

**Zeitschrift:** Mitteilungen aus Lebensmitteluntersuchungen und Hygiene = Travaux de chimie alimentaire et d'hygiène  
**Herausgeber:** Bundesamt für Gesundheit  
**Band:** 95 (2004)  
**Heft:** 5

**Artikel:** Geographic authenticity of Swiss cheeses : selected results for the food control laboratories and perspective for the future  
**Autor:** Pillonel, L. / Tabacchi, R. / Bosset, J.O.  
**DOI:** <https://doi.org/10.5169/seals-981835>

### **Nutzungsbedingungen**

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. [Siehe Rechtliche Hinweise.](#)

### **Conditions d'utilisation**

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. [Voir Informations légales.](#)

### **Terms of use**

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. [See Legal notice.](#)

**Download PDF:** 14.05.2025

**ETH-Bibliothek Zürich, E-Periodica, <https://www.e-periodica.ch>**

# Geographic authenticity of Swiss Cheeses: selected results for the food control laboratories and perspective for the future\*

L. Pillonel<sup>1</sup>, R. Tabacchi<sup>2</sup>, J.O. Bosset<sup>1</sup>

<sup>1</sup>Agroscope Liebefeld-Posieux (ALP), Berne

<sup>2</sup>University of Neuchâtel, Neuchâtel

Received 11 March 2004, accepted 26 August 2004

## Introduction

Authenticity of geographic origin is a well-known determinant of the market value of products such as wine, meat, olive oil or honey. All these products are manufactured and consumed in many countries and their prices are strongly dependent on their provenance. Both international market and price differences, make fraud possible and tempting. Several European cheeses meet these conditions too, e.g. Camembert, Emmental, Parmesan, Feta, Gouda, Cheddar. For many consumers, it does not matter where the milk or the cheese comes from, as long as the product satisfies the quality requirements. This may explain the lack of literature on the geographic origin of cheeses. However in certain regions, especially in Latin and Alpine countries, much importance is given to the origin of foods manufactured according to a long tradition and whose image is bound to a regional or national identity. Feta, Camembert, Parmigiano Reggiano, Emmental, Raclette are some examples of cheeses which are objects of an understandable regional pride and therefore need analytical tools to ensure their authenticity. Another cheese category is that of the PDO (Protected Denomination of Origin) cheeses. They are often produced on a smaller scale and their market significance tends to be limited to their regions of origin. Their regional boundaries are not national but are local borders strictly defined in the product specification in accordance with their PDO registration. PDO fraud often comes from regions close to the PDO area and not necessarily from abroad. A

\*Presented as a lecture at the 116<sup>th</sup> meeting of the Swiss Society of Food and Environmental Chemistry in Sion, 10 September 2004

PDO labels makes the product more attractive. Consumers show their will to support handmade products and traditional activities by paying prices up to 20% higher than those of standard products.

The present article summarises data on the authenticity of Emmentaler Switzerland which was published in ten papers (1–10) during a 3-year project. These data are presented in such a way as to be useful to official and private laboratories in cases of suspected fraud. Some preliminary results obtained for Raclette Suisse are also briefly summarised (11). Finally, the potential of the analytical approach for the authentication of other cheeses manufactured in Switzerland is discussed.

### Authenticity of Emmentaler Switzerland: a case study

Emmentaler Switzerland is manufactured in a large area which stretches across the Midlands of Switzerland, from Fribourg in the west to St-Gallen in the east. The milk processing technology is almost the same in all Emmental dairies. Around 99% of the cheese makers use cultures from ALP. The similarities between the manufacturing processes make it possible to use secondary indicators, i.e. those depending on the process technology, for authentication of the product. In contrast, primary indicators reveal only the milk used. The analytical methods and parameters used in this project are presented in table 1. Sampling procedure, sample origin,

Table 1  
Analytical parameters used in the project for the authentication of Emmentaler Switzerland and their approximate costs

Method/Parameter	Included parameters	Price (CHF)
Volatile short chain acids	Formic acid (C1) Acetic acid (C2) Propionic acid (C3) Butyric acid (C4) Pentanoic acid (C5) Hexanoic acid (C6)	110
Chloride	Cl	35
pH-value	pH	20
Total nitrogen	TN	70
Water soluble nitrogen	WSN	80
12%-TCA soluble nitrogen	TCA-SN	80
Enterococci	ENT	30
Obligate heteroferm. Lb.	OHL	45
<i>Lb. helveticus</i>	<i>Lb. helveticus</i>	100
Lactate	L-Lact D-Lact	100
Pyruvate	Pyru	65
Succinate	Succ	65
L-Leucin-aminopeptidase	LAP	55
Elements (AAS)	Cu, Mg, Na, Zn	150
Stable isotope ratio (IRMS)	$\delta^2\text{H}$ , $\delta^{13}\text{C}$ , $\delta^{15}\text{N}$ and $\delta^{34}\text{S}$	500



ripening time and analytical methods are described in detail elsewhere (9). In a recent study, discriminant analysis and artificial neural network analysis were used to classify 183 samples into seven regions of origin (10).

Using eleven variables (C3, pH, WSN, D-Lact, Succ, LAP, Cu,  $\delta^2\text{H}$ ,  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ ,  $\delta^{34}\text{S}$ ; see abbreviations in Table 1) in a discriminant analysis (DA), a 95 % correct classification was achieved in the jackknifed validation for all 7 origins of the cheese samples (*global analysis*). Five out of 70 Swiss Emmental were misclassified as German or Austrian cheeses, but no foreign sample was classified as Swiss.

A second approach was tested to optimise the discrimination between Emmentaler Switzerland and other cheeses. In this approach, the Swiss samples were compared pairwise with the samples from the other regions, a new DA being carried out for each of the six pairs Switzerland *vs.* another region (*pairwise analysis*). In each pair, 100 % correct classification was achieved using the corresponding groups of variables presented in Table 2. In a given case, all six models must be calculated. If an unknown sample is then assigned to the Swiss category in all six pair comparisons, it can be described as Emmentaler Switzerland with very high reliability. The drawback of both approaches is their price: the measurement of all variables costs approximately CHF 1300.

Table 2  
Variables used in the pairwise analyses

<i>CH vs</i>	<i>Austria</i>	<i>Germany</i>	<i>Finland</i>	<i>Savoie</i>	<i>Bretagne</i>	<i>Eastern-Central France</i>
C2				X		X
C3	X			X		X
pH		X				
TN		X				
OHL	X			X		
ENT		X		X		
D-lactate	X	X	X			
L-lactate	X					
Succinate	X	X				
Pyruvate		X	X			
LAP	X	X	X			
$\delta^2\text{H}$	X					
$\delta^{13}\text{C}$			X		X	X
$\delta^{15}\text{N}$	X			X	X	X
$\delta^{34}\text{S}$	X		X		X	

There are some robust variables, not influenced by the season, which are typical criteria for Switzerland. The content in *Lb helveticus* and LAP are the most important ones. *Lb helveticus* is no longer used as a cheese starter in Switzerland but is frequently used abroad to shorten the ripening time. Its presence can be detected by DNA analysis after polymerase chain reaction. As this analysis is not quantitative, the results were therefore separated into two groups with an arbitrary upper limit of

3 ng DNA/g for the lower group, the samples belonging to the group with the highest values being with high reliability of non-Swiss origin. (Table 3). The detection of *Lb helveticus* allowed exclusion of 77 % of the foreign samples from the Swiss category. This indicator will, of course, only be valid as long as this species is not reintroduced into the Emmentaler Switzerland manufacturing process. LAP is an enzyme with very low activities in Emmentaler Switzerland cheese. The highest value found in a Swiss sample was 4.3 µmol/min substrate (IU). All other values were below 3 IU. A threshold value of 10 IU was therefore set to ensure that all samples with higher activity could be confidently classified as non-Swiss. Half the foreign samples could be excluded in this manner. When 113 foreign samples were subjected to combined LAP and *Lb helveticus* analysis, only 15 % could still be misclassified as Swiss. Figure 1 summarises a possible way to efficiently determine the geographic origin of European Emmental cheese. Samples manufactured overseas will not be assigned correctly by the global analysis method because overseas regions were not sampled. However they can at least be identified as non-Swiss using the pairwise analysis method. The database for carrying out the DA is available from the authors.

Table 3

Distribution of the *Lb helveticus* DNA content using PCR and of the LAP activity in 183 Emmental samples

	Switzerland	Austria	Finland	Bretagne	Savoie	Eastern/ central France	Germany
<i>Lb helveticus</i>							
≤3 ng/g DNA	70	10	0	5	1	1	9
>3 ng/g DNA	0	5	12	14	31	11	14
LAP <sup>1</sup> (IU)							
≤10	70	15	0	2	21	5	14
>10	0	0	12	17	11	7	9

<sup>1</sup>L-Leucine-Aminopeptidase (µmol/min substrate, International Unit)

Fluorescence and mid-infrared spectra of the cheese samples were also recorded (12–15). In the validation set, 77 % of correct classification was obtained by combining 80 principal component (PC) scores from both spectroscopic methods (14). The introduction of some of these PC scores in the discriminant analyses mentioned above did not significantly improve the classification power of the model (data not shown). These spectroscopic methods were therefore not retained in the authentication procedure.



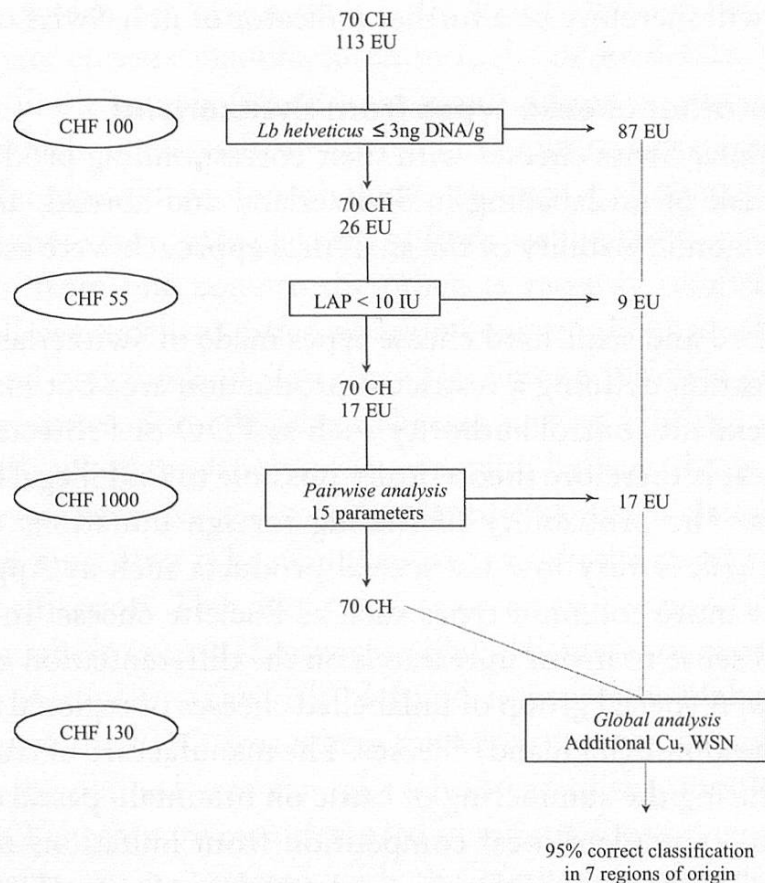


Figure 1 Flow chart for the determination of the geographic origin of European Emmental cheese.

### Authenticity of Raclette Suisse: a preliminary study

Raclette Suisse is surely the second most likely Swiss cheese to be substituted with cheaper imitations. Germany, Austria and especially France manufacture Raclette cheese, partly at lower cost, and export it to Switzerland. Unlike Emmental, the manufacturing conditions of Raclette vary considerably, even within Switzerland. Parameters which may vary between cheese dairies include the type of starter cultures, milk heat treatment (raw or pasteurised) and smear cultures. The use of secondary indicators was therefore less important. However, additives such as natamycin and lysozyme provide very good markers for discriminating between Swiss and foreign Raclette cheeses. The "Raclette Suisse" organisation voluntarily banned the use of such additives to offer a 100 % natural product to consumers. Natamycin or lysozyme was detected in all French samples investigated. However, it is not possible to assume that all foreign samples will contain additives. Primary indicators such as the stable isotope ratios  $^2\text{H}/^1\text{H}$ ,  $^{13}\text{C}/^{12}\text{C}$ ,  $^{15}\text{N}/^{14}\text{N}$  and  $^{34}\text{S}/^{32}\text{S}$  were also investigated. They allowed perfect discrimination between cheeses originating from Switzerland, northwest France and eastern/central France (Figure 2). More details on this preliminary study are given elsewhere (11). The organisation Raclette

Suisse only just decided to also ban smear colorant from their products. The presence of colorant will therefore be a further indicator of non-Swiss origin.

### Perspectives for other cheese types from Switzerland

The most popular Swiss cheeses with their corresponding production are listed in Table 4. The risk of mislabelling in Switzerland and abroad, and the technical feasibility and economic viability of the analytical approach were estimated for each cheese type.

Most of the hard and semi-hard cheese types made in Switzerland are subject to a product specification defining a restricted production area but may not carry the label of an independent control authority such as PDO or Protected Geographical Indication (PGI). It is therefore theoretically possible to find illegal Swiss imitations of such products. The probability of finding foreign imitations depends on the cheese type. The risk is very low for special products such as Appenzeller cheese and very high for more common types such as Raclette cheese. In the latter high-risk case it makes sense to invest in research on the differentiation of Swiss samples from foreign ones. A special group of unlabelled cheeses of regional or even national importance are the alpine (highland) cheeses. The manufacture of true alpine cheeses is only allowed during the summering of cattle on mountain pastures and they may well be subject to fraudulent local competition from imitations made from milk obtained in the valley. Alpine cheeses are very popular in Switzerland and command premium prices because they are made by hand in difficult conditions.

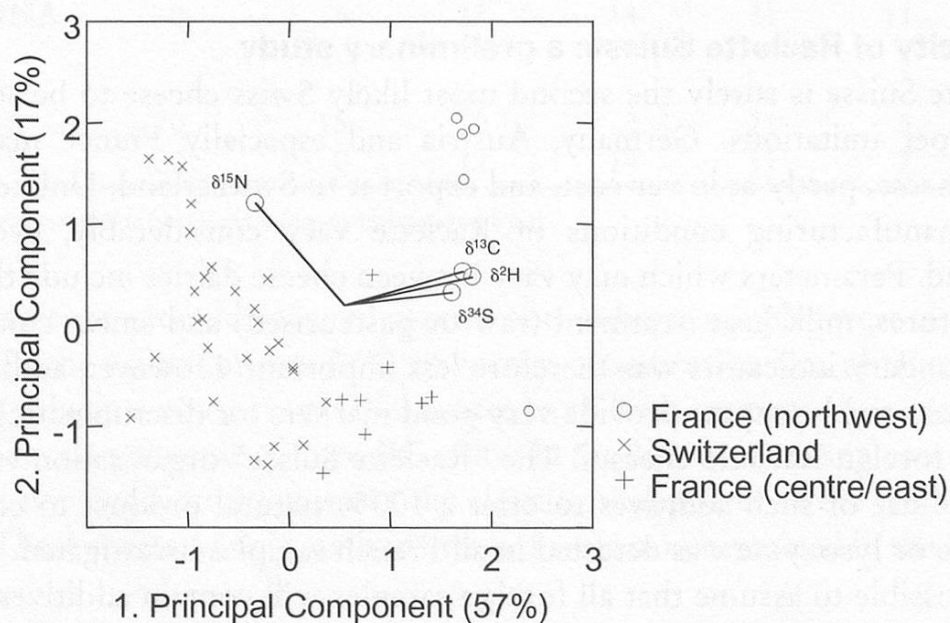


Figure 2 Scores of principal component analysis using the factors  $\delta^2\text{H}$ ,  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$  and  $\delta^{34}\text{S}$ . Discrimination between Raclette cheese originating from Switzerland and two regions of France.



As these cheeses are sold almost exclusively by individuals or small local stores it is difficult to screen for origin on a large scale. There are chemical indicators which differentiate cheeses manufactured in high- or lowlands. Terpenes (16–18) and conjugated linoleic acids (19–20) are good indicators of the diversity of the botanical flora which increases from lowland to mountain pastures. However, local or regional differences in geomorphology, geology and climate affect the flora, therefore use of these surrogate markers of flora are limited to cases with large altitude differences, from one zone to the other. A recently published fluorescence-based method allows excellent differentiation between the three cheese types L'Etivaz, and highland and lowland Gruyère (21). Smoke residues provide additional markers of provenance. Some highland cheeses such as L'Etivaz must be made on an open fire with wood, and polycyclic aromatic hydrocarbons contained in the dissolved smoke are sensitive and specific identifiers of such cheeses (22).

PDO cheeses must always be manufactured within the restricted area defined in the product specification. This may range from a small region (L'Etivaz, Vacherin Mont d'Or) to a whole canton (Formaggio d'alpe ticinese) or even an area covering several cantons (Gruyère). The risk of fraud is generally highest in the regions directly adjacent to the PDO area where the know-how exists and cheese factories located outside the defined area can take advantage of the popularity of the label. Most of the PDO cheeses are manufactured in mountainous regions and one aspect of the authenticity can be covered with the methods mentioned previously for alpine cheeses. For imitations manufactured at similar altitudes but outside the authentic zone, analytical methods will generally be useless. In the extreme case of Gruyère, the PDO area is inhomogeneous and scattered over 11 cantons so that it would seem impossible to prove authentic provenance of Gruyère cheese by laboratory analysis. Nevertheless, tools are urgently needed to allow improved monitoring of the Gruyère market. It is clear from the discrepancy between the quantity of cheese sold and the amount produced that a significant number of Gruyère cheeses are not manufactured in full accordance to the PDO agreements (personal communication). Among the PDO cheeses, only Sbrinz shows a high risk of mislabelled foreign imitations, due to the international character of Parmesan-like cheeses. Parmigiano Reggiano and Grana Padano are not significant competitors as they are almost as expensive as Sbrinz, but it is quite easy to replace Sbrinz with any cheap extra-hard cheese when sold in a grated form. Two PDO candidates may also suffer from similar international competition, i.e. Raclette du Valais and Emmentaler Switzerland. The latter has been investigated in detail in previous studies and the case of Raclette du Valais is more or less identical to the one of Raclette Suisse. If a PDO label is granted to the Raclette du Valais, it will be necessary to differentiate the two Swiss types of Raclette. This is likely to be difficult. One approach could be to identify the method used to heat-treat the milk because Raclette du Valais must be made from raw milk whereas pasteurised milk is often used for Raclette Suisse.



Table 4  
Main cheese types from Switzerland and their risks toward mislabelling

<i>Cheese type</i>	<i>Annual Production Tons</i>	<i>Risk</i>	<i>In Switzerland Feasibility<sup>1</sup></i>	<i>Needs/cost<sup>1</sup></i>	<i>Risk</i>	<i>Abroad Feasibility<sup>1</sup></i>	<i>Needs/cost<sup>1</sup></i>
<b>No label<sup>3</sup></b>							
Alpine cheese	3000	High	++/0 <sup>2</sup>	+	Low	++/0	0
Tilsiter	5977	Medium	0	0	High	+	+
Appenzeller	7912	Medium	0	0	No	-	-
Raclette Suisse	12125	Medium	0	0	High	++	++
<b>PDO</b>							
L'Etivaz	320	High	++/0 <sup>2</sup>	+	No	-	-
Formaggio d'alpe ticinese	400	Medium	++	+	Medium	+	0
Vacherin Mont d'Or	534	Medium	0	0	Medium	0	0
Tête de Moine	1461	Medium	0	0	No	-	-
Sbrinz	2475	Medium	0	0	High	++	++
Gruyère	24965	High	0	+	Low	+	0
<b>PDO candidates</b>							
Raclette du Valais	2013	High	+	+	High	++	++
Emmental	35533	Low	0	0	High	++	++
<b>PGI-candidate</b>							
Vacherin Fribourgeois	2106	Medium	0	0	No	-	-

<sup>1</sup>“++”=good; “+”=fair; “0”=poor; “-”=not to be considered

<sup>2</sup>“++” if produced in lowland, “0” if produced in highland but not according to the requirements

<sup>3</sup>These cheese types have product specific labels which are not controlled by an independent authority

In a last category, Vacherin Fribourgeois is candidate for the PGI label. The risk of imitation by non-Swiss manufacturers is very low for this very typical product and the major risk comes from the regions close to the authorised production area.

### **Acknowledgement**

The authors thank the Swiss Federal Office of Public Health for its financial and logistical support of the project as well as G. Urbach and G. Gremaud for reviewing the publication.

### **Summary**

The main conclusions of a 3-year project on the authenticity of Emmental cheese are presented. The discrimination between Emmental cheese originating from seven European regions (183 samples from Switzerland, Savoie, Bretagne, France East-Central, southern Germany, Austria and Finland) was correct in 95 % of cases by a global analysis (all regions considered simultaneously). The Emmentaler Switzerland could be identified in 100 % of cases by pairwise analysis (Swiss Emmental compared to one foreign region at a time). The main drawback of these analytical procedures is their elevated cost (approx. 1300 CHF/sample). A preliminary study on the authenticity of Raclette Suisse showed the potential of stable isotope ratios ( $\delta^2\text{H}$ ,  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ ) to discriminate between Raclette Suisse and Raclette cheese manufactured in France. Finally the authors present an evaluation of the risks of mislabelling and of the feasibility and cost/benefit ratios of analysis of the main cheese types made in Switzerland. It shows that only a few cheese types such as Sbrinz and Raclette du Valais would present analytical cost/benefit ratios which would justify laboratory research to develop the analytical methods.

### **Zusammenfassung**

Die wichtigsten Schlussfolgerungen eines dreijährigen Forschungsprojektes über die Authentizität von Emmentalerkäse werden vorgestellt. Die Diskriminierung von Emmentalerkäse aus sieben europäischen Regionen (insgesamt 183 Proben aus der Schweiz, Frankreich-Savoyen, Frankreich-Bretagne, östliches Zentralfrankreich, Süddeutschland, Österreich und Finnland) war zu 95 % korrekt bei einer globalen Analyse (alle Regionen gleichzeitig betrachtet). Emmentaler Switzerland wurde in einer paarweisen Analyse zu 100 % richtig erkannt (Schweizer Emmentaler nacheinander Emmentalerkäse aus einer anderen europäischen Region gegenübergestellt). Der grösste Nachteil dieses Modellansatzes ist dessen hoher Preis (ca. 1300 CHF/Probe). Daneben zeigte eine Vorstudie über die Authentizität von Raclette Suisse das Potenzial der stabilen Isotopenverhältnisse ( $\delta^2\text{H}$ ,  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ ,  $\delta^{34}\text{S}$ ) zur Unterscheidung von Raclette Suisse und eines in Frankreich hergestellten Raclettekäses auf. Schliesslich wird eine Risikoeinschätzung einer falschen Kennzeichnung, der analytischen Machbarkeit und des Kosten/Nutzen Verhältnisses einer Herkunftsbestimmung für die wichtigsten in der Schweiz hergestellten Käse-



sorten angegeben. Es scheint, dass nur wenige Käsesorten wie Sbrinz oder Walliser Raclettekäse ein ausreichend günstiges Kosten/Nutzen Verhältnis haben, um die Erforschung und Entwicklung analytischer Methoden zu rechtfertigen.

## Résumé

Ce travail présente les principales conclusions d'un projet de recherche de trois ans sur l'authenticité du fromage Emmental. La discrimination de fromages d'Emmental provenant de sept régions européennes (183 échantillons de Suisse, Savoie, Bretagne, France est-centrale, sud de l'Allemagne, Autriche et Finlande) a été possible à 95 % par une analyse globale (toutes les régions considérées simultanément). L'Emmentaler Switzerland a même pu être reconnu à 100 % dans une analyse par paires (Emmental Suisse opposé aux Emmental d'une région étrangère à la fois). Le principal inconvénient de ces modèles est leur prix élevé (env. 1300 CHF/échantillon). En complément, une étude préliminaire effectuée sur l'authenticité du Raclette Suisse a mis en évidence le potentiel des rapports d'isotopes stables ( $\delta^2\text{H}$ ,  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ ,  $\delta^{34}\text{S}$ ) pour discriminer le Raclette Suisse et le fromage à raclette produit en France. Finalement une estimation des risques de fausse déclaration, de la faisabilité analytique et des rapports coûts/profit pour les principaux fromages suisses est présentée. Elle montre que seules quelques sortes de fromage comme le Sbrinz ou le Raclette du Valais présenteraient des rapports coûts/profit suffisamment bas pour justifier une investigation analytique.

## Key words

Authenticity, Traceability, Emmental cheese, Raclette cheese, geographic origin

## References

- 1 Bosset J.O.: Authenticity of Emmental cheese Switzerland. *Mitt. Lebensm. Hyg.* **92**, 328–332 (2001)
- 2 Pillonel L., Badertscher R., Bütikofer U., Casey M., Dalla Torre M., Lavanchy P., Meyer J., Tabacchi R. and Bosset J.O.: Analytical methods for the determination of the geographic origin of Emmental cheese. Main framework of the project; chemical, biochemical, microbiological, colour and sensory analyses. *Eur. Food Res. Technol.* **215**, 260–267 (2002)
- 3 Pillonel L., Collomb M., Tabacchi R. and Bosset J.O.: Analytical methods for the determination of the geographic origin of Emmental cheese. Free fatty acids, triglycerides and fatty acid composition of cheese fat. *Mitt. Lebensm. Hyg.* **93**, 217–231 (2002)
- 4 Pillonel L., Albrecht B., Badertscher R., Chamba J.F., Bütikofer U., Tabacchi R. and Bosset J.O.: Analytical methods for the determination of the geographic origin of Emmental cheese. Parameters of proteolysis and rheology. *Italian J. Food Sci.* **15**, 49–62 (2003)
- 5 Pillonel L., Luginbühl W., Picque D., Schaller E., Tabacchi R. and Bosset J.O.: Analytical methods for the determination of the geographic origin of Emmental cheese. Mid- and Near-Infrared spectroscopy. *Eur. Food Res. Technol.* **216**, 174–178 (2003)
- 6 Pillonel L., Ampuero S., Tabacchi R. and Bosset J.O.: Analytical methods for the determination of the geographic origin of Emmental cheese. Volatile compounds by GC/MS-FID and electronic nose. *Eur. Food Res. Technol.* **216**, 179–183 (2003)



- 7 Pillonel L., Badertscher R., Froideveaux P., Haberhauer G., Jakob A., Pfammatter E., Piantini U., Rossmann A., Tabacchi R. and Bosset J.O.: Analytical methods for the determination of the geographic origin of Emmental cheese. Stable isotope ratios, major, trace and radioactive elements. *Lebensm.-Wiss u. -Technol.* **36**, 615–623 (2003)
- 8 Pillonel L. and Bosset J.O.: Analytical methods for the determination of the geographic origin of Emmental cheese. Summary of a screening study. *Mitt. Lebensm. Hyg.* **94**, 60–69 (2003)
- 9 Pillonel L., Badertscher R., Casey M., Meyer J., Rossmann A., Tabacchi R. and Bosset J.O.: Geographic origin of European Emmental cheese. 1. Characterisation and descriptive statistics. *Int. Dairy J.* (in press)
- 10 Pillonel L., Bütikofer U., Tabacchi R. and Bosset J.O.: Geographic origin of European Emmental cheese. 2. Use of discriminant analysis and artificial neural network for classification purposes. *Int. Dairy J.* (submitted)
- 11 Pillonel L., Bütikofer U., Rossmann A., Tabacchi R. and Bosset J.O.: Analytical methods for the detection of adulteration and mislabelling of Raclette Suisse® and Fontina PDO cheese. *Mitt. Lebensm. Hyg.* **95**, 489–502 (2004)
- 12 Karoui R., Dufour E., Pillonel L., Picque D., Cattenoz T. and Bosset J.O.: Fluorescence and infrared spectroscopies: a tool for the determination of the geographic origin of Emmental cheeses manufactured during summer. *Le Lait*, **84**, 359–374 (2004)
- 13 Karoui R., Dufour E., Pillonel L., Picque D., Cattenoz T. and Bosset J.O.: Determining the geographic origin of Emmental cheeses produced during winter and summer using a technique based on the concatenation of MIR and fluorescence spectroscopic data. *Eur. J. Food Res. Technol.* **219**, 184–189 (2004)
- 14 Karoui R., Bosset J.O., Mazerolles G., Kulmyrzaev A. and Dufour E.: Monitoring the geographic origin of both experimental French Jura hard cheeses and Swiss Gruyère and l'Etivaz PDO cheeses using mid-infrared and fluorescence spectroscopies. *Int. Dairy J.* (in press)
- 15 Karoui R., Dufour E., Pillonel L., Schaller E., Picque D., Cattenoz T. and Bosset J.O.: Determination of the geographic origin of Emmental cheeses by combining infrared and fluorescence spectroscopies. *Int. Dairy J.* (in press)
- 16 Dumont J.P. and Adda J.: Occurrence of sesquiterpenes in mountain cheese volatiles. *J. Agric. Food Chem.* **26**, 364–367 (1978)
- 17 Mariaca R.G., Berger T.F.H., Gauch R., Imhof M.I., Jeangros B. and Bosset J.O.: Occurrence of volatile mono- and sesquiterpenoids in highland and lowland plant species as possible precursors for flavor compounds in milk and dairy products. *J. Agric. Food Chem.* **45**, 4423–4434 (1997)
- 18 Viallon C., Martin B., Verdier-Metz I., Pradel P., Garel J.P., Coulon J.B. and Berdagué J.L.: Transfer of monoterpenes and sesquiterpenes from forages into milk fat. *Lait* **80**, 635–641 (2000)
- 19 Collomb M., Bütikofer U., Sieber R., Jeangros B. and Bosset J.O.: Composition of fatty acids in cow's milk fat produced in the lowlands, mountains and highlands of Switzerland using high-resolution gas chromatography. *Int. Dairy J.* **12**, 649–659 (2002)
- 20 Lavillonnière F., Martin J.C., Bounoux P. and Sébédio J.L.: Analysis of conjugated linoleic acid isomers and content in French cheeses. *J. Amer. Oil Chemists Soc.* **75**, 343–352 (1998)
- 21 Dufour E., Karoui R. et Bosset J.O.: Utilisation de la fluorescence frontale intrinsèque de fromages de type L'Etivaz AOC et Gruyère AOC pour reconnaître leur origine géographique. *Trav. chim. aliment. hyg.*, **94**, 379–393 (2003)
- 22 Bosset J.O., Bütikofer U., Dafflon O., Koch H., Scheurer-Simonet L. et Sieber R.: Teneur en hydrocarbures aromatiques polycycliques de fromages avec et sans flaveur de fumée. *Sci. Aliments*, **18**, 347–359 (1998)

Corresponding author: Dr. Jacques-Olivier Bosset, Chemistry & Physic unit, Agroscope Liebefeld-Posieux (ALP), CH-3003 Berne,  
E-mail: [jacques-olivier.bosset@alp.admin.ch](mailto:jacques-olivier.bosset@alp.admin.ch)