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Short communication: Fatty acid profile of yak milk from the Qinghai-Tibetan Plateau in different seasons and for different parities

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ABSTRACT

Yaks are the most important grazing livestock for milk production on the Qinghai-Tibetan plateau because these animals are adapted to the high elevations and extremes of cold and can graze throughout the year. In the present study, 30 yaks were selected and the fatty acid (FA) profile of yak milk at different seasons and parities was investigated using gas chromatography. The concentrations of *cis*-9 C18:1, *cis*-11 C18:1, *cis*-9,*trans*-11 C18:2, and C18:3 n-3 in yak milk were higher in summer (25.26, 1.50, 1.46, and 0.33 g/100 g of total FA, respectively) than in winter (22.17, 0.77, 1.27, and 0.28 g/100 g of total FA, respectively). The contents of monounsaturated and polyunsaturated FA in milk fat of multiparous (parities 2 to 5) yaks (31.61 and 4.20 g/100 g of total FA, respectively) were higher than those in primiparous yaks (29.61 and 3.80 g/100 g of total FA, respectively). These results suggest (1) that the potential exists to improve the FA composition of yak milk by developing local supplement resources during the winter and (2) that multiparous yaks have a more favorable FA profile than primiparous yaks.
Key words: yak milk, fatty acid, season, parity

Short Communication

Yaks (*Bos grunniens)* are members of the subfamily Bovinae (Ding et al., 2008). Yaks live in the high reaches of the Himalayan region (Nepalese Himalayas, Indian Kashmir, and Mongolia) and the Qinghai-Tibetan plateau (China). The total world population of yaks is estimated at around 14.2 million, more than 93.7% of which are located in China (Ding et al., 2008). Yaks can thrive in conditions of extreme harshness, and they are the only bovine species that can survive on the Qinghai-Tibetan plateau, at heights of 2,500 to 6,000 m above sea level. According to local herders, yak milk and its products are widely consumed and regarded as the major source of household income for residents on the plateau.

Owing to the extreme cold and high elevation, demand for fat by people in the plateau is greater than by those on the plains. Yak milk is the major supply of fat to the herders, with yak milk fat accounting for 15 to 32% of a herder's daily fat intake; thus, yak milk plays an essential role in vital functions and in providing nutrients important for human health for the people of the Qinghai-Tibetan plateau. Most yak milk is used to produce high-quality yak butter. The composition and fatty acid (**FA**) content are the 2 main factors that determine milk and butter quality, and thus more information is needed about the FA composition of yak milk.

Besides the nutritional value of yak milk fat, the biological roles of specific FA have recently attracted more attention, and more emphasis is being given to improve the FA profiles of food. Many studies have focused on conjugated linoleic acid (**CLA**) and its isomers, because of their potential benefits, such as antidiabetic and anticarcinogenic effects, and their positive influence on immune function (Houseknecht et al., 1998; Maijala, 2000; Pariza et al., 2001). Eicosapentaenoic acid (**EPA**) and docosahexaenoic acid (**DHA**) are recognized as playing an essential role in human health, and are particularly important for the proper function of the brain, heart, and retina (Simopoulos, 1991; Kris-Etherton et al., 2002; Din et al., 2004). Because of the unique grazing environment, yak milk fat may contain some unique FA compared with milk fat from other mammals.

The FA composition of cow milk is affected by many factors, including altitude (Collomb et al., 2002), breed (Lawless et al., 1999; Soyeurt et al., 2006), and diet (Palmquist et al., 2006). Diet is the most important factor influencing the FA profile of ruminant milk (Stanton et al., 1997). Yaks generally feed by grazing naturally

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and do not receive any supplement in winter. Therefore, the quantitative and qualitative availability of yak milk is greatly influenced by season. Seasonal changes in milk FA composition were observed by Thorsdottir et al. (2004). Some reports exist of seasonal variations in FA composition, particularly *cis*-9,*trans*-11 CLA and vaccenic acid content, in the milk fat of pasture-grazed ewes (Nudda et al., 2005; Ostrovský et al., 2009); however, little is known about the seasonal variation of yak milk FA profile.

Parity is another factor affecting the FA profile of milk. Kelsey et al. (2003) reported differences in CLA content in milk fat between primiparous and multiparous animals. The unsaturated FA percentage of milk was greater for multiparous than for primiparous yak milk (Peng et al., 2008). The authors' results indicate that the FA content of yak milk was affected by parity; however, exactly how parity affects yak FA composition is not known.

Therefore, the objective of this study was to investigate the FA profile of yak milk in different seasons and parities. Because of the unique FA profile and economic potential of yak milk, better understanding of its composition could contribute to the added value of yak milk products. Breeding yaks specifically for favorable FA composition might have potential benefits.

Selection and Care of Yaks

Yaks in this study were located in Mabusuona of Gannan, Tibetan Autonomous County, Gansu Province, in northwest China. The climate of the research area is dominated by the southeastern monsoon and high atmospheric pressure from Siberia, with severe, long winters and cool, short summers. During the sampling periods, the mean temperature from August to November was 5°C, and the 4-mo mean precipitation was 53.73 mm. The yaks graze on natural pasture all year round, without irrigation, fertilizer, or other changes to the pasture. Seasonal grazing is the main grazing management in this area; yaks are moved to summer rangeland in July and back to winter rangeland in October every year.

For this study, the care of the yaks was under the control of local herders in the Qinghai-Tibetan Plateau production area. From a herd of 150 yaks, 30 were selected and divided into 5 groups of 6 yaks, based on the number of pregnancies. All primiparous yaks were 4 to 7 yr old; yaks in their second lactation were 6 to 10 yr old; yaks in their third lactation were 8 to 12 yr old; yaks in their fourth lactation were 10 to 13 yr old; and yaks on their fifth lactation were 12 to 16 yr old. The experiment was conducted from August to November 2009.

Feeding Regimens

In this study, the yaks grazed naturally on the pastures during the summer rangeland period (August to September 2009) on rangeland A, which was at an elevation of about 3,510 m (N34°52.299′, E103°3.402′). In the transition period (September 20–27, 2009), the yaks were gradually grazed on natural pasture. Later (October–November), the yaks grazed on dry pastures that were still growing or had plants on rangeland B at an elevation of about 3,540 m (N34°51.674′, E103°3.402′). The plant content of these 2 pastures was the same. The plant types consumed by the yaks included alpine meadow (dominated by *Polygonum* and *Kobresia* spp.), alpine steppe (dominated by *Elymus* and *Poa* spp.), and shrub-meadow plants (dominated by *Potentilla* and *Kobresia* spp.).

Yak Milk Sampling Procedures

Milk samples were obtained from 30 yaks; the yaks were milked once daily at around 0700 to 0800 h. At each milking, milk production was recorded and milk was sampled. Approximately 30 mL of milk from each yak was manually collected from scattered households. The milk was stored in a sterilized centrifuge tube on ice in a sealed sample collection kit. The samples were transferred from the farm to the laboratory, which took approximately 6 h. Samples were stored at −20°C and analyzed the following day.

Total Lipid Extraction

Extraction of total fat from milk samples was performed according to the Röse-Gottlieb method (AOAC, 1990) with the following modifications. Briefly, ammonia (1.5 mL), ethanol (5 mL), ether (10 mL), and petroleum ether (10 mL) were added to 5 mL of sample. Samples were centrifuged at 4°C (845 × *g*) for 10 min and the upper layer was collected. The extraction was repeated a second time using ether (5 mL) and petroleum (5 mL). Samples were centrifuged at 4°C (845 × *g*) for 10 min and the upper layer was collected. A third extraction was repeated using petroleum (5 mL); samples were centrifuged for 10 min (845 × *g*; 4°C) and the upper layer was collected, evaporated, and then weighed.

The FA methyl esters (**FAME**) were prepared by base-catalyzed trans-esterification according to the International Dairy Federation standard procedure (FIL-IDF, 1999). Briefly, approximately 25 mg of lipid extract was mixed with 0.2 mL of 2 mol/L methanolic KOH, mixed by vortex for 2 min, and then centrifuged for 1 min (845 × *g*). After addition of 0.1 g of sodium

hydrogen sulfate monohydrate, the samples were centrifuged for 3 min (845 × *g*), and the supernatant was used for gas chromatography analysis.

FA Analysis

Fatty acid methyl esters were quantified using a gas chromatograph (GC14, Shimadzu Corp., Kyoto, Japan), with a flame-ionization detector and a fused silica capillary column (60 m × 0.25 mm internal diameter × 0.25 μm, DB23, Agilent J&W, Santa Clara, CA). The column oven temperature was held at 50°C for 1 min, increased at a rate of 25°C/min to 175°C followed by a 1-min hold, and then increased at a rate of 4°C/min to 230°C, followed by 20-min hold. The injection port was maintained at 250°C and the detector port at 280°C. The total run time was 42 min. The solution of FAME in hexane (2 μL) was injected into the column with a split ratio of 100:1. Hydrogen was used as the carrier gas at 255 kPa and nitrogen was the makeup gas at 1 mL/min. Chromatograms were recorded using N2000 software (Zhejiang University, Zhejiang Province, PR China). Identification of FAME in the sample was made by comparing the relative retention times of the sample FAME peaks with the standards. The standard 37-component FAME Mix (Supelco, Bellefonte, PA) was purchased from Sigma (Shanghai, China), and individual CLA references (*cis*-9, *trans*-11; *trans*-10, *cis*-12) were obtained from Matreya (Pleasant Gap, PA). However, some FA pairs, mainly of positional isomers, could not be resolved under these conditions.

Statistical Analysis

Statistical analyses were performed using SPSS 13.0 for Windows XP (SPSS, Inc., Chicago, IL). The GC-determined contents of FA compounds in milk samples were analyzed statistically using a one-way ANOVA statistical package. Tests for difference were performed using Duncan's multiple range method. $P < 0.05$ was considered significant.

Milk Fatty Acid Composition

Table 1 shows the fat content and the major FA profile of milk from primiparous yaks in different seasons. The main FA in yak milk were C14:0, C16:0, C18:0, and C18:1, a pattern similar to those reported by Neupaney et al. (2003a,b) and Sheng et al. (2008). The average contents of short-, medium-, and long-chain FA in the yak milk were 9.69, 42.37, and 47.94 g/100 g of total FA, respectively. Of the total fat, 68.68 g/100 g of total FA on average was saturated, which was lower than that in cow milk (Heck et al., 2009). Many studies have shown that a lower proportion of saturated FA in milk fat seems to be favorable for human health because of the negative effect of saturated FA on arteriosclerosis (Pfeuffer and Schrezenmeir, 2000). Of the unsaturated FA, *cis*-9 C18:1 was the most abundant. A high concentration of long-chain unsaturated FA are found in yak milk, mainly due to the high C18:3 n-3 (α-linoleic) acid content in the pastures. α-Linoleic acid is associated with production of specific long-chain unsaturated FA in milk (Baumgard et al., 2000).

As for functional FA, the mean proportion of EPA in yak milk (0.04 g/100 g of total FA) was lower than that in cow milk (0.08 g/100 g of total FA), and that of DHA (0.05 g/100 g of total FA) was similar to that of cow milk (Nudda et al., 2005). The *cis*-9,*trans*-11 CLA content in yak milk was higher than that in cow milk (Lin et al., 1995; Baumgard et al., 2000). Higher contents of these functional FA were related to the high C18:3 n-3 content in the grazing pastures (Ostrovský et al., 2009). Milk from pasture-raised animals is naturally enriched in CLA compared with that from animals fed a TMR (Mel'uchová et al., 2008). Moreover, an unknown substance found in pasture enhances the growth of particular bacteria in the rumen that are responsible for producing CLA and inhibiting further hydrogenation of vaccenic acid (C18:1) to stearic acid (C18:0), which would enhance CLA milk fat content (Nudda et al., 2005; Or-Rashid et al., 2008).

Differences in Milk FA Compositions in Different Seasons

As shown in Table 1, fat content and the major FA profile of milk were significantly affected by season in both primiparous ($P < 0.05$) and multiparous (data not shown) yaks.

During our experimental period, fat content increased from August to November. Similar seasonal patterns have been reported in other studies (Fox and McSweeney, 1998). General changes in the average yak diet composition can help explain the seasonal variation in fat. A lower milk fat content for fresh pasture compared with dry pasture is commonly observed (Couvreur et al., 2006). The linolenic acid content for fresh grass is much higher than that in withered pasture. High levels of linolenic acid are associated with the production of specific long-chain unsaturated FA that inhibit de novo fatty acid synthesis in the mammary gland and decrease the milk fat content (Baumgard et al., 2000; Heck et al., 2009).

The saturated FA content increased from 67.37 g/100 g of total FA in summer to 70.01 g of total FA in winter. A possible reason for this seasonal variation in FA composition is the different diets in the 2 seasons. The

Table 1. Fat content and fatty acid (FA) profile (g/100 g of total FA) of milk from primiparous yaks in different seasons[1]

	Summer rangeland		Winter rangeland	
Item	August	September	October	November
Fat (g/100 mL of milk)	5.27 ± 0.17[a]	6.20 ± 0.38[a]	7.45 ± 0.65[b]	8.05 ± 0.24[b]
C4:0	3.07 ± 0.36	2.42 ± 0.60	3.19 ± 0.81	2.46 ± 0.26
C6:0	2.53 ± 0.52	2.78 ± 0.79	3.17 ± 0.51	2.20 ± 0.14
C8:0	1.24 ± 0.26	1.30 ± 0.33	1.44 ± 0.23	0.97 ± 0.54
C10:0	2.10 ± 0.45	2.21 ± 0.51	2.33 ± 0.38	1.64 ± 0.08
C11:0	0.15 ± 0.23	0.24 ± 0.04	0.20 ± 0.03	0.11 ± 0.03
C12:0	1.42 ± 0.29	1.52 ± 0.33	1.49 ± 0.26	1.20 ± 0.08
C13:0	0.15 ± 0.14	0.08 ± 0.01	0.08 ± 0.01	0.15 ± 0.05
C14:0	7.02 ± 1.23[b]	7.29 ± 1.47[c]	7.63 ± 1.25[d]	6.82 ± 0.21[a]
C14:1	0.23 ± 0.03	0.49 ± 0.06	0.32 ± 0.05	0.33 ± 0.01
C15:0	0.73 ± 0.14	0.76 ± 0.17	0.70 ± 0.15	1.04 ± 0.03
C15:1	1.38 ± 0.22	1.38 ± 0.31	1.413 ± 0.29	1.99 ± 0.03
C16:0	26.90 ± 4.65[a]	28.22 ± 6.38[ab]	27.29 ± 5.46[a]	28.67 ± 0.58[b]
C16:1	1.31 ± 0.25[a]	1.85 ± 0.39[b]	1.94 ± 0.38[b]	2.25 ± 0.69[c]
C17:0	0.55 ± 0.12	0.64 ± 0.10	0.62 ± 0.13	0.94 ± 0.29
C17:1	0.99 ± 0.16	1.03 ± 0.22	1.05 ± 0.20	1.79 ± 0.53
C18:0	18.28 ± 3.10[b]	15.24 ± 3.68[a]	15.38 ± 2.47[a]	18.52 ± 0.73[b]
trans-11 C18:1	8.36 ± 1.69[c]	7.87 ± 1.28[c]	3.69 ± 0.28[b]	2.19 ± 0.28[a]
cis-9 C18:1	25.75 ± 0.59[c]	24.78 ± 5.69[bc]	23.66 ± 5.66[b]	20.68 ± 1.20[a]
cis-11 C18:1	1.85 ± 0.01[c]	1.15 ± 0.14[b]	0.99 ± 0.24[b]	0.54 ± 0.02[a]
18:2 n-6	2.69 ± 0.05[c]	2.46 ± 0.58[c]	1.89 ± 0.47[b]	1.77 ± 0.05[a]
C18:3 n-3	0.34 ± 0.00[c]	0.31 ± 0.09[b]	0.29 ± 0.07[b]	0.27 ± 0.02[a]
cis-9,*trans*-11 conjugated linoleic acid	1.48 ± 0.00[c]	1.44 ± 0.09[c]	1.32 ± 0.07[b]	1.22 ± 0.01[a]
C20:0	0.62 ± 0.76	0.53 ± 0.14	0.63 ± 0.10	0.94 ± 0.02
C20:1 n-9	0.27 ± 0.12	0.32 ± 0.07	0.31 ± 0.03	0.53 ± 0.01
C20:2	0.03 ± 0.03	0.02 ± 0.01	0.03 ± 0.01	0.06 ± 0.01
C21:0	0.09 ± 0.01	0.07 ± 0.03	0.08 ± 0.02	0.22 ± 0.01
C20:3 n-6	0.03 ± 0.01[a]	0.03 ± 0.00[a]	0.05 ± 0.01[a]	0.12 ± 0.00[b]
C20:4	0.11 ± 0.01[a]	0.14 ± 0.03[ab]	0.11 ± 0.01[a]	0.14 ± 0.01[b]
C20:3 n-3	0.03 ± 0.01	0.03 ± 0.04	0.03 ± 0.01	0.04 ± 0.00
C22:0	0.32 ± 0.05	0.26 ± 0.07	0.24 ± 0.04	0.49 ± 0.03
C20:5 EPA[2]	0.06 ± 0.01	0.02 ± 0.00	0.02 ± 0.01	0.06 ± 0.01
C22:1	0.02 ± 0.00	0.02 ± 0.00	0.01 ± 0.01	0.06 ± 0.01
C23:0	0.08 ± 0.01	0.05 ± 0.02	0.05 ± 0.01	0.17 ± 0.01
C24:0	0.07 ± 0.02	0.06 ± 0.05	0.18 ± 0.03	0.14 ± 0.01
C24:1	0.26 ± 0.05	0.21 ± 0.06	0.04 ± 0.00	0.25 ± 0.01
C22:6 DHA[3]	0.05 ± 0.01	0.04 ± 0.00	0.05 ± 0.01	0.06 ± 0.03
Saturated FA[4]	67.78 ± 1.20[a]	66.95 ± 0.62[a]	69.34 ± 0.46[b]	70.67 ± 0.01[c]
Monounsaturated FA	27.31 ± 1.70	28.69 ± 0.72	28.66 ± 0.72	29.61 ± 0.12
Polyunsaturated FA	4.61 ± 0.41[b]	4.31 ± 0.11[b]	4.29 ± 0.26[b]	3.73 ± 0.11[a]
n-3	0.33 ± 0.01[a]	0.37 ± 0.06[a]	0.40 ± 0.03[a]	0.64 ± 0.03[b]
n-6	4.36 ± 0.44[b]	3.97 ± 0.11[b]	3.96 ± 0.25[b]	3.16 ± 0.09[a]
Short-chain FA[5]	10.22 ± 0.85[c]	11.39 ± 0.88[c]	9.76 ± 0.88[b]	7.38 ± 0.46[a]
Medium-chain FA[6]	40.04 ± 1.11[a]	40.62 ± 1.46[a]	46.36 ± 0.94[c]	42.44 ± 0.22[b]
Long-chain FA[7]	49.73 ± 1.96	47.99 ± 1.26	43.87 ± 1.45	50.17 ± 0.33

[a–d]Means with different superscript letters within the same row are significantly different ($P < 0.05$).

[1]Values are mean ± SE of triplicates.

[2]EPA = eicosapentaenoic acid.

[3]DHA = docosahexaenoic acid.

[4]Sum of C4:0 to C24:0.

[5]C4:0 to C11:0.

[6]C12:0 to C16:1.

[7]C17:0 to C24:0.

summer diet contained fresh grass; from late summer onward, grass growth was reduced, and the yaks had less opportunity to select the FA-rich top layers of the grass (Heck et al., 2009). In winter, the diet did not contain fresh grass that had been dry, the yaks grazed on dry pastures that still had growing plants, and the herdsman did not supplement with other feeds, which might explain the increase in saturated FA in winter (Heck et al., 2009). In contrast, no significant seasonal differences in the levels of C4:0, C6:0, and C8:0 were found and only minor variations in the levels of C10:0 and C12:0 (Table 1) were found. Fatty acids C4:0 to

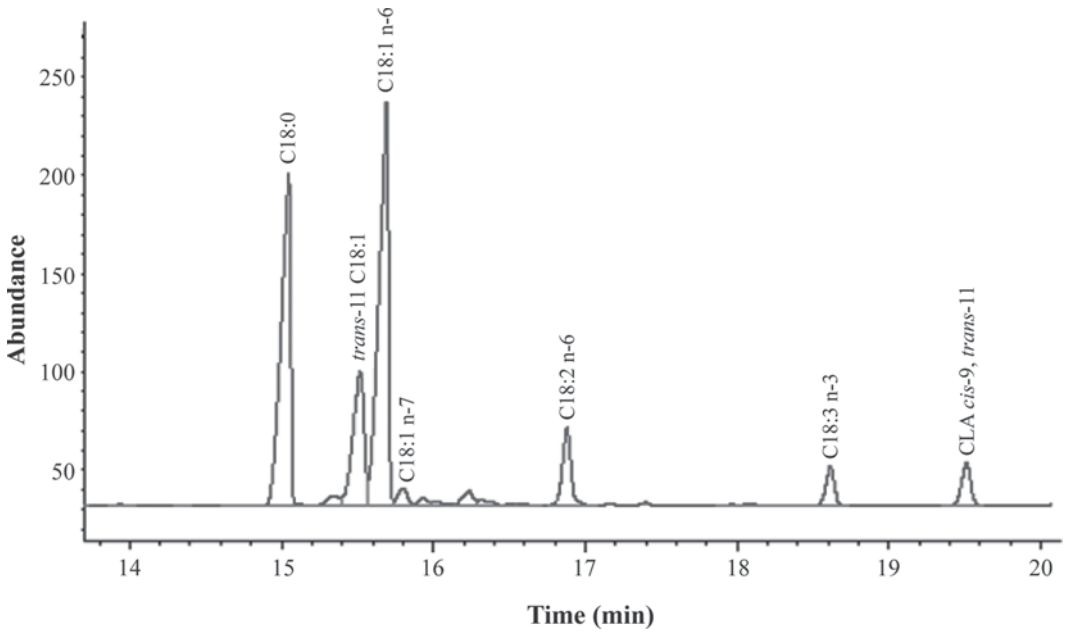

Figure 1. Partial gas chromatographic profile of C18:1, C18:2 n-6, C18:3 n-3, and *cis*-9, *trans*-11 conjugated linoleic acid (CLA) region showing the separation of the yak milk fat.

C14:0 and particularly C16:0 are regarded as de novo products, which are synthesized within the mammary gland of the ruminants. Acetate and β-hydroxybutyrate are believed to be the precursors for de novo FA synthesis in mammary tissue (Or-Rashid et al., 2008). Therefore, synthesis of such FA is unlikely to be seasonally dependent.

For the unsaturated FA, a chromatogram of the C18:1, C18:2 n-6, C18:3 n-3, and *cis*-9,*trans*-11 CLA region for a yak milk sample was observed in Figure 1. It shows that complete separation of the unsaturated FA was achieved using 60-m DB-23 column through a single chromatographic run. The determined contents of C18:1, C18:2 n-6, C18:3 n-3, and *cis*-9,*trans*-11 CLA of yak milk fat are listed in Table 1. The largest seasonal variation was observed for *cis*-9 C18:1, *cis*-11 C18:1, *cis*-9,*trans*-11 CLA, and C18:3 n-3. The concentrations of *cis*-9 C18:1, *cis*-11 C18:1, *cis*-9,*trans*-11 CLA, and C18:3 n-3 were significantly ($P < 0.05$) higher in summer (25.26, 1.50, 1.46, and 0.33 g/100 g of total FA, respectively) than in winter (22.17, 0.77, 1.27, and 0.28 g/100 g of total FA, respectively). The seasonal changes in levels of FA in milk fat were also probably related to the changes in pasture quality (Ostrovský et al., 2009). During the wilting of grass, extensive lipolysis and oxidative losses of FA occur, which decreases the levels of polyunsaturated FA (**PUFA**) in winter, especially that of C18:3 n-3 (Ferlay et al., 2006). In addition, C18:3 n-3 is associated with the production of specific long-chain unsaturated FA that inhibit de novo FA synthesis in the mammary gland (Bauman et al., 2000; Thorsdottir et al., 2004; Dewhurst et al., 2006). Therefore, as the grass matures, the C18:3 n-3 concentration of the grass generally decreases. Consequently, the concentrations of C18:1, *cis*-9,*trans*-11 CLA and C18:3 n-3 generally decrease in yak milk fat (Kay et al., 2004; Heck et al., 2009). In addition, variation in these FA may be influenced by alterations in the rumen bacterial populations (Lock and Bauman, 2004).

For the other functional FA, a balance between EPA and DHA content was observed, and the levels of EPA and DHA in yak milk did not vary throughout the year, apart from that of the C18:3 n-3 content (related to the freshness of the grass, as above), which may be due to variation in Δ^9-desaturase activity.

Differences in Milk FA Compositions for Yaks of Different Parities

The fat content and the major FA profile of yak milk in November of different parities (first to fifth) are displayed in Table 2. The FA profiles in other months had a similar trend (data not shown). During our experimental period, the fat content decreased with the increase in parity. Sevi et al. (2000) observed that the relationship between fat content and parity might depend on differences in endocrine and metabolic status.

Total proportions of monounsaturated FA (**MUFA**) and PUFA in milk fat from multiparous (parities 2 to 5) yaks were higher ($P < 0.05$) than those from

Table 2. Fat content and fatty acid (FA) profile (g/100 g of total FA) of milk from yaks of different parities as measured in samples collected in November 2009[1]

Item	Parity				
	First	Second	Third	Fourth	Fifth
Fat (g/100 mL of milk)	8.05 ± 0.24	8.04 ± 0.89	8.28 ± 0.19	7.83 ± 0.63	7.95 ± 0.27
C4:0	2.46 ± 0.26^{b}	1.67 ± 0.05^{a}	3.14 ± 0.27^{b}	3.14 ± 0.12^{b}	1.05 ± 0.48^{a}
C6:0	2.20 ± 0.14^{bc}	1.78 ± 0.01^{b}	2.44 ± 0.13^{cd}	2.62 ± 0.07^{d}	1.24 ± 0.32^{a}
C8:0	0.97 ± 0.54^{b}	0.79 ± 0.02^{a}	1.08 ± 0.06^{bc}	1.21 ± 0.04^{c}	0.68 ± 0.09^{a}
C10:0	1.64 ± 0.08^{ab}	1.37 ± 0.04^{a}	1.84 ± 0.12^{bc}	2.05 ± 0.08^{c}	1.36 ± 0.08^{a}
C11:0	0.11 ± 0.03^{a}	0.13 ± 0.02^{a}	0.15 ± 0.00^{a}	0.21 ± 0.01^{b}	0.14 ± 0.01^{a}
C12:0	1.20 ± 0.08^{ab}	0.99 ± 0.00^{a}	1.39 ± 0.09^{b}	1.34 ± 0.07^{b}	1.17 ± 0.08^{ab}
C13:0	0.15 ± 0.05	0.08 ± 0.00	0.08 ± 0.00	0.09 ± 0.00	0.08 ± 0.00
C14:0	6.82 ± 0.21^{ab}	6.35 ± 0.03^{a}	7.20 ± 0.27^{b}	6.93 ± 0.23^{ab}	6.98 ± 0.24^{ab}
C14:1	0.33 ± 0.01^{a}	0.34 ± 0.06^{a}	0.36 ± 0.01^{a}	0.48 ± 0.05^{b}	0.32 ± 0.02^{a}
C15:0	1.04 ± 0.03	1.04 ± 0.08	0.98 ± 0.01	1.08 ± 0.04	1.08 ± 0.04
C15:1	1.99 ± 0.03^{abc}	1.87 ± 0.54^{a}	1.94 ± 0.22^{ab}	2.06 ± 0.42^{bc}	2.09 ± 0.77^{c}
C16:0	28.67 ± 0.58^{ab}	28.96 ± 0.66^{ab}	28.02 ± 0.10^{ab}	27.68 ± 0.25^{a}	29.47 ± 0.76^{b}
C16:1	2.25 ± 0.69^{bc}	2.38 ± 0.16^{c}	2.21 ± 0.13^{bc}	1.68 ± 0.10^{a}	2.52 ± 0.08^{d}
C17:0	0.94 ± 0.29^{ab}	0.91 ± 0.21^{a}	0.86 ± 0.00^{a}	0.90 ± 0.03^{a}	1.00 ± 0.03^{b}
C17:1	1.79 ± 0.53^{ab}	1.65 ± 0.02^{a}	1.66 ± 0.01^{a}	1.68 ± 0.07^{a}	1.93 ± 0.07^{b}
C18:0	18.52 ± 0.73^{ab}	21.44 ± 2.13^{bc}	17.56 ± 0.25^{a}	15.79 ± 0.22^{a}	22.04 ± 1.44^{c}
trans-11 C18:1	2.19 ± 0.28^{a}	2.36 ± 0.08^{a}	2.83 ± 0.12^{b}	3.27 ± 0.13^{c}	3.52 ± 0.13^{d}
cis-9 C18:1	20.68 ± 1.20^{a}	21.04 ± 1.52^{a}	22.34 ± 0.70^{b}	23.77 ± 0.46^{c}	24.92 ± 1.19^{d}
cis-11 C18:1	0.54 ± 0.02^{a}	0.57 ± 0.01^{a}	0.70 ± 0.03^{b}	0.71 ± 0.12^{b}	0.67 ± 0.07^{b}
18:2 n-6	1.77 ± 0.05^{a}	1.75 ± 0.11^{a}	1.94 ± 0.10^{b}	1.91 ± 0.09^{b}	1.93 ± 0.04^{b}
C18:3 n-3	0.27 ± 0.02^{a}	0.31 ± 0.02^{b}	0.37 ± 0.01^{b}	0.44 ± 0.03^{c}	0.41 ± 0.01^{c}
cis-9,*trans*-11 conjugated linoleic acid	1.22 ± 0.01^{a}	1.15 ± 0.02^{a}	1.31 ± 0.05^{b}	1.34 ± 0.03^{b}	1.44 ± 0.03^{b}
C20:0	0.94 ± 0.02^{ab}	0.88 ± 0.05^{a}	0.89 ± 0.04^{a}	0.88 ± 0.02^{a}	1.02 ± 0.03^{b}
C20:1 n-9	0.53 ± 0.01^{c}	0.45 ± 0.01^{ab}	0.50 ± 0.04^{bc}	0.42 ± 0.02^{a}	0.55 ± 0.01^{c}
C20:2	0.06 ± 0.01^{b}	0.04 ± 0.00^{a}	0.04 ± 0.00^{a}	0.03 ± 0.00^{a}	0.03 ± 0.00^{a}
C21:0	0.22 ± 0.01^{c}	0.18 ± 0.02^{ab}	0.18 ± 0.00^{a}	0.19 ± 0.01^{ab}	0.21 ± 0.02^{bc}
C20:3 n-6	0.12 ± 0.00^{b}	0.09 ± 0.01^{a}	0.09 ± 0.00^{a}	0.08 ± 0.00^{a}	0.09 ± 0.01^{a}
C20:4	0.14 ± 0.01	0.14 ± 0.00	0.13 ± 0.01	0.15 ± 0.01	0.12 ± 0.02
C20:3 n-3	0.04 ± 0.00	0.03 ± 0.01	0.05 ± 0.01	0.04 ± 0.00	0.03 ± 0.00
C22:0	0.49 ± 0.03^{b}	0.51 ± 0.02^{b}	0.38 ± 0.01^{a}	0.39 ± 0.01^{a}	0.53 ± 0.03^{b}
C20:5 EPA[2]	0.06 ± 0.01^{ab}	0.07 ± 0.01^{b}	0.10 ± 0.01^{b}	0.10 ± 0.01^{b}	0.05 ± 0.01^{a}
C22:1	0.06 ± 0.01^{b}	0.04 ± 0.00^{ab}	0.06 ± 0.00^{b}	0.03 ± 0.00^{a}	0.04 ± 0.00^{ab}
C23:0	0.17 ± 0.01	0.15 ± 0.01	0.14 ± 0.01	0.16 ± 0.02	0.15 ± 0.01
C24:0	0.14 ± 0.01^{a}	0.18 ± 0.03^{a}	0.23 ± 0.00^{b}	0.25 ± 0.01^{b}	0.25 ± 0.01^{b}
C24:1	0.25 ± 0.01^{b}	0.21 ± 0.04^{b}	0.05 ± 0.00^{a}	0.06 ± 0.00^{a}	0.06 ± 0.00^{a}
C22:6 DHA[3]	0.06 ± 0.03^{a}	0.11 ± 0.04^{ab}	0.12 ± 0.01^{bc}	0.16 ± 0.01^{c}	0.15 ± 0.01^{bc}
Saturated FA[4]	70.67 ± 0.01^{d}	67.38 ± 0.28^{b}	64.91 ± 1.14^{a}	66.55 ± 0.15^{a}	68.42 ± 1.02^{c}
Monounsaturated FA	29.61 ± 0.12^{a}	30.16 ± 0.46^{a}	31.21 ± 0.94^{b}	31.84 ± 0.24^{b}	33.21 ± 0.82^{c}
Polyunsaturated FA	3.80 ± 0.11^{a}	4.01 ± 0.14^{b}	4.27 ± 0.29^{c}	4.38 ± 0.94^{c}	4.14 ± 0.13^{b}
n-3	0.64 ± 0.03^{ab}	0.56 ± 0.02^{a}	0.74 ± 0.04^{b}	0.66 ± 0.03^{ab}	0.67 ± 0.02^{ab}
n-6	3.16 ± 0.09^{ab}	3.44 ± 0.15^{ab}	3.52 ± 0.41^{b}	3.02 ± 0.10^{a}	3.47 ± 0.18^{ab}
Short-chain FA[5]	7.38 ± 0.46^{b}	5.73 ± 0.05^{a}	8.65 ± 0.55^{b}	9.22 ± 0.24^{c}	4.44 ± 0.66^{a}
Medium-chain FA[6]	42.44 ± 0.22^{b}	41.99 ± 0.08^{b}	42.17 ± 0.77^{b}	41.35 ± 0.07^{a}	43.21 ± 0.87^{c}
Long-chain FA[7]	50.17 ± 0.33^{a}	52.27 ± 0.54^{b}	49.18 ± 0.89^{a}	49.43 ± 0.20^{a}	52.36 ± 1.01^{b}

[a–d]Means with different superscript letters within the same row are significantly different ($P < 0.05$).

[1]Values are mean ± SE of triplicates.

[2]EPA = eicosapentaenoic acid.

[3]DHA = docosahexaenoic acid.

[4]Sum of C4:0 to C24:0.

[5]C4:0 to C11:0.

[6]C12:0 to C16:1.

[7]C17:0 to C24:0.

primiparous yaks. Specifically, the levels of *cis*-9 C18:1, *cis*-11 C18:1, *cis*-9,*trans*-11 CLA, and C18:3 n-3 in milk fat from multiparous yaks (23.02, 0.66, 1.31, and 0.38 g/100 g of total FA, respectively) were significantly ($P < 0.05$) higher than in milk from primiparous yaks (20.68, 0.54, 1.22, and 0.27 g/100 g of total FA, respectively). These observations agree with those of Stanton et al. (1997), who found that samples from cows with more than 4 offspring had a greater milk fat CLA content than did samples from cows with 2 to 4 offspring at

sampling times. According to Sheng et al. (2008), the reasons for the effect of different parity numbers on the C18:1, CLA, and C18:3 n-3 contents in yak milk might be related to differences in stage of growth of the mammary glands, which are one of the sources for FA synthesis in milk. However, the effect of parity on FA profile might be a result of confounding genetic factors (Short et al., 1990; Sheng et al., 2008).

Although the total proportions of MUFA and PUFA in milk fat from multiparous yaks were significantly ($P < 0.05$) greater than those from primiparous yaks, no consistent effect was observed between parity and levels of MUFA and PUFA. Thus, milk from fourth-parity yaks had a higher content of *cis*-11 C18:1 than did milk from other parities, whereas milk from third-parity yaks had a higher content of C18:2 n-6 than that of other parities.

This work studied the relationship of seasons and parities with variations in FA content of milk from yaks grazed at 3,500 m above sea level on the Qinghai-Tibetan plateau. The most pronounced changes were caused by season, with an obvious increase in proportion of saturated FA and an apparent decrease in C18:1, *cis*-9,*trans*-11 CLA and C18:3 n-3 in winter. In addition, the levels of MUFA and PUFA in milk from multiparous yaks (2–5 parities) were greater than those in milk from primiparous yaks. No consistent effect between parity and FA content was observed. These results suggest that the potential exists to improve the FA compositions of yak milk by developing local supplement resources during the winter and that multiparous yaks have a more favorable FA profile than primiparous yaks.

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