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# Fatty acid composition of mountain milk from Switzerland: Comparison of organic and integrated farming systems

Marius Collomb [a,*], Walter Bisig [a,b], Ueli Bütikofer [a], Robert Sieber [a], Mirjam Bregy [b], Luzi Etter [b]

[a] Agroscope Liebefeld-Posieux Research Station ALP, 3003 Berne, Switzerland
[b] University of Applied Sciences of Berne, Swiss College of Agriculture, 3052 Zollikofen, Switzerland

A R T I C L E I N F O

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A B S T R A C T

During a 12-month study, bulk-tank milk was collected monthly from 3 dairies each of which collected both organic and conventional milks (from integrated farming) in the mountain regions of Switzerland. All milk samples were analyzed for fatty acid (FA) composition. Organic and conventional milks did not significantly differ with respect to saturated FA (SFA) nor *trans* FA contents, but organic milk had significantly higher contents of polyunsaturated FA (PUFA) (+5.5%; $P \leq 0.001$), conjugated linonenic acid (CLA) (+14.9%; $P \leq 0.001$), *n*-3 FA (+12.3%; $P \leq 0.001$) and branched FA (+4.7%; $P \leq 0.001$). Conventional milk had higher contents of monounsaturated FA (MUFA) (+2.3%; $P \leq 0.05$) and *n*-6 FA (+4.2%; $P \leq 0.01$). Significantly higher levels of grasses and lower levels of cereal concentrates in the fodder of organic farming could well explain these results. The differences in the fatty acid composition of milk between the two farming systems were nevertheless small because of low differences in the fodder composition.



## 1. Introduction

Farms in mountainous areas produce milk under more constrained conditions. These constraining factors are the shorter vegetation period, steep hills, less fertile soil, soil and climate only suitable for grassland and long distances from the consumers in the cities. In order that the farmers can continue to make a living under these conditions it is necessary that they produce milk and food with an added value. A good opportunity for this is the production of organic food and milk in which grassland based feeding is central in the specific regulations (IFOAM, International Federation of Organic Agriculture Movements, 2005). These types of food are more and more often preferred by some European countries (Rosati & Aumaitre, 2004). Organic farming in Switzerland specifies that at least 90% of dairy cows' feed has to be roughage which essentially includes fresh, ensiled or dried grass and whole maize crops (Früh & Schmutz, 2007). According to EU regulations no. 2092/91 (EU, 2004) the percentage of roughage has to be 60% or more of the daily ration and at least 50% in early lactation. Up to now, no time based studies have investigated the effects of differences in management systems between organic and integrated farming on mountains within Switzerland on the milk produced, particularly the fatty acid (FA) profile. The integrated farming system is the most used farming system in Switzerland. In other countries (Germany, Italy, Sweden, England and Wales), several studies have investigated the effects of organic farming systems in the lowlands on the CLA (conjugated linonenic acid) content of milk, but the results vary, with some authors reporting higher CLA content in organic milk (Bergamo, Fedele, Iannibelli, & Marzillo, 2003; Jahreis, Fritsche, & Steinhart, 1996, 1997), whereas others found no difference (Ellis et al., 2006; Toledo, Andren, & Björck, 2002).

Bovine milk contains a large number of different FA (Fatty acid), some of which may be of potential benefit to human health, including CLA and PUFA (Polyunsaturated FA) of the *n*-3 FA group (Parodi, 2004). It is recommended, therefore, that consumers increase their intake of these compounds. Many factors affect the FA composition of bovine milk, including breed (Ellis et al., 2006; Ferlay, Martin, Pradel, Coulon & Chilliard, 2006), season (Ellis et al., 2006; Lock & Garnsworthy, 2003; Thorsdottir, Hill, & Ramel, 2004), geographical location (Collomb, Bütikofer, Sieber, Jeangros, & Bosset, 2002a, 2002b), access to fresh grazing (Ellis et al., 2006; Kelly, Kolver, Bauman, van Amburgh, & Muller, 1998), silage type (Dewhurst, Fisher, Tweed, & Wilkins, 2003), cereal feeding (Wijesundera, Shen, Wales, & Dalley, 2003), and oil supplementation of feed (Collomb, Sieber, & Bütikofer, 2004; Mansbridge & Blake, 1997). In the context of a recent study to alter the composition of milk and provide a better source of beneficial FA, it was essential to determine seasonal, herd-level management, and feeding factors that affect milk FA composition. This should allow the formulation of recommendations for producers aiming to enhance the content of these FA.

* Corresponding author. Tel.: +41 31 323 81 33; fax: +41 31 323 82 27.
*E-mail address:* marius.collomb@alp.admin.ch (M. Collomb).

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The aims of the present study were to determine whether there is a difference in FA composition of organic milk and milk from integrated farming in the mountain regions of Switzerland and to compare the influence of fodder on milk FA composition for these two production systems. This study was conducted *in natura* under the usual conditions of farming, and management of herds in the mountains rather than under strictly defined and controlled experimental conditions.

## 2. Materials and methods

### 2.1. Aim and approach

Over a 12-month period (from May 2004 to April 2005), bulk-tank milk was collected monthly from 3 dairies each of which collected both organic milk and milk from integrated farming situated in 3 Swiss mountain regions: Graubunden, Lucerne and Emmental-Berne (altitude: $1102 \pm 390$ m for organic and $1091 \pm 324$ m for integrated farming). For each type of milk a total of 36 milk samples were analyzed. Herds of organic farms and farms with integrated farming methods were mainly made up of Brown Swiss, Swiss Fleckvieh, Simmental, Red Holstein, Holstein and Jersey breeds (Table 1). Large differences in the breeds were found among the three regions. Organic farms in general have lower number of Red Holstein cows but slightly higher number of the Simmental and Jersey breeds.

### 2.2. Fodder composition

The fodder composition and milk production data are presented in Table 2. Data were obtained from a standardised questionnaire filled out by the farmers. The data were partially complemented by estimations based on the quantity of milk produced during the pasture feeding season. Compared with integrated farming, organic farming is essentially characterized by significantly higher levels of feed grasses, fresh grass, grass silage, roughage and a lower level of concentrates in the diet of the cows. Considering that the EU regulations for organic milk production (EU, 2004) require a minimum of 60 or 50% roughage, even the integrated milk production systems in the Swiss mountainous regions with an average of 87% roughage would meet the organic requirement. Three types of concentrates were fed: cereal concentrate (energy 7.1 MJ net energy lactation (NEL), 10% crude protein), protein compensation concentrate (7.0 MJ NEL, 40% crude protein) and milk performance concentrate (7.1 MJ NEL, 16% crude protein) (Table 2). The main fraction of concentrate for organic and integrated farming was cereal concentrate at 3.9 and 7.2%, respectively. Milk performance concentrate made up 3.1 and 4.5% of the diet, respectively, and protein compensation concentrate 0.5 and 0.9%, respectively. The diet in the organic farming system contained lower levels of all the three groups of concentrate, 46% less cereal concentrate, 44% less protein compensation concentrate and 29% less milk performance concentrate.

**Table 1**
Number of farms, average milk performance per cow (kg 305 days$^{-1}$) and percentage of breeds of dairy cows

| | Organic | | Conventional | |
|---|---|---|---|---|
| | $\overline{X}$ | $s_x$ | $\overline{X}$ | $s_x$ |
| Number of farms | 49 | | 29 | |
| Milk performance | 5789 | 829 | 6387 | 1329 |
| Brown Swiss | 66 | 41 | 65 | 47 |
| Swiss Fleckvieh | 12 | 28 | 13 | 24 |
| Simmental | 3 | 15 | 0 | 2 |
| Red Holstein | 4 | 10 | 16 | 29 |
| Holstein | 6 | 19 | 4 | 19 |
| Jersey | 6 | 16 | 1 | 3 |
| Others | 3 | 15 | 0 | 0 |

**Table 2**
Fodder components in both organic and conventional fodder averaged over one year

| Fodder | Org[a] | | Conv[b] | | P |
|---|---|---|---|---|---|
| | $\overline{X}$ | $s_x$ | $\overline{X}$ | $s_x$ | |
| *n* | 36 | | 36 | | |
| Returned questionnaires, % | 64 | 23 | 50 | 17 | |
| Quantity of bulk milk, kg day$^{-1}$ | 4357 | 3137 | 2569 | 1828 | *** |
| Total ration, kg dry matter day$^{-1}$ cow$^{-1}$ | 16.93 | 1.22 | 17.94 | 1.17 | *** |
| Percentage of feed grasses (FG) | 87 | 7 | 83 | 7 | *** |
| Percentage of fresh grass | 42 | 41 | 38 | 38 | ** |
| Percentage of grass silage | 11 | 14 | 9 | 11 | * |
| Percentage of hay | 35 | 27 | 36 | 25 | – |
| Percentage of whole crop maize silage | 2 | 2 | 2 | 2 | – |
| Percentage of roughage[c] | 92 | 3 | 87 | 4 | *** |
| Percentage of concentrates | 7.6 | 3.0 | 12.7 | 4.0 | *** |
| Cereal concentrate[d] | 3.9 | 1.7 | 7.2 | 2.9 | *** |
| Protein compensation concentrate[e] | 0.5 | 0.4 | 0.9 | 0.8 | * |
| Milk performance concentrate[f] | 3.1 | 2.4 | 4.5 | 3.8 | *** |
| Altitude of feed grasses growth, m | 1102 | 390 | 1091 | 324 | – |
| Altitude of cowshed, m | 1129 | 419 | 1138 | 378 | – |

[a] Abbreviations: Org, organic; Conv, conventional; *n*, number of samples; Σ, sum of the concentrations; $\overline{X}$, mean value; $s_x$, standard deviation; *P*, probability: $^{*}P \leq 0.05$; $^{**}P \leq 0.01$; $^{***}P \leq 0.001$.
[b] Integrated farming is the conventional production system.
[c] Essentially constituted of fresh, dried or ensiled grass and whole crop maize but also fed straw, sugar beet pulp, fodder beets, potatoes and some other fiber rich fresh feed.
[d] Energy 7.1 MJ net energy lactation, 10% crude protein.
[e] Energy 7.0 MJ net energy lactation, 40% crude protein.
[f] Energy 7.1 MJ net energy lactation, 16% crude protein.

### 2.3. Sampling and sample treatment

Individual bulk-tank milk samples were collected in 500-mL plastic screw-top containers after stirring the bulk tank for at least 2 min. Bronopol (Merck, Dietikon, Switzerland) was added as a preservative and the containers were stored at 5 °C. Milk samples were centrifuged by $5000 \times g$ for 30 min, and the resulting creams were churned at about 5 °C. The resulting butter was melted at 60 °C, filtered through a hydrophobic filter (1PS folded filter, Whatman, Bottmingen, Switzerland), and the resulting pure butter fat stored at −20 °C until analysis.

### 2.4. Determination of the main components in milk

#### 2.4.1. Methylation

After dissolution of the pure milk fat in hexane, the glycerides were *trans*-esterified to the corresponding methyl esters of fatty acids by a solution of potassium hydroxide in methanol (ISO, 1997).

#### 2.4.2. Gas chromatography analysis

Fatty acid composition was analyzed by high-resolution gas chromatography (Agilent 6890, Santa Clara, CA, USA) with flame ionisation detection according to Collomb & Bühler (2000). The fatty acids were separated on a capillary column CP-Sil 88 (100 m × 0.25 mm i.d. × 0.20 μm; Varian BV, Middleburg, Netherlands) and quantified using nonanoic acid as an internal standard. The results are expressed in absolute values as g fatty acids per 100 g fat. The pure methyl esters of fatty acids, including CLA, were obtained from Matreya Inc. (Pleasant Gap, PA, USA).

#### 2.4.3. High-performance liquid chromatography analysis

CLA isomers were analyzed by silver-ion ($Ag^{+}$)-HPLC on an Agilent LC series 1100 (Santa Clara, CA, USA), equipped with a photodiode array detector (234 nm) using three ChromSpher

Lipid columns in series (stainless steel, 250 × 4.6 mm, 5 μm particle size, Chrompack, Middleburg, Netherlands) according to Collomb et al. (2004). The solvent consisted of UV-grade hexane with 0.1% acetonitrile and 0.5% ethyl ether (flow rate 1 mL $min^{-1}$), prepared fresh daily. The injection volume was 10 μL, representing <250 μg lipid. The HPLC areas for t7c9 + t8c10 + c9t11 were combined and used for comparison with the peak area of the three isomers from the GC chromatogram. The results were expressed as absolute values, in mg $g^{-1}$ fat.

### 2.5. Statistical analyses

The mean values and standard deviations of the organic and conventional groups were calculated. A pairwise *t*-test was applied to the results of the three sites of organic and integrated farming. Systat for Windows version 11 (Anonymous, 2004) software was used for all calculations.

## 3. Results and discussion

Results of the questionnaires clearly indicated that organic farmers followed the regulations: cows were fed with more roughage and lower amounts of concentrates than cows fed according to the integrated farming system (Table 2).

### 3.1. Groups of fatty acids

The mean content of each of the FA groups in both organic and conventional milks averaged over 12 months of the study is shown in Table 3. Organic and conventional milks did not significantly differ with respect to SFA or *trans* FA contents, but organic milk had higher contents of PUFA (+5.5%; $P \leq 0.001$), CLA (+14.9%; $P \leq 0.001$), *n*-3 FA (+12.3%; $P \leq 0.001$) and branched FA (+4.7%; $P \leq 0.001$) compared with conventional milk. Conventional milk had higher contents of MUFA (+2.3%; $P \leq 0.05$) and *n*-6 FA (+4.2%; $P \leq 0.01$) compared to organic milk. Significantly lower amounts of concentrates combined with higher amounts of feed grasses (Table 2) fed to cows by organic farmers explained these results, which were in accordance with those reported by other authors (Dewhurst, Shingfield, Lee & Scollan, 2006; Ferlay et al., 2006; Shingfield et al., 2005). The higher content of branched FA in organic milk compared with conventional milk could also be associated with a higher proportion of grass in the diet (Table 2). In organic dairy farming with diets possibly poorer in energy but richer in crude fiber, a higher activity of rumen bacteria is possible.

Compared to other studies carried out in the lowlands (Ellis et al., 2006; Jahreis et al., 1996; Lund, 1991), relatively low values of SFA (60.4–60.6 g 100 $g^{-1}$ fat) and high values of PUFA (4.7–5.0), *n*-3 FA (1.4–1.6) and CLA (1.2–1.4) were found in the current study. The differences encountered between our results and others are also essentially due to the lower amount of concentrates fed to cows in the mountain areas. The higher botanical diversity of the pasture at relatively high altitudes (Collomb et al., 2002b) could also affect the fermentation processes in the rumen and therefore the fatty acid composition of milk. Compared to the lowlands (600–650 m), Collomb et al. (2002a) reported that in mountain (900–1210 m) and highland milk (1275–2120 m) there was a significant reduction in the SFA content (58.9, 54.7 and 52.7 g 100 $g^{-1}$ fat, respectively), as well as increased contents of PUFA (4.2, 5.4 and 6.9 g 100 $g^{-1}$ fat, respectively), *n*-3 FA (1.4, 1.5 and 2.1 g 100 $g^{-1}$ fat, respectively) and CLA (0.9, 1.6 and 2.4 g 100 $g^{-1}$ fat, respectively). The cow's diet was mixed in the lowlands (grass in the barn or whole crop maize, pasture, concentrates) in contrast to unadulterated pasture feeding in the mountain areas and in the highlands. In cheese manufactured from cows' milk fed on alpine pastures or with partial silage feeding, Hauswirth, Scheeder, and Beer (2004) found levels for *n*-3 FA of 1.6 and 1.5 g 100 $g^{-1}$ FAME (fatty acid methyl esters), respectively, and CLA values of 2.5 and 2.3 g 100 $g^{-1}$ FAME, respectively. In the current study, organic and conventional milks both came from cows grazing in the same regions and almost at the same altitude and therefore the altitude factor should not significantly affect the differences in FA composition of the two types of milk (Table 2).

Fig. 1 shows the concentrations of different groups of FA of organic and conventional milks over the year. A pronounced seasonal variation can be seen and is the same for both types of milk and are in agreement with earlier studies (Chilliard, Ferlay & Doreau, 2001; Ellis et al., 2006). The differences in concentrations, between organic and conventional milks, of these groups of FA were sometimes relatively low, because of relatively small differences in the composition of the fodder between the two

**Table 3**
Mean contents (g 100 $g^{-1}$ milk fat) of groups of fatty acids in both organic and conventional milks averaged over 12 months

| Groups of fatty acids | Org[a] | | Conv | | Org–Conv | | *P* |
|---|---|---|---|---|---|---|---|
| | $\bar{X}$ | $s_x$ | $\bar{X}$ | $s_x$ | $\bar{X}$ | $s_x$ | |
| *Groups of FA, concentrations of which were significantly higher in organic milk* | | | | | | | |
| Σ C18:2[b] | 3.70 | 0.63 | 3.56 | 0.56 | 0.14 | 0.32 | * |
| Σ polyunsaturated[c] | 5.00 | 0.72 | 4.74 | 0.66 | 0.26 | 0.39 | *** |
| Σ *n*-3 FA[d] | 1.55 | 0.27 | 1.38 | 0.25 | 0.17 | 0.19 | *** |
| Σ branched chain[e] | 2.44 | 0.18 | 2.33 | 0.15 | 0.12 | 0.30 | *** |
| Σ CLA[f] | 1.39 | 0.46 | 1.21 | 0.38 | 0.17 | 0.20 | *** |
| Σ *n*-3 FA/Σ *n*-6 FA | 0.74 | 0.15 | 0.63 | 0.14 | 0.11 | 0.11 | *** |
| *Groups of FA, concentrations of which were significantly higher in conventional milk* | | | | | | | |
| Σ C18:1[g] | 21.86 | 2.79 | 22.39 | 2.63 | −0.54 | 1.39 | * |
| Σ monounsaturated[h] | 24.40 | 2.69 | 24.96 | 2.53 | −0.56 | 1.37 | * |
| Σ *n*-6 FA[i] | 2.13 | 0.28 | 2.22 | 0.27 | −0.09 | 0.18 | ** |
| *Groups of FA, concentrations of which didnot significantly change* | | | | | | | |
| Σ short chain[j] | 9.31 | 0.60 | 9.31 | 0.58 | −0.01 | 0.44 | – |
| Σ medium chain[k] | 43.32 | 4.03 | 42.92 | 3.72 | 0.41 | 1.59 | – |
| Σ long chain[l] | 37.53 | 4.46 | 38.07 | 4.21 | −0.54 | 2.08 | – |
| Σ saturated [m] | 60.60 | 3.45 | 60.44 | 3.18 | 0.16 | 1.49 | – |
| Σ unsaturated[n] | 29.43 | 3.34 | 29.73 | 3.07 | −0.31 | 1.59 | – |
| Σ C18: 1t[o] | 4.13 | 1.16 | 4.00 | 1.09 | 0.13 | 0.50 | – |
| Σ *trans* without CLA[p] | 5.31 | 1.44 | 5.12 | 1.36 | 0.19 | 0.64 | – |

[a] Abbreviations: Org, organic; Conv, conventional; *n*, number of samples; Σ, sum of the concentrations; CLA, conjugated linonenic acid; $\bar{X}$, mean value, $n = 36$, ; $s_x$, standard deviation; *P*, Probability: *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$; t: *trans*; c: *cis*; NMID: non methylene interrupted diene; MID: methylene interrupted diene.
[b] C18:2 -ttNMID, -t9t12, -c9t13 + -t8c12, -c9t12 + -c,c-MID + -t8c13, -t11c15 + -t9c12, -c9c12, -c9c15, -c9t11 + -t8c10 + -t7c9, -t11c13 + -c9c11, -t9t11.
[c] Σ 18:2, C18:3 c6c9c12, C18:3 c9c12c15, C20:2 c,c (*n*-6), C20:3 (*n*-3), C20:4 (*n*-6), C20:5 (EPA) (*n*-3), C22:5 (DPA) (*n*-3), C22:6 (DHA) (*n*-3).
[d] C18:2 t11c15 + C18:2 c9c15, C18:3 c9c12c15, C20:3 (*n*-3), C20:5, C22:5, C22:6.
[e] C13 iso + aiso, C14 iso, C15 iso + aiso, C16 iso, C17 iso + aiso, C18 iso + aiso.
[f] C18:2 -t12t14, -t11t13, -t10t12, -t9t11, -t8t10, -t7t9, -t6t8, -ct12,14, -t11c13, -c11t13, -t10c12, -c9t11, -t8c10, -t7c9.
[g] C18:1 -t4, -t5, -t6-8, -t9, -t10 + 11, -t12, -t13 + 14 + -c6-8, -c9, -c11, -c12, -c13, -16 + c14.
[h] C10:1, C14:1 ct, C16:1 ct, C17:1 ct, Σ C18:1, C20:1 t, C20:1 c5, C20:1 c9, C20:1 c11.
[i] C18:1 t12, C18:1 c12, C18:2 t9t12, C18:2 c9t12 + c,c-MID + t8c13, C18:2 c9c12, C18:3 c6c9c12, C20:2cc, C20:3 (*n*-6), C20:4 (*n*-6).
[j] C4, C5, C6, C7, C8, C10, C10:1.
[k] C12, C13 iso, C13 aiso, C12:1 c + C13, C14 iso, C14, C15 iso, C14:1 t, C15 aiso, C14:1 c, C15, C16 iso, C16, C17 iso, C16:1 t, C17 aiso, C16:1 c.
[l] C17, C18 iso, C17:1 t, C18 aiso, C18, Σ C18:1, C19, Σ C18:2, C20, C20:1 t, C18:3 c6c9c12, C20:1 c5, C20:1 c9, C20:1 c11, C18:3 c9c12c15, C18:2 c9t11 + t8c10 + t7c9, C18:2 t11c13 + c9c11, C18:2 t9t11, C20:2 c,c (*n*-6), C22, C20:3 (*n*-6), C20:3 (*n*-3), C20:4 (*n*-6), C20:5 (EPA) (*n*-3), C22:5 (DPA) (*n*-3), C22:6 (DHA) (*n*-3).
[m] C4, C5, C6, C7, C8, C10, C12, Σ branched chain, C14, C15, C16, C17, C18, C19, C20, C22.
[n] C10:1, C14:1 ct, C16:1 ct, C17:1 t, Σ C18:1, Σ C18:2, C20:1 t, C18:3 c6c9c12, C20:1 c5, C20:1 c9, C20:1 c11, C18:3 c9c12c15, C18:2 c9t11 + t8c10 + t7c9, C18:2 t11c13 + c9c11, C18:2 t9t11, C20:2 c,c (*n*-6), C20:3 (*n*-6), C20:3 (*n*-3), C20:4 (*n*-6), C20:5 (EPA) (*n*-3), C22:5 (DPA) (*n*-3), C22:6 (DHA) (*n*-3).
[o] C18:1 -t4, -t5, -t6-8, -t9, -t10-11, -t12, -t13-14 + -c6-8.
[p] C14:1 t, C16:1 t, C17:1 t, C20:1 t, Σ C18:1 t + Σ C18:2 t (without CLA *trans*).

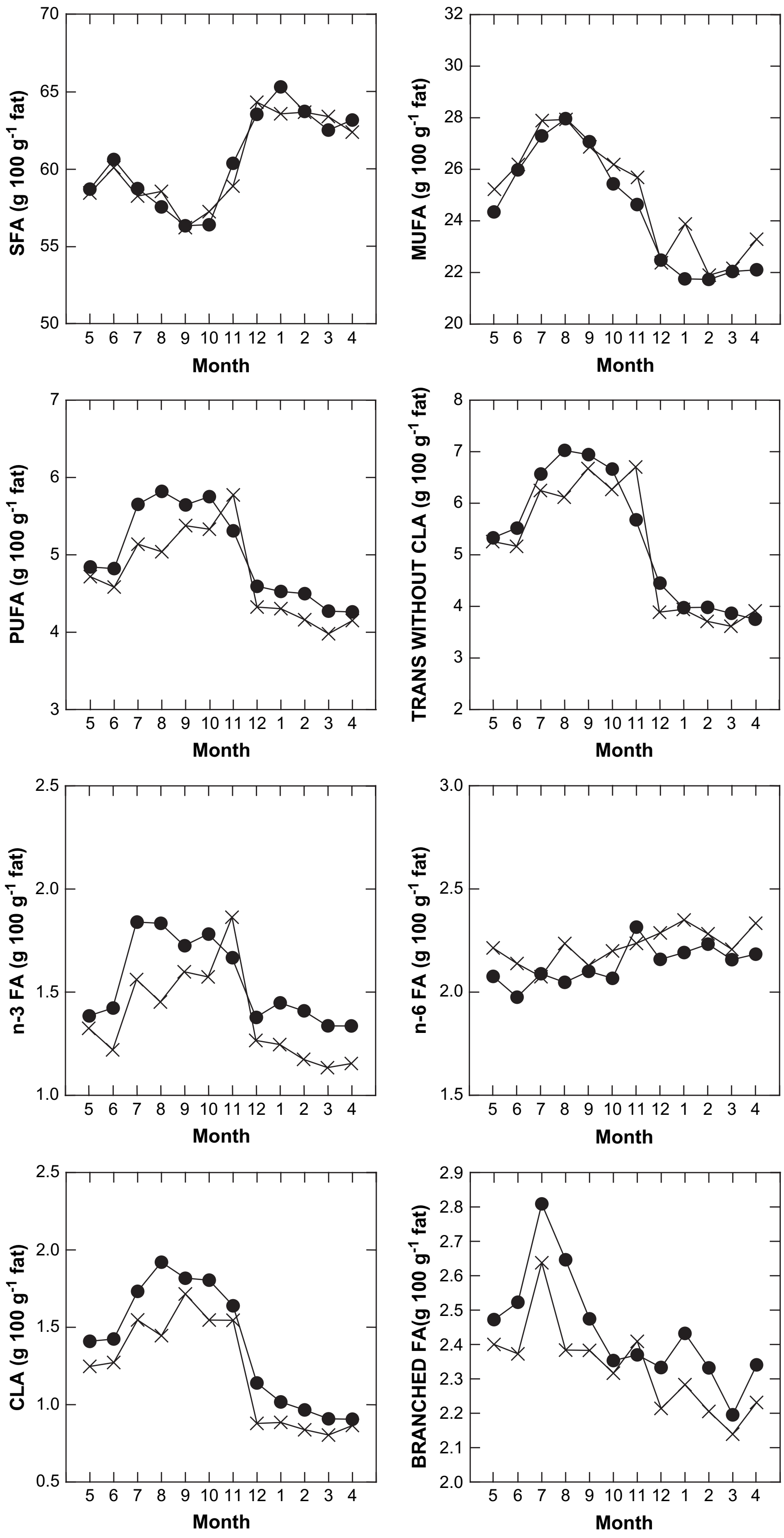


**Fig. 1.** Concentrations (g 100 $g^{-1}$ milk fat) of different groups of FA in organic (●) and conventional (X) milk over one year.

**Table 4**
Mean contents (g 100 g$^{-1}$ milk fat) of individual fatty acids in both organic and conventional milks averaged over one year

| Fatty acids | Org[a] | | Conv | | Org–Conv | | P |
|---|---|---|---|---|---|---|---|
| | $\bar{X}$ | $s_x$ | $\bar{X}$ | $s_x$ | $\bar{X}$ | $s_x$ | |
| n | 36 | | 36 | | | | |
| *FA, concentrations of which were significantly higher in organic milk* | | | | | | | |
| C12 | 2.67 | 0.38 | 2.59 | 0.32 | 0.08 | 0.20 | * |
| C12:1 c + C13 | 0.14 | 0.02 | 0.13 | 0.02 | 0.00 | 0.01 | * |
| C13 iso | 0.13 | 0.02 | 0.12 | 0.01 | 0.01 | 0.01 | *** |
| C14 iso | 0.27 | 0.02 | 0.25 | 0.02 | 0.02 | 0.02 | *** |
| C14 aiso | 0.50 | 0.04 | 0.47 | 0.03 | 0.03 | 0.05 | *** |
| C15 | 1.12 | 0.10 | 1.05 | 0.08 | 0.07 | 0.08 | *** |
| C15 iso | 0.26 | 0.02 | 0.24 | 0.02 | 0.01 | 0.02 | *** |
| C16:1 t | 0.15 | 0.06 | 0.14 | 0.05 | 0.01 | 0.02 | ** |
| C16 aiso | 0.52 | 0.08 | 0.51 | 0.06 | 0.01 | 0.04 | * |
| C17 | 0.60 | 0.04 | 0.57 | 0.04 | 0.03 | 0.04 | *** |
| C17 iso | 0.07 | 0.01 | 0.06 | 0.01 | 0.01 | 0.01 | *** |
| C17 aiso | 0.24 | 0.03 | 0.23 | 0.02 | 0.01 | 0.02 | *** |
| C18:1 t5 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | * |
| C18:1 t10 + C18:1 t11 (tVA) | 2.98 | 1.01 | 2.75 | 0.92 | 0.23 | 0.42 | ** |
| C18:2 ttNMID | 0.13 | 0.04 | 0.12 | 0.04 | 0.01 | 0.02 | ** |
| C18:2 t11c15 + t9c12 | 0.40 | 0.14 | 0.35 | 0.14 | 0.05 | 0.08 | *** |
| C20:1 t | 0.03 | 0.01 | 0.03 | 0.01 | 0.00 | 0.01 | * |
| C18:3 c9c12c15 | 0.89 | 0.15 | 0.79 | 0.12 | 0.10 | 0.12 | *** |
| C18:2 c9t11 + t8c10 + t7c9 | 1.22 | 0.41 | 1.10 | 0.36 | 0.12 | 0.22 | ** |
| C18:2 t11c13 + c9c11 | 0.07 | 0.02 | 0.06 | 0.02 | 0.01 | 0.02 | *** |
| C20:3 (*n*-6) | 0.05 | 0.01 | 0.05 | 0.01 | 0.00 | 0.01 | * |
| C20:5 (EPA) (*n*-3) | 0.08 | 0.01 | 0.07 | 0.01 | 0.01 | 0.01 | *** |
| C22:5 (DPA) (*n*-3) | 0.11 | 0.01 | 0.10 | 0.01 | 0.01 | 0.01 | *** |
| *FA, concentrations of which were significantly higher in conventional milk* | | | | | | | |
| C4 | 3.39 | 0.21 | 3.46 | 0.20 | −0.07 | 0.20 | * |
| C16:1 c | 1.11 | 0.09 | 1.13 | 0.11 | −0.03 | 0.06 | * |
| C18 | 9.21 | 1.08 | 9.49 | 1.06 | −0.29 | 0.59 | ** |
| C18:1 t6-8 | 0.14 | 0.03 | 0.16 | 0.05 | −0.02 | 0.03 | *** |
| C18:1 t9 | 0.25 | 0.04 | 0.27 | 0.05 | −0.02 | 0.04 | ** |
| C18:1 t12 | 0.19 | 0.04 | 0.21 | 0.05 | −0.02 | 0.04 | *** |
| C18:1 t13-14 + c6-8 | 0.54 | 0.10 | 0.58 | 0.12 | −0.04 | 0.08 | * |
| C18:1 c9 | 16.77 | 1.76 | 17.39 | 1.74 | −0.62 | 1.11 | ** |
| C18:1 c12 | 0.14 | 0.04 | 0.15 | 0.04 | −0.02 | 0.02 | *** |
| C18:1 c13 | 0.05 | 0.01 | 0.06 | 0.01 | −0.01 | 0.01 | ** |
| C18:2 c9t12 + (c,c-MID + t8c13) | 0.24 | 0.02 | 0.25 | 0.02 | −0.01 | 0.02 | * |
| C20 | 0.16 | 0.02 | 0.17 | 0.02 | −0.01 | 0.02 | * |
| C20:1 c9 | 0.13 | 0.01 | 0.14 | 0.02 | −0.01 | 0.03 | * |
| C20:1 c11 | 0.04 | 0.01 | 0.05 | 0.01 | −0.01 | 0.02 | * |
| *FA, concentrations of which didnot significantly change* | | | | | | | |
| C5 | 0.04 | 0.01 | 0.04 | 0.01 | 0.00 | 0.01 | – |
| C6 | 2.02 | 0.12 | 2.02 | 0.12 | −0.01 | 0.10 | – |
| C7 | 0.02 | 0.01 | 0.02 | 0.01 | 0.00 | 0.01 | – |
| C8 | 1.14 | 0.10 | 1.13 | 0.09 | 0.01 | 0.06 | – |
| C10 | 2.42 | 0.32 | 2.37 | 0.28 | 0.06 | 0.17 | – |
| C10:1 | 0.28 | 0.04 | 0.28 | 0.04 | 0.00 | 0.02 | – |
| C12 iso | 0.03 | 0.01 | 0.03 | 0.01 | 0.00 | 0.00 | – |
| C12 aiso | 0.07 | 0.01 | 0.07 | 0.01 | 0.00 | 0.01 | – |
| C14 | 9.57 | 0.94 | 9.40 | 0.73 | 0.16 | 0.49 | – |
| C14:1 t | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | – |
| C14:1 c | 0.79 | 0.11 | 0.79 | 0.09 | 0.00 | 0.08 | – |
| C16 | 25.64 | 2.68 | 25.62 | 2.69 | 0.01 | 1.02 | – |
| C16 iso | 0.35 | 0.04 | 0.34 | 0.04 | 0.00 | 0.02 | – |
| C17:1 t | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | – |
| C18:1 t4 | 0.01 | 0.01 | 0.02 | 0.01 | 0.00 | 0.01 | – |
| C18:1 c11 | 0.49 | 0.09 | 0.51 | 0.08 | −0.02 | 0.05 | – |
| C18:1 t16 + c14 | 0.28 | 0.05 | 0.28 | 0.05 | 0.00 | 0.04 | – |
| C19 | 0.10 | 0.03 | 0.09 | 0.02 | 0.00 | 0.02 | – |
| C18:2 t9t12 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | – |
| C18:2 c9t13 + t8c12 | 0.20 | 0.04 | 0.20 | 0.04 | 0.00 | 0.03 | – |
| C18:2 c9c12 | 1.37 | 0.22 | 1.41 | 0.21 | −0.04 | 0.14 | – |
| C22:6 (DHA) (*n*-3) | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | – |
| C18:2 c9c15 | 0.04 | 0.01 | 0.04 | 0.01 | 0.00 | 0.01 | – |
| C18:3 c6c9c12 | 0.02 | 0.00 | 0.02 | 0.01 | 0.00 | 0.01 | – |
| C20:1 c5 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | – |
| C18:2 t9t11 | 0.03 | 0.01 | 0.02 | 0.00 | 0.00 | 0.01 | – |
| C20:2 c,c (*n*-6) | 0.02 | 0.01 | 0.02 | 0.00 | 0.00 | 0.01 | – |
| C22 | 0.07 | 0.01 | 0.07 | 0.01 | 0.00 | 0.01 | – |
| C20:3 (*n*-3) | 0.02 | 0.01 | 0.02 | 0.01 | 0.00 | 0.01 | – |
| C20:4 (*n*-6) | 0.09 | 0.02 | 0.09 | 0.02 | 0.00 | 0.01 | – |

[a] Abbreviations: Org, organic; Conv, conventional; *n*, number of samples; Σ, sum of the concentrations; CLA, conjugated linonenic acid; $\bar{X}$, mean value, $n = 38$, ; $s_x$, standard deviation; *P*, probability: *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$; t: *trans*; c: *cis*; NMID: non methylene interrupted diene; MID: methylene interrupted diene.

farming systems usually practiced in mountain regions of Switzerland. The proportion of feed grasses at 83% is also high in the integrated farming system which is the conventional farming system in the investigated regions (Table 2).

### 3.2. Individual fatty acids

The mean content of each of the FA in both organic and conventional milks averaged over 12 months of the study is shown in Table 4. Compared to conventional milk, the concentrations of several FA were significantly higher in organic milk: α-linonenic acid, the most branched FA the most important *trans* FA (i.e. C18:1 t10 + t11, C18:2 t11c15 + t9c12), and finally the most important CLA (i.e. CLA C18:2 c9t11 + t8c10 + t7c9).

On the other hand, the concentrations of different FA (i.e. stearic acid (C18) and oleic acid (C18:1 c9)) were significantly higher in conventional milk than in organic milk.

The significantly higher content of the FA C18:3 c9c12c15 (α-linonenic acid), C18:1 t10 + t11, C18:2 t11c15 + t9c12, and C18:2 c9t11 + t8c10 + t7c9 in organic milk should be associated with the specific fermentation processes in the rumen of the cows. Organic dairy farming differentiates from integrated farming in a higher content of green feed richer in PUFA, grass and legumes silages and a lower proportion of concentrates (Table 2) leading to the development of specific rumen bacteria populations with more intensive activity. Grazing on fresh PUFA-rich grass increased therefore the content of α-linonenic acid in milk fat, and the resulting fermented FA, CLA and *trans* vaccenic acid (tVA; C18:1 t11) (Precht, 1995; Dewhurst et al., 2006). Leiber, Kreuzer, Nigg, Wettstein, and Scheeder (2005) as well as Leiber, Scheeder, Wettstein, and Kreuzer (2004) hypothesised that the increased α-linonenic acid in alpine milk is mainly due to pasture feeding as well as to the absence or low amounts of concentrates and that these effects are amplified by specific body fat mobilization in cows with alpine-specific hypoxia as well as reduced ruminal biohydrogenation due to energy shortage or secondary plant ingredients such as polyphenols and terpenoids that inhibit hydrogenating microorganisms in the rumen.

The higher content of the combined FA C18:2 t11c15 + t9c12 in conventional milk can also be attributed to the fermentation processes in the rumen of cows leading to a higher concentration of C18:2 t11c15 FA. It is well known that the pathway for the hydrogenation of α-linonenic acid (C18:3 c9c12c15) in the rumen involves an initial isomerization to a conjugated triene (C18:3 c9t11c15), followed by a reduction of double bonds at carbons 9, 15, and 11 to yield the FA C18:2 t11c15, C18:1 t11 (tVA), and 18:0 (stearic acid), respectively (Wilde & Dawson, 1966). As regards the significantly higher contents of the FA C15 and C17 in organic milk, this has already been reported by Arnold (1984) but not by Jahreis et al. (1996).

On the other hand, significantly higher contents of stearic acid were found in conventional milk than in organic milk (9.49 and 9.21 g 100 g$^{-1}$, respectively). The same was true for oleic acid (C18:1 c9) (17.39 and 16.77 g 100 g$^{-1}$, respectively). These results are surprising, because of the higher proportion of grass and lower levels of concentrates in the organic group compared to the conventional group. Differences in the ruminal fermentation processes between the two farming systems cannot be excluded. The milk fat of the organic group in this study had a higher concentration of α-linonenic acid, but a lower concentration of oleic acid. The same configuration was also noted by Lund (1991), Jahreis et al. (1996) and Bergamo et al. (2003).

### 3.3. Conjugated linonenic acid isomers

The mean content of each of the CLA isomers in both organic and conventional milks averaged over 12 months is shown in Table 5. Organic and conventional milks did not differ with respect to milk CLA isomers t10t12, t8t10, t7t9 and t6t8 contents, but conventional milk had higher contents of the t7c9 isomer (+10.5%) compared to organic milk ($P \leq 0.001$) and, conversely, organic milk had higher contents of all other isomers ($P \leq 0.01$–$0.001$). Higher concentrations of the main (c9t11) and second most important (t11c13) CLA isomers were found in organic milk compared to conventional milk (23.7 and 15.3%, respectively).

A number of studies have confirmed that the milk fat CLA content increases with increasing proportions of pasture in the diet (Dewhurst et al., 2006; Dhiman, Arnand, Satter, & Pariza, 1999; Kelly et al., 1998; Stanton et al., 1997; Stockdale et al., 2003). The CLA-enriching effect of pasture has been attributed to the effects on biohydrogenation and the provision of α-linonenic acid as a lipid substrate for the formation of tVA in the rumen and its subsequent desaturation to c9t11 CLA in the mammary gland (Bauman, Corl, & Peterson, 2003).

With increasing altitude, which is accompanied by a decrease in the proportion of grasses and a corresponding increase in dicotyledonous species, relatively high contents of different CLA isomers (i.e., 11.8 and 10.2 mg g$^{-1}$ fat for the CLA c9t11 and 0.73 and 0.59 mg g$^{-1}$ fat for the CLA t11c13 in organic and conventional milk, respectively) are not surprising (Table 5). Moreover, values over 20 mg g$^{-1}$ fat for the CLA c9t11 were found in different individual bulk milks (data not shown). Our results showed that the concentration of the CLA isomer t11c13 is the second most predominant isomer and that the concentration of the third most important isomer (CLA t7c9) was higher in conventional milk than in organic milk. Kraft, Collomb, Möckel, Sieber, and Jahreis (2003) hypothesised that α-linonenic acid is the indirect precursor of t11c13 CLA. Therefore, this CLA could be a useful indicator of milk products of alpine origin or of milk from cows fed essentially grass.

**Table 5**
Mean contents (mg g$^{-1}$ milk fat) of conjugated linonenic acids in both organic and conventional milks averaged over one year

| CLA | Org[a] | | Conv | | Org–Conv | | P |
|---|---|---|---|---|---|---|---|
| | $\bar{X}$ | $s_x$ | $\bar{X}$ | $s_x$ | $\bar{X}$ | $s_x$ | |
| *CLA, concentrations which were significantly higher in organic milk* | | | | | | | |
| C18:2 t12t14 | 0.14 | 0.05 | 0.12 | 0.05 | 0.02 | 0.02 | *** |
| C18:2 t11t13 | 0.29 | 0.11 | 0.25 | 0.11 | 0.04 | 0.04 | *** |
| C18:2 t9t11 | 0.15 | 0.02 | 0.13 | 0.02 | 0.01 | 0.01 | *** |
| C18:2 t11c13 | 0.73 | 0.25 | 0.59 | 0.22 | 0.14 | 0.13 | *** |
| C18:2 c/t 12, 14 | 0.04 | 0.01 | 0.04 | 0.01 | 0.00 | 0.01 | ** |
| C18:2 c11t13 | 0.03 | 0.01 | 0.02 | 0.01 | 0.00 | 0.01 | * |
| C18:2 c9t11 | 11.78 | 4.14 | 10.22 | 3.29 | 1.56 | 1.83 | *** |
| C18:2 t10c12 | 0.02 | 0.01 | 0.02 | 0.01 | 0.00 | 0.00 | ** |
| C18:2 t8c10 | 0.19 | 0.07 | 0.17 | 0.06 | 0.02 | 0.02 | *** |
| CLA t11c13/CLA t7c9 | 1.88 | 0.51 | 1.37 | 0.44 | 0.51 | 0.29 | *** |
| Σ CLA | 13.90 | 4.62 | 12.16 | 3.76 | 1.74 | 1.99 | *** |
| *CLA, concentrations of which were significantly higher in conventional milk* | | | | | | | |
| C18:2 t7c9 | 0.38 | 0.06 | 0.42 | 0.08 | −0.04 | 0.06 | *** |
| *CLA, concentrations of which did not significantly change* | | | | | | | |
| C18:2 t10t12 | 0.03 | 0.01 | 0.04 | 0.01 | 0.00 | 0.01 | – |
| C18:2 t8t10 | 0.02 | 0.00 | 0.02 | 0.01 | 0.00 | 0.01 | – |
| C18:2 t7t9 | 0.08 | 0.01 | 0.08 | 0.01 | 0.00 | 0.01 | – |
| C18:2 t6t8 | 0.04 | 0.01 | 0.04 | 0.01 | 0.00 | 0.01 | – |

[a] Abbreviations: Org, organic; Conv, conventional; $n$, number of samples; Σ, sum of the concentrations; CLA, conjugated linonenic acid; $\bar{X}$, mean value; $n = 36$; $s_x$, standard deviation; $P$, Probability: $^{*}P \leq 0.05$; $^{**}P \leq 0.01$; $^{***}P \leq 0.001$.

## 4. Conclusion

According to the results obtained in the current study, the feeding of higher amounts of grasses including grass and grass silages as well as lower amounts of concentrates fed to cows in organic farming compared to integrated farming explains the differences in the FA spectra between organic and conventional milks. Comparisons between countries of the fatty acid composition of milk fat from cows fed organic fodder are not always reliable because of large differences in fodder requirements. In Switzerland, the differences in the fatty acid composition of milk between the two farming systems in the mountains were small because of low differences in the fodder composition.

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