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Correlation between fatty acids in cows' milk fat produced in the Lowlands, Mountains and Highlands of Switzerland and botanical composition of the fodder

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Abstract

The relationships between fodder plants and the fatty acid composition of milk fat were studied in lowland (600–650 m), mountain (900–1210 m) and highland (1275–2120 m) areas of Switzerland. Correlation coefficients have been calculated between the occurrence of plant families and species and the concentrations of groups of fatty acids in milk fats from the Mountains and Highlands regions, where the botanical composition of the pasture was more similar than in the Lowlands. Besides further contributing factors linked to the altitude in Mountains and Highlands (e.g. walking), the correlations indicate which plants could be responsible for the occurrence of the most abundant fatty acids in milk fat. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Milk fat; Fatty acid; Botanical composition; Pasture; Lowlands and Highland pasture

1. Introduction

The quality of milk and ripened cheese is influenced by different factors including the composition of fodder consumed by the cow and the altitude at which the cow grazes. Of these, the composition of the fodder is very important, as already stated in previous investigations on grass (Vertes & Hoden, 1989), forage preservation, grass versus hay (Coulon, Verdier, & Pradel, 1996), silage versus hay (Verdier-Metz, Coulon, Pradel, Viallon, & Berdagué, 1998) and botanical composition of dry forage (Viallon et al., 1999) or pasture grass (Buchin, Martin, Dupont, Bornard, & Achilleos, 1999). Altitude also significantly influences the composition of milk (Bianca & Puhan, 1974; Bovolenta, Ventura, Piasentier, & Malossini, 1998; Bugaud, Buchin, Coulon, Hauwuy, & Dupont, 2001b; Tschager et al., 1994) and the concentration of volatile components of cheese (Bosset, Bütikofer, Gauch, & Sieber, 1994; Bugaud, Buchin, Coulon, & Hauwuy, 2001a; Dumont & Adda, 1978).

Only few studies have investigated the influence of plants from pasture at different altitudes on the fatty acid composition of milk fat. Buchin et al. (1999) and Bugaud et al. (2001a) systematically investigated the effect of composition of highland pasture on the chemical, physical and sensory properties of *Abondance* cheese. The location of the pastures, even at the same altitude, influenced the composition of, and consequently the flavour of, *Abondance* cheese.

We have undertaken a study *in natura* (Jeangros, Scehovic, Troxler, & Bosset, 2000) to investigate the composition of pastures, milks and cheeses on three vegetation sites in Switzerland: Lowlands (600–650 m), Mountains (900–1210 m) and Highlands (1275–2120 m). Differences were found in the botanical and chemical compositions of pastures at these different vegetation sites and in the composition of the corresponding milk and cheese (Bosset et al., 1999; Jeangros, Scehovic, Troxler, Bachmann, & Bosset, 1999; Jeangros et al., 1997; Scehovic, Jeangros, Troxler, & Bosset, 1998). In particular, the analysis of the fatty acid composition of 44 milk samples, using a high-resolution gas

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chromatographic method which makes it possible to determine about 70 fatty acids, showed differences in concentrations of saturated, monounsaturated and polyunsaturated fatty acids, and conjugated linoleic acids (CLA) between the three vegetation sites (Collomb, Bütikofer, Sieber, Jeangros, & Bosset, 2002).

The objective of the current work was to determine whether the fatty acid composition of milk fat is affected by the botanical composition of pastures at three vegetation sites in Switzerland: Lowlands, Mountains and Highlands. The relationships between the botanical composition of the vegetation sites and the fatty acid composition of milk were established by way of linear correlations. This study particularly focussed on the Mountain and Highland regions, where the breeding practices are more similar than those in the Lowlands, where the botanical composition is more diversified compared to that found in the Lowlands, and where the milk has the highest content of CLA. The correlation coefficients were firstly calculated between the botanical composition and the fatty acid composition of milk for the Mountain and Highland regions and secondly for the three regions together.

2. Materials and methods

2.1. Details of vegetation sites and cow herds

A summary of the sites, observations, main characteristics of the milk herds and feeding modes have been described by Collomb et al. (2002).

2.2. Botanical composition of the fodder

The methods used to determine the botanical composition of the grassland were those described by Jeangros et al. (1999). Botanical records for each vegetation type (16 in Lowlands, 31 in Mountains and 55 in Highlands) were kept. The diversity of the botanical composition was estimated and expressed as index of Shannon. (The index of Shannon (H) (Shannon & Weaver, 1963) takes into account of the number of plant species and their relative importance: $H = \sum[(C_{si} \log 2(C_{si}/100)]$, where C_{si} expresses the specific contribution of the plant species i.) The botanical composition of the grassland consumed by the cow for the production of a given milk sample was determined.

2.3. Determination of fatty acids: sampling, preparation of the samples and method of analysis

The procedures used for collection and preparation of the 44 milk samples (11 from Lowlands, 12 from Mountains and 21 from Highlands) were those described by Collomb et al. (2002). High-resolution gas chromatography was used to analyse the fatty acid composition of milk fat (Collomb & Bühler, 2000).

2.4. Statistical analysis

Descriptive statistics and Pearson correlations were performed with Systat for Windows version 9.0 (Anonymous, 1999).

3. Results and discussion

A summary of the botanical composition of the pasture in the three vegetation sites is shown in Tables 1 and 2. The pastures of the Lowlands, composed of only eight species, was dominated by the two families, Poaceae and Fabaceae (Table 1) and by the following plant species *Zea mays*, *Trifolium repens*, *Lolium hybridum* and *perenne*, *Trifolium pratense, Dactylis glomerata* and *Festuca pratensis* (Table 2). The Poaceae was also the dominant family in the pastures from the Mountains and Highlands, with lower occurrences of the Asteraceae, Fabaceae, Ranunculaceae, Rosaceae and further families. The pastures from the Highlands, and to a lesser extent those from the Mountains, were thus characterized by a much greater number of plant species than the pastures from the Lowlands (Table 1).

3.1. Correlations found between fatty acids of milk fat and botanical families

Table 3 lists the most significant correlation coefficients of Pearson ($P < 0.05$) obtained between the main groups of fatty acids of milk fat and the botanical

Table 1
Main botanical families (as a percentage of total number of species) in the Lowlands, Mountains and Highlands grazing sites

Observation sites	Lowlands		Mountains		Highlands	
Altitude (m)	600–650		900–1210		1275–2120	
Number of botanical records	16		31		55	
	$\bar{x}$	s_x	$\bar{x}$	s_x	$\bar{x}$	s_x
Poaceae	64.7	8.3	64.5	5.5	42.4	7.9
Asteraceae	0.0	0.0	6.2	2.0	14.5	4.7
Fabaceae	35.3	8.3	6.5	0.9	9.5	3.5
Ranunculaceae	0.0	0.0	5.8	1.9	4.9	4.1
Rosaceae	0.0	0.0	2.6	0.7	5.5	2.9
Plantaginaceae	0.0	0.0	2.7	1.4	4.4	2.6
Cyperaceae	0.0	0.0	0.6	0.5	4.3	4.5
Apiaceae	0.0	0.0	1.4	0.7	4.1	2.2
Lamiaceae	0.0	0.0	1.6	0.7	2.1	1.2
Other plant families	0.0	0.0	8.1	3.0	8.3	2.9

$\bar{x}$ = mean; s_x = standard deviation.

Table 2
Main plant species (as a percentage of total number of species) in the lowlands, mountains and highlands grazing sites (only the species making up ⩾1% of total)

Observation sites		Lowlands		Mountains		Highlands	
Altitude (m)		600–650		900–1210		1275–2120	
Mean and standard deviation		$\bar{x}$	s_x	$\bar{x}$	s_x	$\bar{x}$	s_x
Number of species		6.1	1.13	52.1	3.49	52.9	9.01
Index of Shannon[a]		2.1	0.26	4.1	0.12	4.3	0.28
Fa	*Trifolium repens*	26.0	10.3	3.6	1.6	4.3	2.5
	Trifolium pratense	10.6	6.0	1.4	0.6	3.1	1.9
	Lotus corniculatus (and *alpinus*)	0.0	0.0	0.1	0.1	1.1	0.9
Po	*Zea mays*	19.5	22.9	0.0	0.0	0.0	0.0
	Lolium perenne	11.1	9.3	3.4	3.6	0.1	0.5
	Dactylis glomerata	7.2	5.7	3.7	0.9	2.5	2.6
	Festuca pratensis	5.5	4.3	7.2	2.8	2.7	2.9
	Agrostis capillaris	0.0	0.0	14.6	2.9	11.3	4.0
	Festuca rubra	0.0	0.0	13.2	2.6	9.1	4.8
	Lolium hybridum	13.1	23.8	0.0	0.0	0.0	0.0
	Poa trivialis	0.0	0.0	8.3	3.1	2.9	4.8
	Cynosorus cristatus	0.0	0.0	3.0	0.8	4.6	5.0
	Phleum pratense	7.0	5.2	3.4	1.6	0.2	0.4
	Holcus lanatus	0.0	0.0	3.6	1.7	0.6	1.3
	Anthoxanthum odoratum	0.0	0.0	1.6	1.0	1.7	1.2
	Deschampsia cespitosa	0.0	0.0	0.2	0.3	1.0	1.2
	Phleum alpinum	0.0	0.0	0.0	0.0	1.1	1.7
	Nardus stricta	0.0	0.0	0.0	0.0	1.7	3.4
As	*Leontodon hispidus*	0.0	0.0	1.1	1.0	6.8	5.0
	Taraxacum officinale	0.0	0.0	2.3	1.1	1.6	1.7
	Aposeris foetida	0.0	0.0	0.0	0.0	1.0	1.4
Ro	*Alchemilla vulgaris*	0.0	0.0	2.2	0.9	3.9	2.4
Pl	*Plantago lanceolata*	0.0	0.0	2.5	1.4	1.5	2.1
	Plantago alpina	0.0	0.0	0.0	0.0	2.1	2.5
Cy	*Carex sempervirens* (and *ferruginea*)	0.0	0.0	0.0	0.0	2.0	3.7
Ra	*Ranunculus acris friesianus*	0.0	0.0	2.3	0.8	1.1	1.0
	Ranunculus repens	0.0	0.0	2.0	1.5	1.4	3.2
	Ranunculus ficaria	0.0	0.0	1.2	1.2	0.0	0.1
Ap	*Carum carvi*	0.0	0.0	0.6	0.6	1.4	1.7
	Ligusticum mutellina	0.0	0.0	0.0	0.0	1.3	2.6
La	*Prunella vulgaris*	0.0	0.0	1.0	0.6	1.3	1.0
	Veronica chamaedrys	0.0	0.0	2.2	0.9	0.7	0.9

[a] The index of Shannon (H) is often used to express the diversity of the botanical composition (Shannon & Weaver, 1963). It takes into account the number of plant species and their relative importance ($H = \sum[(C_{si} \log 2(C_{si}/100)]$, where C_{si} expresses the specific contribution of the plant species i; $\bar{x}$ = mean; s_x = standard deviation; Fa = Fabaceae; Po = Poaceae, As = Asteraceae, Ro = Rosaceae, Pl = Plantaginaceae, Cy = Cyperaceae, Ra = Ranunculaceae, Ap = Apiaceae, La = Lamiaceae.

families of pastures in the Mountain and Highland vegetation sites taken together. The percentage of Poaceae in the Mountain and Highland pastures correlated positively with the concentration of saturated fatty acids but negatively with all the other groups of fatty acids detected in milk fat. The percentage of five further families of grasses in the Mountain and Highland pastures were positively correlated with the concentration of polyunsaturated fatty acids. The percentage of these families in the Mountain and Highland pastures also correlated with the content of CLA and with the concentration of trans monounsaturated fatty acids C18:1. No correlations have been observed between the percentage of plant families in the Mountain and Highland pastures and the concentration of monounsaturated fatty acids.

Except for the Fabaceae, all the significant correlation coefficients calculated for the Mountain and Highland vegetation sites did not change greatly when the Lowland pastures were included in the calculations.

3.2. Correlations between concentrations of fatty acids in milk fat and the percentage of individual plant species

As with plant families, the significant coefficients of correlation of Pearson were calculated between the main groups of fatty acids in milk fat and the plant species growing on the Mountain and Highland vegetation sites (Table 4).

It has been established that the percentage of seven plant species in the Mountain and Highland pastures (*Veronica chamaedrys, Festuca pratensis, Poa trivialis,*

Table 3
Most significant Pearson's correlation coefficients between the principal groups of fatty acids of bovine milk fat and the main botanical families in the pastures of the Mountains and Highland regions ($P<0.05$)

Fatty acid groups	Families (Pearson correlation coefficient)
∑ saturated [(1)]	**Poaceae** (0.54), (0.62*) **Asteraceae** (−0.53), (−0.79*), **Rosaceae** (−0.40), (−0.69*)
∑ monounsaturated [(2)]	—
∑ polyunsaturated [(3)]	**Asteraceae** (0.74), (0.87*), **Apiaceae** (0.63), (0.76*), Fabaceae (0.53), **Rosaceae** (0.41), (0.69*), **Cyperaceae** (0.41), (0.51*) **Poaceae** (−0.77), (−0.77*)
∑ CLA [(4)]	**Asteraceae** (0.65), (0.85*), **Apiaceae** (0.58), (0.75*), **Cyperaceae** (0.47), (0.54*), **Fabaceae** (0.45), (−0.71*), **Rosaceae** (0.44), (0.72*), **Lamiaceae** (0.33), (0.68*) **Poaceae** (−0.73), (−0.72*)
∑ C18:1 trans [(5)]	**Asteraceae** (0.67), (0.85*), **Cyperaceae** (0.63), (0.62*), **Rosaceae** (0.55), (0.76*), **Apiaceae** (0.50), (0.70*), Fabaceae (0.45). **Plantaginaceae** (0.41) (0.70*), **Lamiaceae** (0.33), (0.68*) **Poaceae** (−0.77), (−0.72*)

*Including Lowlands; bold: significant correlations confirmed including Lowlands.
Fatty acids ordered according to increasing gas chromatographic retention time:

(1) 4, C5, C6, C7, C8, C10, C12, C12 iso, C12 aiso, C13 iso, C14, C14 iso, C14 aiso, C15, C15 iso, C16, C16 iso, C16 aiso; C17, C17 iso, C17 aiso, C18, C19, C20, C22.

(2) C10:1, C14:1 ct, C16:1 ct, C17:1 t, C18:1 t4, C18:1 t5, C18:1 t6–8, C8:1 t9, C18:1 t10–11, C18:1 t12, C18:1 t13–14 + c6–8, C18:1 c9, C18:1 c11, C18:1 c12, C18:1 c13, C18:1 t16 + c14, C20:1 t, C20:1 c5, C20:1 c9, C20:1 c11.

(3) C18:2 ttNMID, C18:2 t9t12, C18:2 c9t13 + (t8c12), C18:2 c9t12 + (ccMID + t8c13), C18:2 t11c15 + t9c12, C18:2 c9c12, C18:2 c9c15, C18:3 c6c9c12, C18:3 c9c12c15, C18:2 c9t11, C18:2 c9c11 + t11c13, C18:2 t9t11, C20:2 c,c (ω–6), C20:3 (ω–6), C20:3 (ω–3), C20:4 (ω–6), C20:5 (EPA) (ω–3), C22:5 (DPA) (ω–3), C22:6 (DHA) (ω–3).

(4) CLA total (∑ C18:2 −c9t11, −c9c11 + t11c13, −t9t11).

(5) C18:1 (∑−t4, −t5, −t6–8, −t9, −t10–11, −t12, -t13–14).

Phleum pratense, Holcus lanatus, Ranunculus acris friesianus and *Ranunculus ficaria*) correlated positively with the concentration of the saturated fatty acids in milk fat. The percentage of all these plant species correlated negatively with the concentration of polyunsaturated fatty acids and with the concentration of CLA and monounsaturated trans C18:1 fatty acids.

The percentage of five plant species (*Leontodon hispidus*, *Plantago alpina*, *Aposeris foetida*, *Lotus corniculatus* (and *alpina*) and *Deschampsia cespitosa*), dominant in the Mountains and Highlands, correlated negatively with the concentration of saturated fatty acids. The percentage of three species (*Leontodon hispidus*, *Lotus corniculatus* (and *alpina*) and *Trifolium pratense*) correlated positively with the concentration of polyunsaturated fatty acids and, with the concentrations of CLA and monounsaturated trans C18:1 fatty acids in milk fat. Moreover, the concentration of polyunsaturated fatty acids correlated positively with the percentage of *Carum carvi* and *Aposeris foetida* in the pasture grass, the concentration of CLA with the occurrence of *Plantago alpina* and *Prunella vulgaris*, and the concentration of monounsaturated trans C18:1 with the percentage of five other species (e.g. *Plantago alpina*, *Carex sempervirens* (and *ferruginea*)).

It is noteworthy that the concentration of saturated fatty acids correlated positively with the percentage of particular plant species or families; in contrast, the concentrations of polyunsaturated, CLA and trans C18:1 fatty acids correlated negatively with these particular plant species. The opposite was also found to be true. Different mechanisms may regulate the concentrations of both groups of fatty acids.

The *Lolium perenne* was the only plant species which was correlated positively with the concentration of monounsaturated fatty acids compared to the other pools of fatty acids. The production of monounsaturated fatty acids seems to be regulated differently from other fatty acid groups. Their occurrence in milk is less dependant on botanical composition.

Moreover, if the botanical composition of the Lowlands is also included with those of the Mountains and Highlands for the calculation of the correlation coefficients, about half of the correlations between the percentage of plant species and the concentration of groups of fatty acids in milk fat can be confirmed. The very different botanical composition of the pasture in the Lowlands compared to that at higher altitudes explains this observation, and confirms the difficulty of comparing two different systems of breeding (temporary grasslands in Lowlands and permanent pastures in Mountain and Highlands).

To our knowledge, no study has been carried out on this subject. Therefore, the correlations between the percentage of plant species or families in the grasses at different altitudes and the concentration of fatty acids in milk cannot be compared with data from the literature.

Bugaud et al. (2001b) suggested that the high proportion of long-chain unsaturated fatty acids in milk fat from cows fed at high altitude (i.e., Mountains,

Table 4
Significant Pearson's correlation coefficients between groups of fatty acids in milk and individual plant species in the Mountain and Highland regions ($P<0.05$)

Fatty acid groups	Plants (Pearson correlation coefficient)
$\sum$ saturated (1)	*Veronica chamaedrys*^{La} (0.60), ***Festuca pratensis*** ^{Po} (0.53), (0.34*), *Poa trivialis* ^{Po} (0.53), ***Phleum pratense*** ^{Po} (0.46), (0.58*), *Holcus lanatus* ^{Po} (0.45), *Ranunculus acris friesianus* ^{Ra} (0.45), *Ranunculus ficaria* ^{Ra} (0.42)
	Leontodon hispidus^{As} (−0.58), (−0.62*), ***Plantago alpina***^{Pl} (−0.48), (−0.47*), ***Aposeris foetida*** ^{As} (−0.46), (−0.44*), ***Lotus corniculatus (*** and ***alpina)*** ^{Fa} (−0.43), (−0.53*), ***Deschampsia cespitosa***^{Po} (−0.35), (−0.44*)
$\sum$ monounsaturated (2)	*Lolium perenne* ^{Po} (0.39)
$\sum$ polyunsaturated (3)	***Leontodon hispidus*** ^{As} (0.64), (0.69*), ***Lotus corniculatus (*** and ***alpina)*** ^{Fa} (0.56), (0.62*), *Trifolium pratense*^{Fa} (0.48), ***Carum carvi*** ^{Ap} (0.38), (0.49*), ***Aposeris foetida*** ^{As} (0.36), (0.42*)
	Phleum pratense ^{Po} (−0.74), (−0.63*), *Veronica chamaedrys*^{La} (−0.67), ***Festuca pratensis*** ^{Po} (−0.58), (−0.43*), *Poa trivialis* ^{Po} (−0.56), *Ranunculus ficaria* ^{Ra} (−0.55), ***Lolium perenne*** ^{Po} (−0.51), (−0.56*), *Holcus lanatus* ^{Po} (−0.51), *Ranunculus acris friesianus* ^{Ra} (−0.50), *Festuca rubra* ^{Po} (−0.37)
$\sum$ CLA (4)	***Leontodon hispidus*** ^{As} (0.62), (0.67*), ***Lotus corniculatus (*** and ***alpina)*** ^{Fa} (0.50), (0.58*), *Trifolium pratense*^{Fa} (0.42), ***Plantago alpina***^{Pl} (0.36) (0.44*), ***Prunella Vulgaris***^{La} (0.35), (0.60*)
	Phleum pratense ^{Po} (−0.71), (−0.71*), *Veronica chamaedrys*^{La} (−0.71), ***Festuca pratensis*** ^{Po} (−0.63), (0.42*), *Poa trivialis* ^{Po} (−0.56), ***Lolium perenne*** ^{Po} (−0.52), (−0.64*), *Ranunculus ficaria* ^{Ra} (−0.50), *Ranunculus acris friesianus* ^{Ra} (−0.49), *Holcus lanatus* ^{Po} (−0.48)
$\sum$ C18:1 trans (5)	***Leontodon hispidus*** ^{As} (0.67), (0.69*), ***Lotus corniculatus (*** and ***alpina)*** ^{Fa} (0.56), (0.61*), *Trifolium pratense*^{Fa} (0.56), ***Plantago alpina***^{Pl} (0.44), (0.48*), ***Carex sempervirens (*** and ***ferruginea)***^{Cy} (0.39), (0.38*), ***Aposeris foetida*** ^{As} (0.38), (0.42*), ***Phleum alpinum***^{Po} (0.37), (0.39*), ***Deschampsia cespitosa***^{Po} (0.35), (0.45*)
	Festuca pratensis ^{Po} (−0.77), (−0.49*), *Veronica chamaedrys*^{La} (−0.76), *Poa trivialis* ^{Po} (−0.68), ***Phleum pratense*** ^{Po} (−0.68), (−0.70*), *Ranunculus acris friesianus* ^{Ra} (−0.58), *Ranunculus ficaria* ^{Ra} (−0.49), ***Dactylis glomerata***^{Po} (−0.46), (−0.55*), ***Lolium perenne*** ^{Po} (−0.46), (−0.63*), *Holcus lanatus* ^{Po} (−0.43), *Ranunculus repens* ^{Ra} (−0.43), *Agrostis capillaris*^{Po} (−0.41), *Taraxacum officinale*^{As} (−0.36)

*Including Lowlands; bold: significant correlations confirmed including Lowlands.
Fatty acids ordered according to increasing gas chromatographic retention times:

(1) C4, C5, C6, C7, C8, C10, C12, C12 iso, C12 aiso, C13 iso, C14, C14 iso, C14 aiso, C15, C15 iso, C16, C16 iso, C16 aiso; C17, C17 iso, C17 aiso, C18, C19, C20, C22.

(2) C10:1, C14:1 ct, C16:1 ct, C17:1 t, C18:1 t4, C18:1 t5, C18:1 t6–8, C8:1 t9, C18:1 t10–11, C18:1 t12, C18:1 t13–14 + c6–8, C18:1 c9, C18:1 c11, C18:1 c12, C18:1 c13, C18:1 t16 + c14, C20:1 t, C20:1 c5, C20:1 c9, C20:1 c11.

(3) C18:2 ttNMID, C18:2 t9t12, C18:2 c9t13 + (t8c12), C18:2 c9t12 + (ccMID + t8c13), C18:2 t11c15 + t9c12, C18:2 c9c12, C18:2 c9c15, C18:3 c6c9c12, C18:3 c9c12c15, C18:2 c9t11, C18:2 c9c11 + t11c13, C18:2 t9t11, C20:2 c,c (ω−6), C20:3 (ω−6), C20:3 (ω−3), C20:4 (ω−6), C20:5 (EPA) (ω−3), C22:5 (DPA) (ω−3), C22:6 (DHA) (ω−3).

(4) CLA total ($\sum$ C18:2 –c9t11, −c9c11 + t11c13, −t9t11).

(5) C18:1 ($\sum$−t4, −t5, −t6−8, −t9, −t10-11, −t12, −t13−14).

Highlands), compared to the Lowlands, may be attributable to a number of factors associated with high altitude grazing, including: lower temperature, the greater level of exercise of the cows (which could induced an increase in the content of oleic acid derived from fat metabolism), and/or a decrease in fat intake. However, the high concentration of CLA and trans vaccenic acid in milk fat from high altitudes (Collomb et al., 2002) indicates that there was increased biohydrogenation in the rumen of the cow probably due to the presence of a high content of polyunsaturated fatty acid in the fodder plant species (e.g. *Leontodon hispidus*, *Lotus corniculatus* (and *alpina*), *Trifolium pratense*). The fatty acid composition of fodder plants will be systematically investigated in the future.

4. Conclusion

The current study was carried out *in natura* (high number of plant species), which explains why no precise and well-established conclusions can be drawn. Nevertheless, it leads us to conclude that the intake of different plant families could be related to the fatty acid composition of milk fat. The concentration of fatty acids in the milk could also be related to the plant species, independent of the families they belong to.

Indeed, the correlations obtained between the concentration of different fatty acid groups and the percentage of the plant species should be considered carefully since a large number of plant species, some of which are present only at low concentrations, are encountered in the Mountains and Highlands. Verification of the preliminary correlations between the concentrations of different groups of fatty acids and the presence of different grass species (at different levels in the pasture) require further investigations in which the feeding conditions of the cows on pastures with specific plant species are defined, and the fatty acid composition of the fat in both the grasses and milk are measured. The results of such investigations should help to establish if the relatively low levels of unsaturated fatty acids in the milk fat from the Lowlands are due to the relatively high production of endogenous fatty acids in the mammary gland. Nevertheless, the increase in the content of trans vaccenic acid and CLA as a function of altitude (Collomb et al., 2002) proved that a high rate of biohydrogenation occurred in the rumen of the cows grazing in the Highlands. This effect can only be related to a higher content of polyunsaturated fatty acids in the fat of the plant species in the Highlands.

The trends found in the current study, especially that showing a high concentration of the highly valuable CLA in the milk fat from cows fed on the Mountains and Highlands, should prove a credible justification for the retention of dairying agriculture in these often-economically unfavourable regions.

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