

3 Results

After 3 days only, the olive cake was accepted by the animals and no refusal was recorded all along the trial after this short time of adaptation.

3.1 Composition of the olive cake and nutritive value of the diet

The olive cake provided to camels was composed of 243 $g.kg^{-1}$ water, 91 $g.kg^{-1}$ oil, 424 $g.kg^{-1}$ dry stone, 30 $g.kg^{-1}$ almond and 212 $g.kg^{-1}$ mesocarpium and epicarpium. Regarding its nutritive value, the chemical composition (in gram per kilogram of dry matter) was 948 $g.kg^{-1}$ organic matter, 73 $g.kg^{-1}$ crude protein, 671 $g.kg^{-1}$ NDF, 552 $g.kg^{-1}$ ADF and 304 $g.kg^{-1}$ ADL. The fat content of olive cake was 120 $g.kg^{-1}$ of the DM and the main FA were palmitic acid (C16:0), palmitoleic acid (C16:1), oleic acid (C18:1), linoleic (C18:2) and linolenic (C18:3), respectively, 14.9%, 3.1%, 39.5%, 35.2% and 4.3%. These five fatty acids accounted for 97% of the total FA.

The percentages of NDF, ADF and ADL (in percent of DM) were reported both for alfalfa and barley (Table 2). Regarding nutritive value, the treated group received less energetic diet than control group but with higher crude protein content (Table 3).

Table 2 Chemical composition of the components of the diet (on DM basis)

Component	DM (%)	CP (g.kg^{-1})	NDF (%)	ADF (%)	ADL (%)
Alfalfa	88.5	163	49.5	31.6	6.3
Barley	87.2	116	28.2	6.8	1.6
Concentrate	90	121	–	–	–
Olive cake	76	74	67.1	55.2	30.4

CP crude protein, *NDF* neutral detergent fiber, *ADF* acid detergent fiber, *ADL* acid detergent lignin

The total intake was 12.5 and 12.3 kg DM in treated and control group, respectively.

3.2 Milk production

The milk production was on average significantly higher in treated group (7.5± 1.8 L.day^{-1}) than in control (4.9±1.9 L.day^{-1}) (Table 4), but by using ANOVA on repeated measures, there was no significant change all along the experiment (Fig. 1), except the last day of the trial (day 102) where the treated group had a higher mean milk production (7.88 L) than control group (5.22 L). In clear, statistically no clear negative or positive effect of the olive cake distribution on the milk production appeared with our experimental conditions.

3.3 Main milk components

There was no difference between groups regarding the fat (34.2±8.0 in treated group vs 33.5±8.1 g.L^{-1} in control group) and protein concentration (32.0±1.9 vs 31.6± 2.0 g.L^{-1}, respectively), but due to the difference in camel milk production, a slight significant difference ($P<0.05$) was observed from day 57 up to day 92 in the total milk fat excretion (Fig. 2) and from days 48 to 92 in the total protein excretion with higher values in treated group (Table 4).

3.4 Milk fatty acid composition

Regarding the whole samples, the milk pattern of FA showed the predominance of C16:0, C18:1 ω-9, C14:0, C16:1, C18:0 which represented 87.1% of the total FA

Table 3 Protein and energy level of diet distributed to control (4 kg barley) and treated (1.5 kg Barley+3 kg olive cake) camel groups

Component	CP (g.kg^{-1} DM)	Energy (FUM.kg^{-1} DM)
Alfalfa	163	0.62
Barley	116	1.10
Concentrate	121	1.18
Olive cake	73	0.33
Total control	1,906 (g)	7.14
Total treated	1,869 (g)	7.89

CP crude protein, *FUM* forage units for milk production, *DM* dry matter

Table 4 Milk yield, fat and protein composition of the camel milk in control and treated group (mean and SD all along the experiment)

Parameter	Control	Treated	*n*
Milk yield (L)	4.9±1.9a	7.5±1.8 b	2×510
Fat (%)	3.35±0.81 a	3.42±0.80 a	2×75
Fat excretion (g)	157±74 a	270±72 b	2×75
Protein (%)	3.16±0.20 a	3.20±0.19 a	2×75
Protein excretion (g)	150±56 a	236±68 b	2×75

Means with a different lowercase letter differ ($P<0.05$)

(Fig. 3). Regarding the FA individually, there was some differences between the two groups of camels especially the fatty acids C15:0 iso, C15:0, C16:0 iso, C17:1 and C18:1 ω-7 (isopentadecanoic, pentadecanoic, isopalmitic, heptadecenoic and vaccenic) which decreased in treated group. At reverse, palmitic acid (C16:0) and γ-linolenic (C18:3 ω-6) increased significantly in treated group (Table 5). The differences appearing mainly at the end of the trial, the olive cake addition in the diet did not seem have a short-term effect on milk FA composition, but after a sufficient time of supply.

After clustering analysis of individual FA time-profiles (control and treated animals all together), three types of patterns were identified (Fig. 4): (1) fatty acids increasing at day 48 and 63 (type 1) mainly long-chain fatty acids (C16-0iso, C17-0iso, C17:0, C18:0, C18-1 ω-7, C18-3 ω-6, C18-3 ω-3, C22-6 ω-3 and C4:0); (2) fatty acids with stable values all along the experiment (type 2) including all others fatty acids except (3) C12:0 and C18:1iso which strongly decreased from days 7 to 28, then increased regularly (type 3). However, in all types, the concentrations of the different FA were similar at the beginning and at the end of the trial. There was no difference between the groups (control vs treated) whatever the types of patterns.

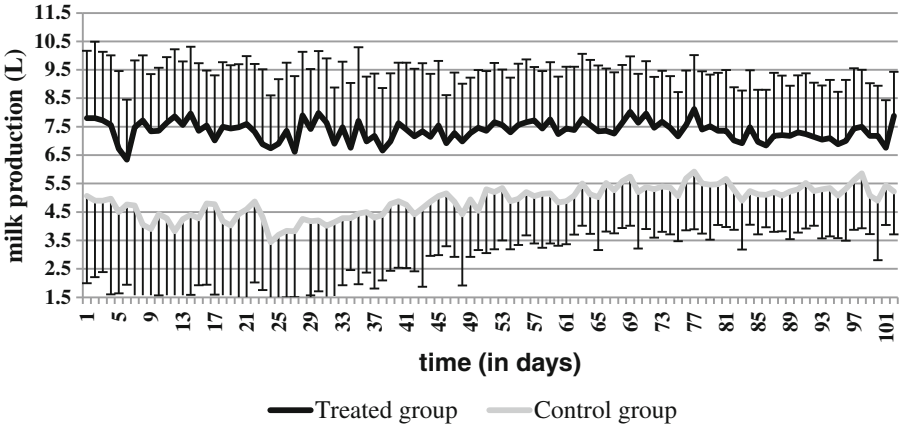

Fig. 1 Changes in daily milk production (mean and SD) in treated (n=510) and control (n=510) camel groups all along the experiment

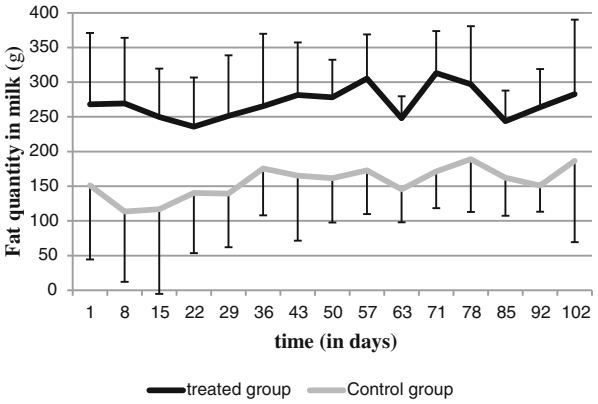

Fig. 2 Total milk fat excretion in control (n=75) and treated (n=75) group receiving 3 kg olive cake in the daily diet (weekly mean and SD for each group)

No significant difference was observed also by gathering the FA according to the length of the chain (short-chain fatty acid, SCFA; medium-chain fatty acid, MCFA; long-chain fatty acid, LCFA). However, a trend in increasing of long-chain FA was observed in treated group (Fig. 5 and Table 5).

Similar results were observed regarding the saturated (SAT), mono-unsaturated (MUSAT) and poly-unsaturated fatty acids (PUSAT) even if the ratio PUSAT/SAT increased from 4.97 to 5.10% in treated group while the ratio decreased from 4.96 to 4.88% in control one from d7 to d98 (Table 5).

Considering all over the trial, the index of atherogenicity was similar in control group (2.73) compared to treated one (2.98). The ω-6/ω-3 ratio was comparable also in the two groups: 3.16±0.84 in control group vs 3.21±0.4 in treated group.

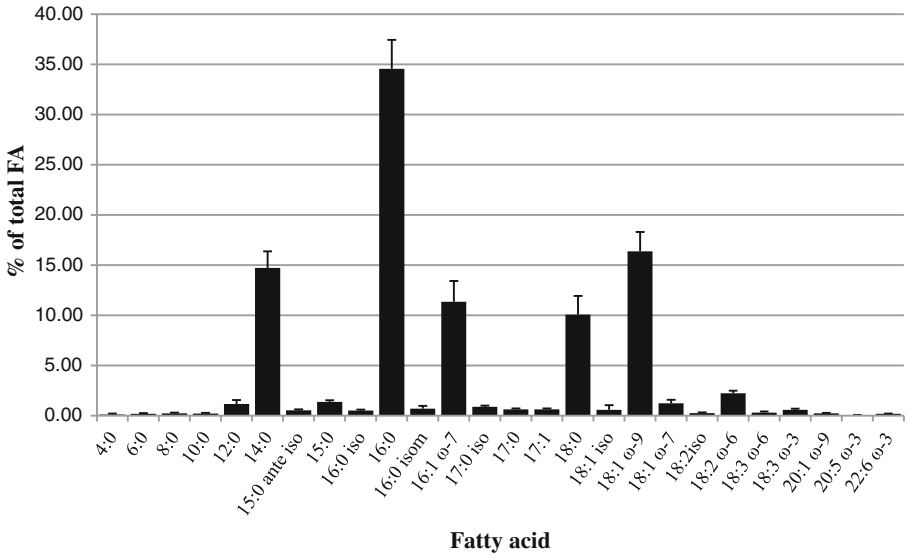

Fig. 3 Mean (and SD) fatty acid composition of the camel milk (in percent of the total fatty acid) in the camel population (n=50 analyses) independently of the dietary treatments

Table 5 Mean values of the different fatty acids in control and treated groups of camel all along the experiment, the treated group receiving 3 kg olive cake.day^{-1} in its diet. The column "time difference" indicates the day where a significant difference was observed

Fatty acid	Full name	Control (n=25)	Treated (n=25)	Time difference	P value
4:0	Butyric	0.14±0.07	0.12±0.08		NS
6:0	Caproic	0.21±0.06	0.20±0.06		NS
8:0	Caprylic	0.25±0.08	0.22±0.06		NS
10:0	Capric	0.24±0.08	0.22±0.05		NS
12:0	Lauric	1.19±0.31	1.15±0.38		NS
14:0	Myristic	15.09±1.92	14.64±1.85		NS
15:0 iso	Isopentadecanoic	0.58±0.06	0.49±0.11	Day 98	<0.01
15:0	Pentadecanoic	1.43±0.11	1.32±0.18	Day 48	<0.05
16:0 iso	Isopalmitic	0.56±0.08	0.49±0.09	Day 98	<0.05
16:0	Palmitic	33.14±3.28	35.54±2.16	Days 48 to 58	<0.01
16:0 isom	Palmitic isomere	0.78±0.26	0.63±0.27		NS
16:1 ω-7	Palmitoleic	12.23±2.4	10.65±1.34		NS
17:0 iso	Isoheptadecanoic	0.91±0.15	0.85±0.10		NS
17:0	Heptadecanoic	0.61±0.12	0.64±0.09		NS
17:1	Heptadecenoic	0.68±0.11	0.59±0.07	Days 48 to 98	<0.05
18:0	Stearic	9.37±2.18	10.58±1.33		NS
18:1 iso	Isooleic	0.51±0.23	0.66±0.60		NS
18:1 ω-9	Oleic	16.59±1.99	16.04±1.84		NS
18:1 ω-7	Vaccenic	1.41±0.21	1.10±0.28	Days 7 and 48	<0.05
18:2iso	Isolinoleic	0.26±0.05	0.25±0.08		NS
18:2 ω-6	Linoleic	2.26±0.26	2.21±0.25		NS
18:3 ω-6	γ-Linolenic	0.27±0.14	0.36±0.08	Day 98	<0.001
18:3 ω-3	α-Linolenic	0.58±0.12	0.58±0.14		NS
20:1 ω-9	Eicosenoic	0.24±0.04	0.25±0.05		NS
20:5 ω-3	Eicosapentaenoic	0.06±0.03	0.06±0.02		NS
22:6 ω-3)	Docosahexaenoic	0.19±0.05	0.18±0.03		NS
SCFA	Short chain	0.82±0.23	0.77±0.23		NS
MCFA	Medium chain	16.67±2.76	16.01±2.55		NS
LCFA	Long chain	82.65±2.70	83.35±2.43		NS
SAT	Saturated	63.81±4.52	66.57±2.91		NS
MUSAT	Mono-unsaturated	32.56±4.43	29.81±2.77		NS
PUSAT	Poly-unsaturated	3.57±0.41	3.60±0.44		NS

4 Discussion

On average, the fatty acid composition of dromedary milk in our study was in the mean of the values reported in the literature in very various conditions (Fig. 6): samples mixing Bactrian and dromedary camels (Konuspayeva et al. 2008; Narmuratora et al. 2006), wild Bactrian camels (Jirimutu et al. 2010), Maghrebi camel (Shibani et al. 2011) or dromedaries reared in Germany (Dreiucker and Vetter 2011). Bactrian camels have a

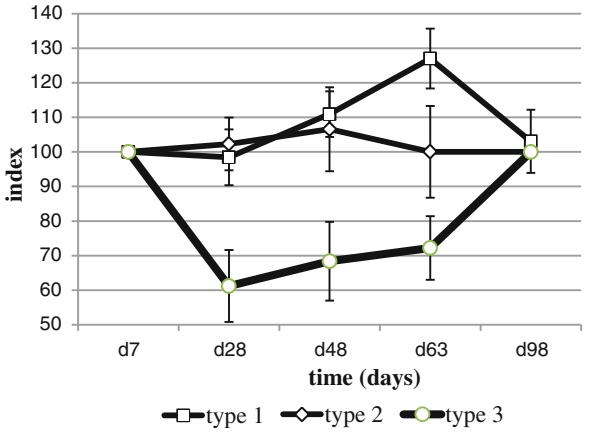

Fig. 4 Types of pattern of time change in fatty acid concentration (index 100 at day 7) independently of the dietary treatments (type 1: C16-0iso, C17-0iso, C17:0, C18:0, C18-1 ω-7, C18-3 ω-6, C18-3 ω-3, C22-6 ω-3 and C4:0; type 2: C6:0, C8:0, C10:0, C14:0, C15:0iso, C15:0, C16:0; C16:0isom, C16:1 ω-7, C17:1, 18:1 ω-9, C18:2iso, 18:2 ω-6, 20:1 ω-9, 20:5 ω-3;type 3: C12:0 and C18:1iso)

higher proportion of saturated FA compared to dromedary but the studies on the variability in FA composition due to types of diet were not available in camel.

4.1 Olive cake in camel diet

In the present trial, the two diets were not iso-energetic and iso-proteic because the aim of the study was to substitute barley (costly in water) by available local by-product, and to assess the impact of such substitution on milk production.

The use of olive cake in camel feeding is not common and rarely cited in reports contrary to sheep. The digestibility of olive cake has been rarely studied (and exclusively in sheep), the references are old and the results heterogeneous (Molina-Alcaide and Yañez-Ruiz 2008; Thériez and Boule 1970). Moreover, camel is known for its ability to better digest low nutritive feed than other ruminants (Jouany 2000) and probably the values reported in the literature were not adapted to camel. Thus, it is difficult to estimate the optimal quantity to be distributed. However, it was reported that on average, the diet for sheep could contain 1.4 to 2.2 kg DM.day^{-1} (Sancoucy 1984). We have fixed a total amount of 3 kg as fed (i.e. 2.3 kg DM) in our trial which was accepted by the animal in spite of the low palatability. However, by the mixing with barley, no refusal was observed after the adaptation period. The depressive effect of olive cake on organic digestibility was reported, but the mechanisms appeared controversial (Zaidi et al. 2008). According to Molina-Alcaide et al. (2008), olive cake could be used in the practical feeding of ruminants without negatively affecting microbial amino-acid supply.

4.2 Impact on milk production

The difference in the milk production between the two groups randomly selected could be partly explained by the slight (but no significant) difference in the mean parity, the control group being younger. Indeed, the milk yield in camels from our

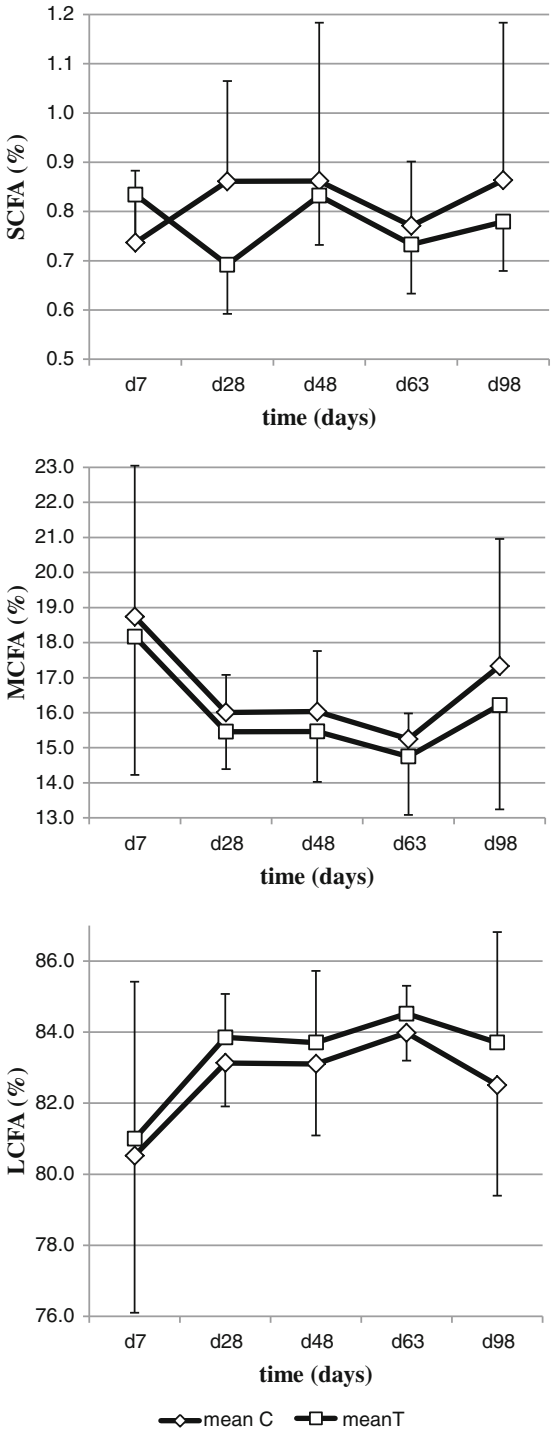

Fig. 5 Changes in fatty acid composition (short-, medium- and long-chain fatty acids) of camel milk in control (*diamond*) group and treated (*square*) group receiving 3 kg olive cake per day (n=25 in each group)

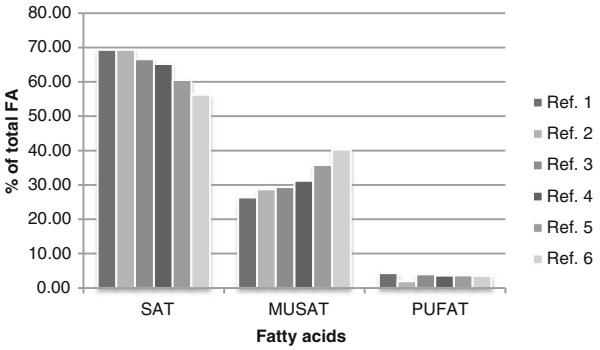

Fig. 6 Comparison between fatty acid composition of camel milk according to Narmuratova et al. (2006) (*Ref. 1*), Konuspayeva et al. (2008) (*Ref. 2*), Jirimutu et al. (2010) (*Ref. 3*), the present results (*Ref. 4*), Dreiucker and Vetter (2011) (*Ref. 5*) and Shibani et al. (2011) (*Ref. 6*)

farm is maximal in parity 6 (Musaad et al. 2012). In Chios ewes, Damascus goats and Friesian cows, Hadjipanayiotou (1999) did not report any significant effect of diet enriched with olive cake silage on the daily milk yield. Chiofalo et al. (2002) observed reversely an increase in total milk yield of ewes with 200 g of olive cake per kg of concentrate. In our study, the olive cake represented a low part of the diet (17%) which is the lowest proportion generally used in experiments (Chiofalo et al. 2002). With such level, no negative or positive effect was observed on dairy yield. It was stated that high level of lipid supplementation could affect feed intake, milk yield or protein/fat content (Chilliard and Ferlay 2004).

4.3 Effect on milk main components

The proportion of fat in the camel diet increased in treated group. Three kg of crude olive cake provided 273 g of oil. According to the low content of fat in alfalfa (25 $g.kg^{-1}$ DM) and in barley (19 $g.kg^{-1}$ DM), the olive cake raised the fat content of the total diet by 115%. The fat content in the diet passed from 2% in control group to 4.2% in treated group. In spite of this high increase in fat intake, no change in fat concentration in milk was observed in camel, but the total fat excretion was higher at the end of the trial, as well as protein excretion which increased significantly also at the end of the experiment due to the higher milk yield at the end of trial. In the trial of Hadjipanayiotou (1999), only an effect in ewe milk was observed, the fat content passing from 48.2 $g.kg^{-1}$ in control group to 54.0 $g.kg^{-1}$ with an increasing fat by 65% in the diet. However, this author did not report significant effect on fat content in goat and cow milk.

4.4 Effect on fatty acid composition

The main effect described by several authors in other species than camel was the effect of different types of oil supplementation on milk FA composition. For example, soybean and marine algal oil could modify the FA composition of ewe milk (Reynolds et al. 2006). Soybean, canola and sunflower oil had similar effect, especially on mono-unsaturated and poly-unsaturated FA (Matsuhita et al. 2007). The

addition of fish oil in goat at the end of gestation appeared a way for enrichment of colostrum in ω-3 poly-unsaturated FA (Cattaneo et al. 2006). The supplementation of ewes with sunflower seeds increased the concentrations of mono-unsaturated, poly-unsaturated and long-chain FA (Zhang et al. 2006). As the olive cake contained high concentrations of FA in C16 and C18 (except stearic acid C18:0), the impact of enriched diet was expected to increase similar FA in milk. In fact, if it is the case for palmitic and γ-linolenic acids, surprisingly the concentration in oleic acid was not different in supplemented camels. Yet, a significant increase of oleic acid concentration after olive cake supplementation was observed by many authors in sheep milk (Caparra et al. 2005; Reynolds et al. 2006). The distribution of diet enriched in oleic acid in our experimental conditions (duration, type and quantity of olive cake) was not sufficient to observe a significant effect in camel.

In ewe receiving silage of olive cake, an increase of different FA from C18 group (stearic, oleic, isooleic and linoleic acids) was observed except CLA (C18:2-*cis*9 *trans*11) and γ-Linolenic (18:3 ω-6) while short-chain and medium-chain FA decreased (Abdeddou et al. 2011; Caparra et al. 2005). An important interaction was observed between the oil source and the forage type. The changes in FA patterns could vary according to the composition of the basal diet (Bernard et al. 2009) and according to the type of olive cake: crude, with extracted oil or silage (Caparra et al. 2005).

In ruminants, the FAs present in the diet are metabolized and biohydrogenated in the rumen, resulting not only in the production of C18:0, but also in a wide range of isomers of poly-unsaturated and mono-unsaturated FA (Chilliard et al. 2007). In other species than camel, when feeding unprotected vegetable oilseeds containing high level of C18:1, C18:2 ω-6 or C18:3 ω-3 as crude olive cake, the proportions of both C18:0 and C18:1 increased in milk (Chilliard et al., 2007).

The FA composition could change according to the lactation stage (Stoop et al. 2009). In camel, it has been stated that the MCFA increased at the first month of lactation whereas percentage LCFA decreased (Kamal and Salama 2009). In our trial, all selected camels were at least at 3-week lactation stage at day 1. As the mean lactation stage was not significantly different in the two groups of our study, the variation in milk FA composition could not be attributed to the number of post-partum days.

However in the conditions of our experimentation with the lack of any former experience regarding camel feeding with olive cake, it was difficult to evaluate the optimal quantity of supplementation and the length of the trial to get a more significant effect on the fatty composition of camel milk.

5 Conclusion

As for other ruminants, there is a potential to modify milk FA in camel by changing the feeding conditions in general and by adding supplement rich in oil as crude olive cake. The main observations of the present experiment were to attest that the supplementation of the camel diet with crude olive cake (representing 17% of the dry matter) did not affect the dairy yield, neither the fat nor protein content, and could modulate the FA composition, especially by increasing γ-linolenic and palmitic acid.

The distribution of crude olive cake to camels in the context of Saudi Arabia where the forage production is quite problematic in terms of water management could be an efficient alternative, both for the valorization of olive by-products and for camel feeding. However, further experiments are needed to evaluate the optimal form of supplementation and the interactions with the other components of the diet.

Acknowledgements This study has been achieved within FAO camel project UTF/SAU/021/SAU in collaboration with the FAO olive project UTF/SAU/016/SAU and with the support of Camel and Range Research Center (CRRC). The authors thank Mr. Sallal Issa Al-Mutairi, head of the CRRC for his encouragements and support. We thank also the staff of the camel farm (Mrs. Hassan and Surish) for the monitoring of the camel feeding. Thanks also to FAO team leader at Riyadh, Dr. A. Oihabi and the FAO regional officer, Dr. Bengoumi who supported this project from the beginning. Finally, we thank Mr. G. Piombo from the UMR IATE-lipotechnie (CIRAD, France) for the analysis of fatty acids in milk.

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