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Utilisation of mid-infrared spectroscopy for determination of the geographic origin of Gruyère PDO and L'Etivaz PDO Swiss cheeses

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Abstract

The potential of mid-infrared spectroscopy (MIR), using an attenuated total reflectance (ATR) cell, was evaluated for the authentication of 25 Gruyère PDO and L'Etivaz PDO cheeses produced at different altitudes in Switzerland. In order to test the ability of MIR to authenticate the investigated cheeses, chemometric tools, such as principal component analysis (PCA) and factorial discriminant analysis (FDA), were applied to the three spectral regions of the MIR (e.g. 3000–2800 cm^{-1}, 1700–1500 cm^{-1}, and 1500–900 cm^{-1}). By applying the FDA to the first 10 principal components (PCs) of the PCA applied to each spectral regions, the best rate of correct classification was obtained in the 3000–2800 cm^{-1} and 1500–900 cm^{-1} spectral regions, since 90.5% and 90.9% were achieved, respectively. It can be concluded that these two spectral regions could be considered as valuable tools for the determination of the geographical origin of the investigated cheeses.

Keywords: Gruyère PDO cheese; L'Etivaz PDO cheese; Mid-infrared; Chemometric; Geographic origin

1. Introduction

Product authenticity and authentication are emerging topics within the food sector (Karoui et al., 2004). Authentication is a major concern, not only for consumers, but also for producers and distributors (Fernandez, Astier, Rock, Coulon, & Berdagué, 2003). Indeed, regulatory authorities, food processors, retailers and consumer groups are all interested in ensuring that foods are correctly labelled. Food adulteration has been practised since biblical times, but has become more sophisticated in the recent past. Foods or ingredients most likely to be targets for adulteration include those which are of high-value and which undergo a number of processing steps before they appear on the market. With the European harmonisation of the agricultural policy and the emergence of the international markets, authentication of such foodstuffs focuses more attention. This trend is the result of efforts made by regional authorities, as well as producers, to protect and support local productions (Karoui, Mazerolles, & Dufour, 2003).

The quality of milk plays a very important role in the production of all types of cheeses, affecting both cheese yield and characteristics of the cheese (Summer et al., 2003). In regions with high production costs, agriculture needs to produce food of good quality. The products can be labelled according to the specific conditions which characterise their origin and the processing technology (Bosset

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et al., 1997). These regions can be designed for products presenting Protected Designation of Origin (PDO) or Protected Geographical Indication (PGI).

Animal feeding is one of the elements often considered as important by cheese-makers (Buchin, Martin, Dupont, Bornard, & Achilleos, 1999; Bugaud, Buchin, Coulon, Hauwuy, & Dupont, 2001; Bugaud et al., 2001). Grass of natural highland pastures presents a highly diversified botanical composition, as well as abundant secondary metabolites, which may influence milk and therefore cheese quality (Bugaud et al., 2001; Bugaud et al., 2001). While the gramineae and legumineae families dominate artificial pastures of lowlands, permanent pastures of highlands contain significant proportions of plants belonging to many other botanical families, such as rosaceae and plantaginaceae (Bugaud et al., 2001; Bugaud et al., 2001; Jeangros, Scehovic, Troxler, Bachmann, & Bosset, 1999).

The relationships between the quality of milk and the grass fed by cows have been studied by several researchers (Bugaud et al., 2001; Collomb, Bütikofer, Sieber, Jeangros, & Bosset, 2002; Fernandez et al., 2003; Martin et al., 2002; Ritz et al., 2005). Fernandez et al. (2003) have reported, by using dynamic head space-gas chromatography coupled to mass spectrometry, that milks collected from highland regions were richer in sesquiterpenes than those produced in lowland regions. In addition, the proportion of C18:1, and the total of C18:2 + C18:3 determined by gas chromatography, were higher in mountain milks than in valley milks (Bugaud et al., 2001).

Regarding the relationships between the origin of cheeses and the type of pasture given to the herd, only limited papers have been published. In addition, these relationships were usually determined by well-known destructive methods such as gas/liquid chromatography, isotope ratio mass spectrometry, olfactometry and physicochemical analyses (Bosset et al., 1999; Carpino, Acree, Barbano, Licitra, & Siebert, 2002; Manca et al., 2001; Mariaca et al., 1997; Pillonel, Ampuero, Tabacchi, & Bosset, 2003; Pillonel et al., 2005).

Traditional analytical strategies to uncover adulteration and guarantee quality have relied on wet chemistry to determine the amount of a marker compound or compounds in a suspect material and a subsequent comparison of the value(s) obtained with those established for equivalent material of known provenance (Downey, 1996). This approach suffers from a number of disadvantages, namely, the ever-increasing range of analytes which must be included in any test procedure and the limited knowledge of the range of each constituent in normal lots of the substance. These ranges may be expected to vary with the geographic source and dairy products manufacturing procedure. For all these reasons, there is a continuing demand for new, rapid and relatively cheaper methods for direct quality measurement in food and food ingredients.

At present, mid-infrared (MIR) spectroscopy is among the most preferred method for milk and dairy product analysis. This is due to the fact that almost every chemical substance (apart from some salts and very simple chemical compounds) has its own distinctive spectrum. Only substances occurring in very low concentrations can be difficult to determine, as the noise level of the method might be encountered in such a case. Water absorbs in the MIR region and may consequently affect the interpretation of the spectra. Water is a very strong infrared absorber with prominent bands centred at 3360 cm^{-1} (H–O stretching band), at 2130 cm^{-1} (water association band), and at 1640 cm^{-1} due to the H–O–H bending vibration (Safar, Bertrand, Devaux, & Genot, 1994). Precise subtractions of the H_2O bands are possible due to the frequency precision achievable with Fourier transform infrared measurement. The development of the attenuated total reflectance (ATR) device allows the sampling problems encountered when collecting spectra from opaque and viscous samples to be overcome. In this study, MIR spectroscopy, combined with multivariate statistical methods, was employed to discriminate between cheeses made using milk from cows fed a highland grass, with a highly diversified botanical composition from those produced using milk from cows fed on lowland grass.

2. Materials and methods

2.1. Gruyère PDO and L'Etivaz PDO Swiss cheese samples

Twenty-five (25) hard cheeses were collected in Switzerland from three production sites located at different altitudes. L'Etivaz PDO cheeses were produced in alpine cabins ($n = 6$, 1500–1850 m). Gruyère PDO cheeses were manufactured at two production sites: (i) in the highlands between 1100 and 1500 m ($n = 8$) and (ii) in the lowlands (<800 m, $n = 11$) (Table 1). All the investigated cheeses were ripened at a temperature ranging from 12 to 18 °C for 240 days. Previous detailed investigations have shown that the botanical composition of the investigated sites were markedly different (Jeangros et al., 1997; Jeangros et al., 1999). The traditional cheese-making procedures of Gruyère and L'Etivaz PDO cheeses are comparable, except for the milk heating. L'Etivaz PDO cheeses are produced using an open log fire, producing some smoke, whereas steam-heated vats are used for producing Gruyère PDO in the highland and the lowland regions. The weight of round Gruyère PDO cheeses ranges from 25 to 40 kg (diameter: 55–65 cm, high: 9.5–12 cm). The loaf size of L'Etivaz PDO cheese may be between 10 and 38 kg (diameter: 30–65 cm, high: 8–11 cm). No information about the starter cultures used for the production of Gruyere and L'Etivaz Swiss cheese was provided by the producers.

2.2. Mid-infrared spectroscopy

MIR spectra were recorded between 3000 and 900 cm^{-1} at a resolution of 4 cm^{-1} on a Fourier transform spectrometer 740 SX (Thermo Electron, square Franklin, 78180 Montigny le Bretonneux, France) mounted with an ATR

Table 1
Geographic origin of L'Etivaz PDO cheeses and Gruyère PDO cheeses produced from milks collected from cows grazing pastures at different altitudes in Switzerland

Cheese type[a]	Place of manufacture in Switzerland[b]
Gruyère	Vuisternens/Romont: lowland (800 m)
Gruyère	Prez-vers-Siviriez: lowland (800 m)
Gruyère	Montbovon: lowland (800 m)
Gruyère	Vuadens: lowland (800 m)
Gruyère	Cottens: lowland (800 m)
Gruyère	La Côte-aux-Fées: lowland (800 m)
Gruyère	Les Jordans: lowland (800 m)
Gruyère	Châtonnaye: lowland (800 m)
Gruyère	L'Isle: lowland (800 m)
Gruyère	Prez-vers-Siviriez: lowland (800 m)
Gruyère	Corcelles-le-Jorat: lowland (800 m)
Gruyère	Montbovon: highland (1100 m)
Gruyère	Montbovon: highland (1200 m)
Gruyère	Montbovon: highland (1200 m)
Gruyère	Montbovon: highland (1450 m)
Gruyère	Montbovon: highland (1550 m)
Gruyère	Montbovon: highland (1200 m)
Gruyère	Montbovon: highland (1500 m)
Gruyère	Montbovon: highland (1400 m)
L'Etivaz	L'Etivaz: L'Etivaz (1700 m)
L'Etivaz	L'Etivaz: L'Etivaz (1700 m)
L'Etivaz	L'Etivaz: L'Etivaz (1850 m)
L'Etivaz	L'Etivaz: L'Etivaz (1500 m)
L'Etivaz	L'Etivaz: L'Etivaz (1700 m)
L'Etivaz	L'Etivaz: L'Etivaz (1500 m)

[a] There was only 1 cheese for each cheese type.
[b] The number in brackets indicates the altitude of the region.

accessory equipped with a grip. Slices of cheese (8 cm × 1 cm × 0.5 cm) were set on the crystal and a pressure on the grip ensured a good contact between the two elements. To improve the signal-to-noise ratio, 250 scans were accumulated for each spectrum. The sample station was equipped with an overhead m-ATR accessory that contains transfer optics, through which infrared radiation can be directed to a detachable ATR crystal. The m-ATR cell used as a sampling accessory has a single reflection horizontal ATR crystal made of zinc selenide (ZnSe) with an incidence angle of 45°. Before each measurement, the spectrum of the ZnSe crystal was recorded and used as background. Baseline and ATR corrections, smoothing and water subtraction were applied to the spectra, using OMNIC Software (OMNIC 4.0, Thermo Electron, square Franklin, 78180 Montigny le Bretonneux, France). After every measurement, the m-ATR crystal was thoroughly washed with ethanol and distilled water and then dried. The cleaned crystal was examined by repeated blank measurement to ensure that no sample residue from the previous sample was retained on the crystal surface. All experiments were done in triplicate, using different cheese samples.

2.3. Mathematical treatment of data

2.3.1. Principal component analysis

The three different spectral regions in the MIR (3000–2800 cm^{-1}, 1700–1500 cm^{-1} and 1500–900 cm^{-1}) were first normalised by reducing the area under each spectrum to a value of 1 according to Bertrand and Scotter (1992). The principal component analysis (PCA) was applied to the normalised spectra in order to investigate differences in the spectra of the investigated cheeses (Jolliffe, 1986). This statistical multivariate treatment makes it possible to draw similarity maps of the samples and to get spectral patterns (Bertrand & Scotter, 1992; Jolliffe, 1986). While the similarity maps allow the comparison of the spectra in such a way that two neighbouring points represent two similar spectra, the spectral patterns exhibit the absorption bands that explain the similarities observed on the maps.

2.3.2. Factorial discriminant analysis

Factorial discriminant analysis (FDA) was performed, separately, on the first 10 principal components (PCs) resulting from the PCA applied to the three spectral regions. The aim of this technique is to predict the membership of an individual to a qualitative group defined as a preliminary (Safar et al., 1994). A group was created for each type of cheese, namely Gruyère PDO cheeses produced in lowlands, Gruyère PDO cheeses made in highlands and L'Etivaz PDO cheeses manufactured in L'Etivaz. The method cannot be applied in a straightforward way to continuous spectra because of the high correlations occurring between the wavelengths. Advantages were found in the preliminary transformation of the data into their PCs. The FDA assesses new synthetic variables called "discriminant factors", which are linear combinations of the selected PCs, and allows a better separation of the centres of gravity of the considered groups. The individual cheese samples can be reallocated within one of the three groups. For each group, the distance from the various centre of gravity of the groups is calculated. The cheese sample is assigned to the group where its distance between the centre of gravity is the shortest. Comparison of the assigned group to the real group is an indicator of the quality of the discrimination.

The PCA and FDA were performed using StatBoxPro (Grimmer Logiciels, Paris, France).

3. Results and discussion

Because each chemical compound in the milk contributes to the absorbance spectrum, the MIR spectrum of a cheese sample contains information for the compounds which are present at levels >0.1% (w/w). The absorption bands observed in the MIR (3000–900 cm^{-1}) are associated with fundamental valence vibrations of functional groups of the molecule. Most of the spectral information used for the discriminant analysis was located in three wavenumber regions.

The 3000–2800 cm^{-1} spectral region corresponds to the C–H bond of methyl and methylene groups of fatty acids. This region was dominated by two strong bands located at 2919 and 2851 cm^{-1} which have been assigned to methylene anti-symmetric and symmetric stretching modes (Casal & Mantsch, 1984), respectively (Fig. 1). Two other weaker

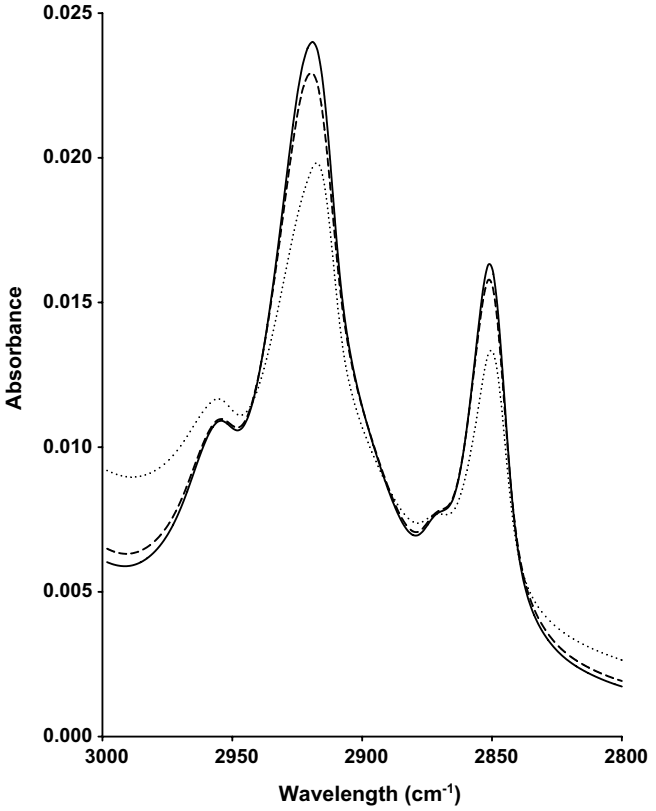

Fig. 1. Averaged mid-infrared spectra in the 3000–2800 cm^{-1} for Gruyère PDO cheeses produced in lowlands (---), Gruyère PDO cheeses produced in highlands (···), and L'Etivaz PDO cheeses produced in L'Etivaz (—) regions.

bands, located at 2955 and 2872 cm^{-1}, were assigned to the asymmetric and symmetric stretching modes of the terminal methyl group.

L'Etivaz cheeses presented the highest intensity at 2921 and 2851 cm^{-1}. In addition, the spectra showed different shapes according to the geographical origin of cheeses. First, it was observed that the $A\gamma_{CH_2}/A\gamma_{CH_3}$ values were different between L'Etivaz PDO and Gruyère PDO cheeses produced in lowlands. Furthermore, a slight shift to higher wavelengths of the CH_2 stretching mode was observed for L'Etivaz PDO chesses and Gruyère PDO chesses produced in lowlands. Differences in the shape of the 3000–2800 cm^{-1} spectra could be due to differences in both the nature and concentration of fatty acids. Indeed, Collomb et al. (2002) reported that milks produced in highlands had smaller amounts of saturated short-and medium-chain fatty acids and more poly-unsaturated fatty acids than those collected from lowlands. This could also be due to the effect of microbial association on the production of many compounds through lipolysis. Therefore, microbial population may affect the chemical composition of cheese and consequently the shape of the spectra. In addition, Bugaud et al. (2001) and Bosset et al. (1997) reported that milk produced in highlands had lower contents of saturated fatty acids with 4–16 carbon atoms and higher contents of stearic, oleic and poly-unsaturated fatty acids, especially C18:2 and C18:3, than had milks produced in the lowlands.

In order to extract information from the data set, PCA was applied to the 3000–2800 cm^{-1} region and the map defined by the first two PCs did not allow any discrimination between the investigated cheeses according to their geographical origin. The FDA was then applied to the first 10 PCs and the similarity map of the first two discriminant factors, which took into account 100% of the total variance, is shown in Fig. 2a. According to discriminant factor 1, accounting for 59.8% of the total variance, L'Etivaz PDO cheeses presented positive scores, whereas Gruyère PDO cheeses produced in lowlands had mostly negative score values. Although Gruyère PDO cheeses produced in highlands presented coordinates close to the origin, these cheeses were quite discriminated from the two other cheese groups. The quite good discrimination observed on the map could be due to the differences in cheese-making procedures at each production site (such as the use of raw milk with a specific microbial flora, as well as the use of technological procedures, to heat the milk). Indeed, as mentioned above, a smoking open log fire was used in alpine cabins for milks used to produce L'Etivaz PDO cheese, whereas steam was utilised to heat the milk for Gruyère PDO lowland and highland cheeses.

Correct classification of 90.5% was observed. Considering L'Etivaz PDO cheeses, one spectrum was classified as belonging to Gruyère PDO cheeses produced in lowlands and another one to highland Gruyère PDO cheese (Table 2). Regarding Gruyère PDO cheeses produced in highlands, one spectrum was classified as L'Etivaz PDO cheese and another as lowland Gruyère PDO cheese. Correct classification of 90.9% was obtained for Gruyère PDO cheeses made in lowlands. From the obtained results it can be concluded that the 3000–2800 cm^{-1} spectral region could be considered as a fingerprint allowing good authentication of cheeses.

The 1700–1500 cm^{-1} region was characterised by the presence of bands related to peptides and proteins. Thus, these bands contain some information on the proteins and on the interaction of these latter with other components, such as ions, water and other proteins. Fig. 3 shows the shapes of the spectra of the investigated cheeses. Contribution to the amide I band, which was used to investigate the secondary structure of several proteins, can be observed around 1633 cm^{-1}. The absorption bands at 1544 and 1514 cm^{-1} are generally assigned to the amide II vibrations (Fig. 3).

PCA was applied to the normalised spectra recorded in the 1700–1500 cm^{-1} spectral region in order to discriminate between the three groups of cheeses. The map defined by PC1 and PC2 accounted for 73.5% of the total variance. The PC1, which took into account 51.2%, discriminated slightly between Gruyère PDO cheeses produced in highland and lowland regions (data not shown).

The ability of 1700–1500 cm^{-1} spectral region to discriminate between the investigated cheeses was assessed

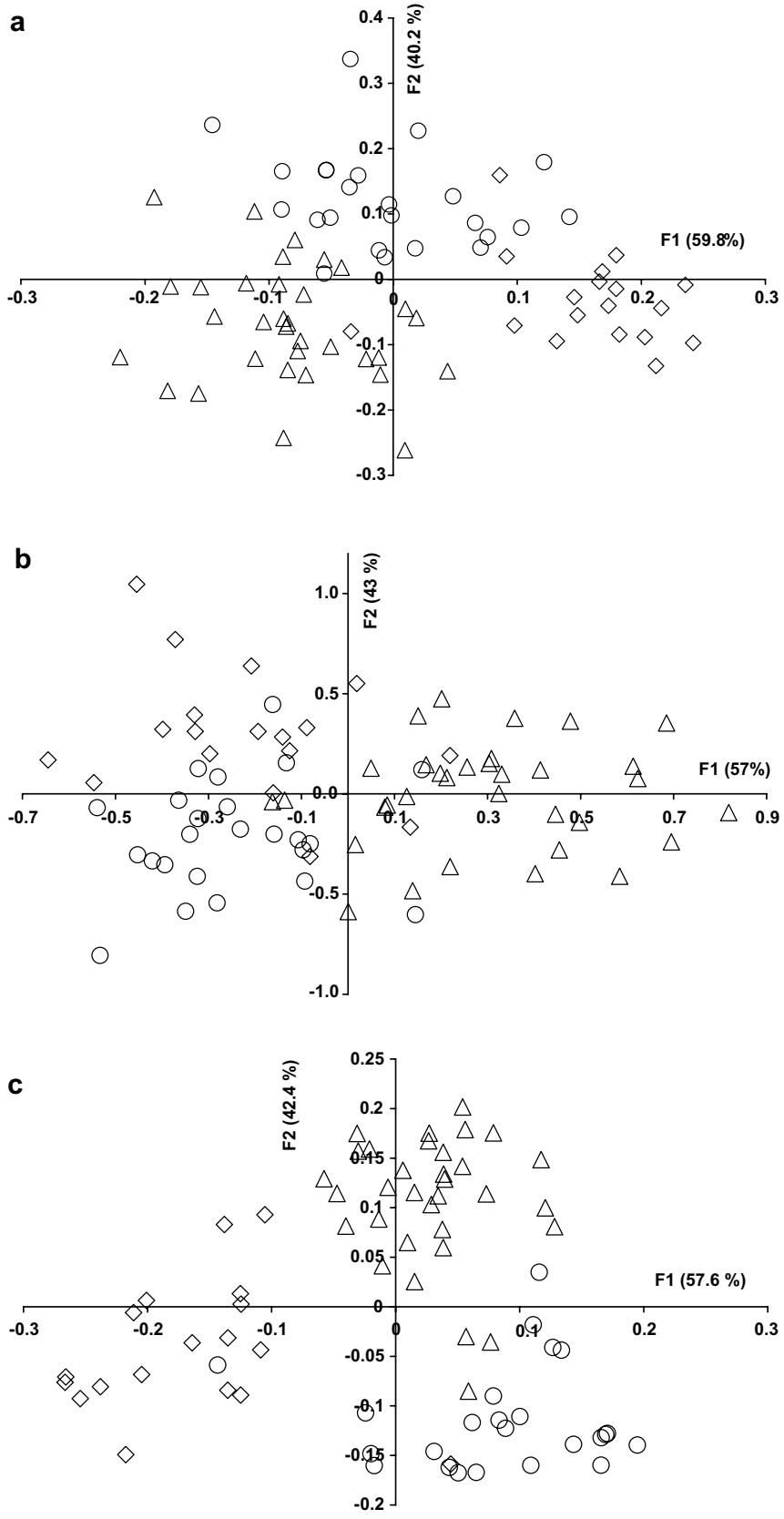

Fig. 2. Discriminant analysis similarity map determined by discriminant factors 1 (F1) and 2 (F2) for the factorial discriminant analysis (FDA) performed on the first 10 principal components (PCs) of the principal component analysis (PCA) applied to the 3000–2800 cm^{-1} (a), 1700–1500 cm^{-1} (b) and 1500–900 cm^{-1} (c) spectral region of Gruyère PDO cheeses produced in lowlands (△), Gruyère PDO cheeses produced in highlands (○) and L'Etivaz PDO cheeses produced in L'Etivaz (◇) regions.

Table 2
Classification of Gruyère PDO cheeses and L'Etivaz PDO cheeses based on the 3000–2800, 1700–1500 and 1500–900 cm^{-1} data set

Predicted[d]	Observed[e]			Total
	Lowland Gruyère PDO[a]	Highland Gruyère PDO[b]	L'Etivaz PDO[c]	
3000–2800 cm^{-1}				
Lowland Gruyère PDO	30	1	1	
Highland Gruyère PDO	3	22	1	
L'Etivaz PDO	–	1	16	
% Correct classification	90.9	91.7	88.9	90.5
1700–1500 cm^{-1}				
Lowland Gruyère PDO	29	2	2	
Highland Gruyère PDO	4	18	3	
L'Etivaz PDO	–	4	13	
% Correct classification	87.9	75	72.2	80
1500–900 cm^{-1}				
Lowland Gruyère PDO	30	1	1	
Highland Gruyère PDO	3	22	1	
L'Etivaz PDO	–	1	16	
% Correct classification	90.9	91.7	88.9	90.7

[a] Gruyère PDO cheeses produced in lowland regions of Switzerland with an altitude of 800 m.
[b] Gruyère PDO cheeses produced in Montbovon region of Switzerland with an altitude of 1100–1500 m.
[c] L'Etivaz PDO cheeses produced in L'Etivaz region of Switzerland with an altitude of 1500–1850 m.
[d] The number of predicted cheese samples.
[e] The number of observed cheese samples.

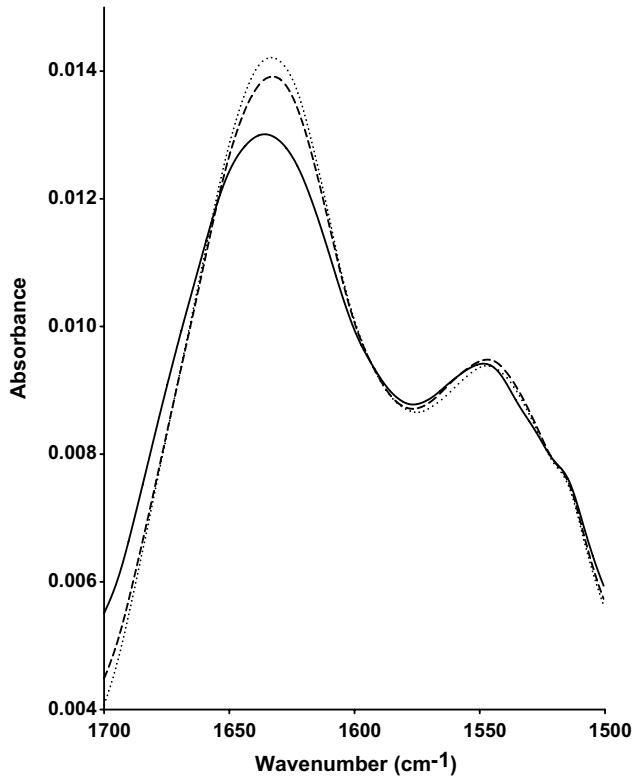

Fig. 3. Averaged mid-infrared spectra in the 1700–1500 cm^{-1} region for Gruyère PDO cheeses produced in lowlands (---), Gruyère PDO cheeses produced in highlands (···), and L'Etivaz PDO cheeses produced in L'Etivaz (—) regions.

by applying FDA to the first 10 PCs of the PCA applied to the 1700–1500 cm^{-1} region. The map defined by the discriminant factors 1 and 2 represented 100% of the total variance with discriminant factor 1 accounting for 57% (Fig. 2b). Considering discriminant factor 1, L'Etivaz PDO cheeses and highland Gruyère PDO cheeses exhibited negative scores, whereas Gruyère PDO cheeses produced in lowlands had positive score values. The discriminant factor 2 which took into account 43% of the total variance differentiated between L'Etivaz PDO cheeses and highland Gruyère PDO cheeses. The difference observed between cheeses produced at altitudes of 1100–1500 m and 1500–1850 m from those produced in lowland regions (800 m) could be due to the difference in the level of conjugated linoleic acid (CLA) which present bands around 1650 cm^{-1}, as has been reported by Meurens, Baeten, He Yan, Mignolet, and Larondelle (2005). CLA is an intermediate product in the biohydrogenation of linoleic acid and other poly-unsatured fatty acids from plants in the rumen of the cow (Campbell, Drake, & Larick, 2003; Chilliard, Ferlay, Mansbridge, & Doreau, 2000). The proportions of CLA in milk fat have been reported to be dependent on the altitude. Indeed, the CLA content increases with increase in grazing altitude of the cows, a trend which is related to the fodder composition. Collomb, Bütikofer, Sieber, Bosset, and Jeangros (2001) reported that the CLA content in milk collected in lowlands was about 0.81 g fatty acids 100 g^{-1} fat, whereas milks produced in mountains and highlands had 1.5 g and 2.18 g fatty acids 100 g^{-1} fat, respectively. The authors related the highest content of CLA in milk produced in the highlands to the intense biohydrogenation in the rumen of cows because the plants fed by the cows are likely to be rich in poly-unsaturated fatty acids (Collomb et al., 2001). Another explanation could arise from the effect of microbial association on the production of many compounds through proteolysis.

Correct classification of 80% was obtained, as shown in Table 2. This table shows that some misclassification occurred between L'Etivaz PDO, highland Gruyère PDO and lowland Gruyère PDO cheeses. The best classification was obtained for Gruyère PDO cheeses produced in lowlands since only four spectra were classified as belonging to highland Gruyère PDO cheeses. Again, the worst classification was obtained for L'Etivaz PDO cheeses since only 72.2% of correct classification was observed.

The region 1500–900 cm^{-1}, called the fingerprint region, refers to C–O and C–C stretching modes (1153–900 cm^{-1}). The bands observed at 1458, 1414 and 1234 cm^{-1} (Fig. 4) are due to bending modes of O–C–H, C–C–H and C–O–H as has been reported previously (Paradkar, Sivakesava, & Irudayaraj, 2003; Sivakesava & Irudayaraj, 2001). The strong band located at 1156 and 1095 could be related to P═O stretching (Bellamy, 1975). Indeed, this latter author reported that PO_2^- and PO_3^- compounds present bands in the 1323–1092 cm^{-1} and 1140 and 1055 cm^{-1} regions, respectively. The band located at 960 nm is related to unsaturated fatty acids, due to CH out-of-plane deformation (Meurens et al., 2005).

The FDA was then applied to the first 10 PCs of the PCA applied to the 1500–900 cm^{-1} region. The similarity map of the FDA allowed a good discrimination of the investigated cheeses. According to the discriminant factor 1, L'Etivaz PDO cheeses were observed mostly on the left, while the other cheeses were located mostly on the right. From Fig. 2c, the following results can be observed: (i) highland Gruyère PDO cheese samples exhibited mostly positive scores according to discriminant factor 1 and almost negative scores according to discriminant factor 2; (ii) lowland Gruyère PDO cheeses presented mostly positive scores according to discriminant factors 1 and 2 and (iii) L'Etivaz PDO cheese samples had mostly negative score values according to discriminant factors 1 and 2. In addition, a clear separation between the three cheese groups was observed on the map (Fig. 2c). These results suggest that the 1500–900 cm^{-1} region could be considered as a fingerprint, allowing a good identification of the geographical origin of cheeses. The present results were in good agreement with our previous findings reporting that the 1500–900 cm^{-1} spectral region is a fingerprint region that allowed a good discrimination of Emmental cheeses produced during winter time and of different geographic origins (Karoui et al., 2005).

The percentage of samples correctly classified by the FDA was 90.9% (Table 2). Considering L'Etivaz PDO cheeses, only two spectra were misclassified. Regarding highland Gruyère PDO cheeses, one spectrum was classified as belonging to L'Etivaz PDO cheese and another one to lowland Gruyère PDO cheese. Regarding Gruyère PDO cheeses produced in lowlands, three spectra were classified as highland Gruyère PDO cheeses.

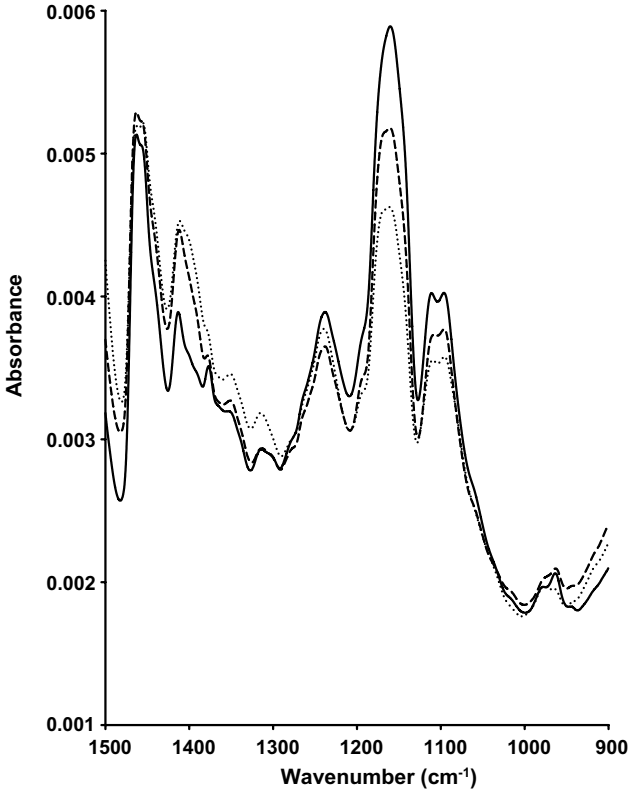

Fig. 4. Averaged mid-infrared spectra in the 1500–900 cm^{-1} region for Gruyère PDO cheeses produced in lowlands (---), Gruyère PDO cheeses produced in highlands (···), and L'Etivaz PDO cheeses produced in L'Etivaz (—) regions.

4. Conclusion

This preliminary study showed that the 3000–2800 cm^{-1} and 1500–900 cm^{-1} spectral regions, combined with chemometric tools, offer a promising approach to the authentication of the geographical origin of L'Etivaz PDO and Gruyère PDO cheeses. The current results have illustrated that the determination of the geographic origin of L'Etivaz and Gruyère PDO cheeses can be very well reproduced by using mid-infrared (MIR) spectroscopy and multivariate statistical analyses. Of course the proposed MIR spectroscopic method needs a considerable amount of preliminary work to establish the chemometric models based on samples of known geographical origin. In order to test the accuracy of the MIR for discriminating cheeses according to their geographical origin, the spectral data sets should be increased and then divided into two calibration and validation data sets, which will be done by our laboratory in the future. Once the classification models have been set, the technique allows a rapid determination of the geographic origin without particular sample preparation or special qualification of laboratory personnel.

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