Analytical methods for the determination of the geographic origin of Emmentaler cheese. Main framework of the project; chemical, biochemical, microbiological, colour and sensory analyses

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Abstract Emmentaler is a hard cheese produced and consumed in many countries. The authenticity of this cheese variety is becoming a matter of national importance with the imminent opening of the cheese market in Switzerland and the introduction of the PDO label for the Emmentaler Switzerland™. This paper is the first in a series reporting the search for parameters that make possible a geographic discrimination of Emmentalers. Twenty Emmentaler cheese samples from six regions in Europe (one from Switzerland, two from France, one from Austria, one from Germany and one from Finland) were considered. In this paper, chemical, biochemical, microbiological, colour and sensory parameters were investigated leading to the following preliminary results. The presence of *Lb. helveticus* seemed to be a good indicator of an origin other than Swiss. The concentration of enterococci, facultative and obligate heterofermentative lactobacilli and salt tolerant bacteria was significantly lower in Emmentaler Switzerland™ than in the foreign cheeses. Chemical parameters such as fat content and pH value as well as biochemical parameters such as L- and D-lactate and pyruvate allowed us to partially discriminate between the regions when these data were combined by principal component analysis. The colour of the body also showed significant differences.

Keywords Emmentaler · Swiss cheese · Authenticity · Geographic origin · Traceability · PDO

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Introduction

Determination of food authenticity and geographic origin is a crucial issue in food quality control and safety. The 5th Food Authenticity and Security International Symposium, June 9–11, 1999 in La Baule (F) [1] highlighted the fact that food misrepresentations and adulterations are distinguished both by their abundance and their variety. Well-known adulterated products are wine [2] and olive oil [3, 4] for which several methods of authentication have already been developed. But adulterations are also known for dairy products. The geographic origin of butter [5] and milk [6], the addition of cow's milk to ewe's or goat's milk or other dairy products [7] and the use of added whey solids or processed cheeses in grated cheese [8] have already been investigated. A less common but potential type of misrepresentation may concern the geographic origin of cheese.

The originality of a cheese depends on several factors such as milk and cheesemaking procedures (incl. microbiology and technology), which are both dependent on the geographic origin. The climate, geology, forage and breed itself influence the milk quality while local, regional or national traditions influence the cheesemaking. The determination of origin is a key component of Protected Designation of Origin (PDO) products and, where industrial copies exist, of goods manufactured by a traditional method.

The imminent opening of the Swiss cheese market will unquestionably allow massive quantities of foreign cheeses to be imported. Moreover, Emment(h)al(er) cheese, often called "Swiss cheese," is the example par excellence of a cheese variety that is widespread and very popular in many countries. However, less than 10% of the European production is manufactured in Switzerland (Table 1) [9]. Bordering countries such as France and Germany together produce more than half of the European manufacture and at lower cost. Therefore the problem of the analytical authentication of Emmentaler cheese will be a major challenge in the near or more dis-

Table 1 Production level (1997) of Emmentaler cheese in several countries

Country	Production (t/y)
France	275 000
Netherlands	89 400
Germany	88 300
Switzerland	45 000
Sweden	28 400
Finland	26 400
Austria	12 800
Denmark	6 600
Ireland	5 000

tant future both for people responsible for suppression of misrepresentations as well as producers of Emmentaler. This consideration is not only true for Switzerland but also for every region in Europe producing a cheese type in a traditional and more expensive way than in large industrial plants.

Many investigations have been carried out to characterise the Emmentaler Switzerland™ [10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21], the German [22, 23, 24, 25] or the French Emmentaler [26, 27], but few are dedicated to the geographic origin of a cheese sample. Rohm [28] carried out a regional classification of Emmentaler cheese in western Austria based on some chemical parameters. Bosset et al. [29] and Collomb et al. [30] found significant differences in the amount of terpenes and conjugated linoleic acids in Gruyère cheese between a lowland and an highland production zone. Manca et al [31] could distinguish between Pecorino Sardo, Siciliano and Pugliese using stable isotope ratios and free amino acids ratios. Grappin et al. [32] could correctly discriminate the origin of 20 Comté cheeses made in five different cheese plants according to some physico-chemical variables, microbial counts and sensory characteristics.

Sensory analyses mainly focus on the characterisation of a cheese type or on the description of the evolution during ripening. However, such analyses have been applied to differentiate Parmigiano-Reggiano [33, 34] and Grana Padano [35] from their imitations. Muir et al. [36] showed differences in flavour and texture between raw milk farmhouse Cheddar and Cheddar from a factory made from pasteurised milk. However no differences were found between the different countries of production. The French Emmentaler "Grand-Cru" was characterised by a more intense flavour including the terms fruity, salted, pungent and sweet and by a weaker rancid odour than from the other French Emmentaler [27]. Monnet et al. [37] positively correlated the type of soil (edaphic parameters) with the sensory quality of 20 Comté cheeses from the French Jura. The influence of altitude on Abondance cheese flavour was investigated by Bugaud et al. [38]. Furthermore, no correlation seems yet to have been established between the origin of a cheese and its microbial flora.

Therefore, the present study aims to evaluate the potential of a large variety of analytical methods for determining the geographic origin of an Emmentaler cheese. This first paper in a series deals with chemical, biochemical, microbiological, sensory and colour analyses. The next publications will deal with further analytical techniques: compounds resulting from the proteolysis and rheology; infrared spectroscopy; detailed composition of fat (free fatty acids, fatty acid composition and triglycerides); volatile compounds using GC/MS and electronic nose; as well as the inorganic composition of the cheeses (major and trace elements, radioactivity, and stable isotope ratios). At the end, all the above mentioned methods will be compared and the best set of methods will be selected for a follow-up of the project, which also takes into account their cost, rapidity and robustness. Using these methods, a larger number of samples will then be investigated in the future in order i) to obtain a cheese fingerprint from each region of production, ii) to allow the cheeses to be easily classified according to their origin and iii) to build up a corresponding database.

Materials and methods

Origin and selection of the cheese samples

Table 2 summarises the geographic origin, the date of manufacture and the ripening period of the 20 Emmentaler cheeses selected from six regions (Fig. 1). Three samples were chosen from each region (except for Switzerland with six and Finland with two samples). Three regions were adjacent to Switzerland (Savoie (F), Allgäu (D), Vorarlberg (A)). The geographic and climatic proximity of these regions, as well as the similar technologies used, allows

Table 2 Origin and ripening time of the 20 cheese samples investigated

Samples	Region (country)	Date of fabrication	Ripening time (month)
AL 1–3	Allgäu (D)	20.12.2000	4
BR 1–3	Bretagne (F)	16.02.2001	2.5
CH 1–6	Switzerland (CH)	26.12.2000	4
FI 1–2	Middle Finland (FI)	07.02.2001	3
SA 1–3	Savoie (F)	08.02.2001	3
VO 1–3	Vorarlberg (A)	02.02.2001	3

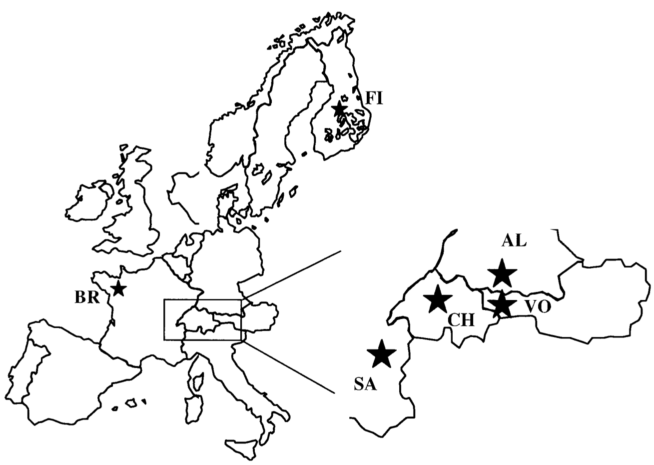

Fig. 1 Sampling areas

one to test the robustness of the methods (intra-variability within a region vs. inter-variability between regions). The two remaining regions (Bretagne (F) and the central region of Finland) are quite distant from Switzerland. Taken together, these six regions account for approx. 77% of European Emmentaler production. The samples were supplied directly by the cheese factories (Austria, Finland, Switzerland) or were collected with the help of a national dairy research centre (France and Germany). The samples (approx. 8 kg) were supplied as sectors or slices of a whole block. The first 2 cm from the rind were discarded. For analyses, where grated cheese was required, portions were cut across the whole block (height) to take into account concentration gradients. The cheeses investigated were chosen at ages between 2.5–4 months of ripening, which corresponds to that sold in stores. For most regions, this corresponds to the average ripening time. In Switzerland, a 4-month old Emmentaler is considered very young. Indeed, an important part of the market is made up of Emmentaler over 8 months old. We limited, however, our investigation to young Emmentaler Switzerland™ and the corresponding foreign samples since the risk of confusion is highest with young cheeses.

Chemical and biochemical analyses

The samples were kept frozen until the following analyses were performed: water gravimetric [39], fat according to Gerber van Gulik [40], total nitrogen according to Kjeldahl [41], sodium chloride potentiometric with a silver electrode [42], L- and D-lactate, citrate, succinate and pyruvate with an enzymatic test kit after extraction [43], volatile organic acids [44], alkaline phosphatase photometric with *p*-nitrophenylphosphate as substrate [45], vitamins A and E using HPLC [46]. The pH-value was determined at room temperature using a penetrometric electrode (Mettler-Toledo, no. 104063123).

Microbial analyses

Fresh samples were analysed except for *Lb. helveticus*. For the latter, samples were frozen. The following microorganisms were determined: enterococci (ECOC) [47], propionic acid bacteria (PAB) [48], facultative heterofermentative lactobacilli (FHL) [49], obligate heterofermentative lactobacilli (OHL) [49], salt tolerant bacteria (STB) [50]. The occurrence of *Lb. helveticus* was investigated by polymerase chain reaction (PCR) according to a method not yet published.

Sensory analyses

Fresh samples were analysed according to a protocol described in [51]. The samples were evaluated by the accredited sensory panel of the FAM in four series: Three series with two samples from each region (except Finland) and one series with the two Finnish Emmentalers.

Colour analyses

After storing the cheese samples at 15±0.5 °C overnight and preparing cheese slices (height >30 mm), tristimulus reflectance measurements (each one made twice) were carried out with a Hunterlab D 25-D-2 Optical Head in the system according to Hunter; L=brightness (L=0: black; L=100: white); a=green-red component (a<0: green; a>0: red); b=blue-yellow component (b<0: blue; b>0: yellow). The method has been described by Bosset et al. [52]

Statistical analyses

The decimal logarithm of the microbiological counts was used for the calculations. The averages and standard deviations were calculated for each parameters. Descriptive statistics, analysis of variance (ANOVA), pairwise comparisons of mean values with Fisher's LSD test, principal component analysis (PCA) and correlation test were performed with Systat for Windows version 9.0 (SPSS Inc., Chicago, IL). The correlation coefficients were always calculated using the individual values of each region.

Results and discussions

Chemical composition

The chemical compositions of the 20 Emmentaler samples from the six regions are listed in Tables 3 and 4. "Vorarlberg" showed a significantly higher fat content than all others except for "Allgäu." "Bretagne" had the lowest fat content. "Allgäu" contained significantly more sodium chloride than "Switzerland," "Savoie" and "Vorarlberg." "Savoie" showed the highest p*H*-value, "Bretagne" the lowest. No differences were found in the vitamin content.

The results of alkaline phosphatase (AP) were very surprising. This enzyme is denatured by pasteurisation and therefore used as indicator of milk heat treatment. Though the Swiss factories produce Emmentaler from raw milk, it showed the lowest AP values. On the contrary, in Finland, where thermisation is applied and the curd is heated at the highest temperature of all regions (54 °C), the samples nevertheless showed a high AP activity. The broad activity range of this enzyme may be explained as follows: i) the native milk may contain different AP concentrations (up to 30% relative standard deviation), ii) the duration of scalding, the temperature at which the coagulum is transferred into the moulds and the size of the block also influence the degree of AP denaturation, iii) some micro-organisms are known to produce significant amount of AP [53] and iv) the presence of a strong gradient within the block. From the zone under the rind to the core of the block, the activity of the enzyme can drop off by several orders of magnitude [54]. This gradient is due to the slower cooling inside the cheese. Moreover, the reliability of the measurements decreases strongly with the age of the cheese. Finally the value of these results must be put into perspective because the position of the samples within the block were not rigorously the same. Therefore, the alkaline phosphatase activity can be an appropriate method for the characterisation of heat treatment only under the strict condition that the sample to be investigated is located just below the rind.

"Finland" no longer contained L- and D-lactate nor pyruvate. This fact indicates a very high activity of propionic acid bacteria. "Allgäu," "Bretagne" and "Vorarlberg" had the highest lactate concentrations, which indicates a lower propionic fermentation. The concentrations of propionic acid and L+D-lactate were highly negatively correlated (r=–0.94). "Bretagne" showed a high average citrate concentration due to one sample (BR3) containing 7.7 mmol/kg. Citrate is normally catabolised to formate by facultative heterofermentative bacteria (FHL). How-

Table 3 Gross chemical composition, pH-value, alkaline phosphatase and vitamins in the 20 Emmentaler cheese samples investigated

Region (n=)	ANOVA	AL (3)		BR (3)		CH (6)		FI (2)		SA (3)		VO (3)	
		x	s_x	**x**	s_x	**x**	s_x	**x**	s_x	**x**	s_x	**x**	s
Total nitrogen (g/kg)	*	**44.1**^{AB}	1.8	**45.0**^{AB}	0.72	**44.4**^{AB}	0.85	**45.5**^{AB}	1.3	**46.2**^{A}	0.77	**42.9**^{B}	1.6
Fat (g/kg)	***	**322**^{AB}	15	**300**^{C}	7.9	**318**^{B}	7.4	**307**^{BC}	2.5	**306**^{BC}	7.7	**342**^{A}	6.3
Fat in dry matter (g/kg)	**	**494**^{AB}	19	**473**^{B}	3.6	**494**^{B}	9.5	**483**^{B}	4.1	**474**^{B}	11	**520**^{A}	13
Water (g/kg)	*	**346**^{AB}	9.2	**366**^{AB}	12	**355**^{AB}	6.8	**363**^{AB}	11	**354**^{AB}	4.9	**341**^{B}	9.2
Water in fat-free matter (g/kg)	ns	**511**	11	**523**	11	**521**	8.4	**525**	14	**511**	7.1	**519**	16
Sodium chloride (g/kg)	**	**6.43**^{A}	0.83	**4.37**^{AB}	1.58	**3.43**^{B}	0.41	**5.60**^{AB}	1.13	**3.60**^{B}	1.04	**3.57**^{B}	0.98
pH-value	***	**5.73**^{AB}	0.05	**5.57**^{C}	0.05	**5.63**^{BC}	0.06	**5.73**^{AB}	0.02	**5.79**^{A}	0.08	**5.65**^{BC}	0.03
Alkaline phosphatase (IU)	ns	**1700**	1834	**226**	176	**29**	47	**1500**	675	**945**	660	**211**	216
Vitamin A (IE/kg)	ns	**6179**	1274	**6936**	1048	**6950**	1391	**6318**	181	**5992**	607	**5534**	719
Vitamin E (mg/kg)	ns	**4.00**	0.39	**3.32**	0.49	**4.13**	0.60	**4.01**	0.34	**3.81**	0.62	**4.48**	0.75

x=mean value; s_x=standard deviation; ANOVA: ns=not significant, *p=0.05, **p=0.01, ***p=0.001
Production sites: A>B>C>D (=significantly different contents p=0.01) or AB=A and B overlap by using an univariate discriminant analysis

AL=Allgäu, BR=Bretagne, CH=Switzerland, FI=Finland, SA=Savoie, VO=Vorarlberg
n=number of samples

Table 4 Organic acids content of the 20 Emmentaler cheese samples investigated

Region (n=) (mmol/kg)	ANOVA	AL (3)		BR (3)		CH (6)		FI (2)		SA (3)		VO (3)	
		x	s_x	**x**	s_x	**x**	s_x	**x**	s_x	**x**	s_x	**x**	s
L-Lactate	***	**45**^{A}	13	**47**^{A}	15	**23.8**^{B}	4.4	**0.00**^{C}	0.00	**27.0**^{AB}	9.5	**45.7**^{A}	4.5
D-Lactate	***	**59**^{A}	29	**48.7**^{AB}	7.6	**21.8**^{CD}	6.2	**0.00**^{D}	0.00	**24.3**^{BCD}	9.9	**35.0**^{ABC}	2.7
L/D ratio (no unit)	ns	**0.87**	0.31	**0.96**	0.19	**1.13**	0.21	**–**	–	**1.13**	0.10	**1.31**	0.18
Citrate	ns	**0.10**	0.10	**2.6**	4.4	**0.22**	0.48	**0.05**	0.07	**0.13**	0.06	**0.07**	0.12
Succinate	***	**6.7**^{ABC}	4.4	**8.6**^{AB}	3.4	**3.2**^{C}	0.48	**13.1**^{A}	1.3	**12.5**^{A}	1.9	**4.9**^{BC}	3.3
Pyruvate	**	**2.8**^{CD}	3.9	**8.2**^{AB}	2.7	**6.1**^{ABC}	1.5	**0.20**^{D}	0.00	**8.9**^{AB}	0.12	**7.4**^{BC}	1.9
Formate (C1)	*	**4.59**^{AB}	0.38	**3.55**^{B}	0.60	**4.04**^{AB}	0.32	**3.59**^{B}	0.19	**4.04**^{AB}	0.17	**4.90**^{A}	0.76
Acetate (C2)	**	**39.0**^{BC}	9.9	**32.3**^{C}	7.0	**44.6**^{AB}	3.6	**50.7**^{A}	0.8	**51.8**^{A}	3.3	**40.2**^{ABC}	2.7
Propionate (C3)	***	**23.9**^{C}	17.1	**30.4**^{C}	5.7	**59.5**^{A}	7.8	**69.9**^{A}	0.7	**53.2**^{AB}	3.1	**36.9**^{BC}	6.5
Butyrate (C4)	***	**0.91**^{B}	0.18	**4.88**^{A}	0.65	**0.94**^{B}	0.19	**1.49**^{B}	1.41	**0.86**^{B}	0.08	**0.92**^{B}	0.04
iso-butyrate (iC4)	ns	**0.011**	0.011	**0.003**	0.004	**0.030**	0.026	**0.031**	0.009	**0.015**	0.007	**0.008**	0.013
iso-valerate (iC5)	ns	**0.061**	0.026	**0.064**	0.070	**0.216**	0.161	**0.101**	0.017	**0.118**	0.029	**0.111**	0.074
Capronate (C6)	*	**0.302**^{A}	0.008	**0.211**^{AB}	0.091	**0.318**^{A}	0.100	**0.095**^{B}	0.010	**0.239**^{AB}	0.026	**0.280**^{AB}	0.069
iso-capronate (iC6)	ns	**0.002**	0.003	**0.006**	0.010	**0.002**	0.004	**0.000**	0.000	**0.004**	0.006	**0.008**	0.001
Total volatile fatty acids	***	**68.7**^{C}	26.7	**71.5**^{C}	13.1	**109.6**^{AB}	11.7	**126.0**^{A}	1.3	**110.3**^{AB}	6.0	**83.4**^{BC}	9.5

see Table 3

ever, there was no correlation between the citrate and the FHL concentrations. "Finland" and "Savoie" had a very high succinate concentration while "Switzerland" had a very low concentration. During propionic acid fermentation, aspartate and indirectly asparagine can be catabolised to succinate. However, a negative correlation was found only with asparagine (r=–0.68, data not shown). "Finland" and "Savoie" showed the highest acetate concentration, "Bretagne" the lowest. Acetate is produced during propionic fermentation and a high negative correlation was found between the acetate and the L+D-lactate concentrations (r=–0.80). In the Bretagne and in Finland, cows are commonly fed with silo forage during the winter months. This agricultural practice is reflected by the much higher butyrate concentration in "Bretagne" than in the other cheese samples. "Finland" also had a high butyrate concentration, but only in one sample (2.49 mmol/kg). The capronate concentration was significantly higher in "Allgäu" and "Switzerland" than in "Finland."

Applying a principal component analysis on the four high discriminating parameters p*H*-value, fat, L-lactate and pyruvate, "Finland," "Savoie" and "Vorarlberg" showed a clear tendency towards separation (Fig. 2). "Switzerland" with even only two parameters (succinate and L-lactate) was quite well separated from the others (Fig. 3).

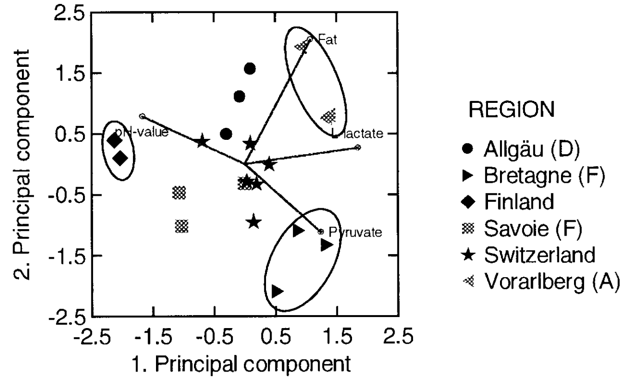

Fig. 2 Principal component analysis of the parameters fat, L-lactate and pyruvate content as well as pH-value. Separation of the groups "Finland," "Vorarlberg" and "Bretagne"

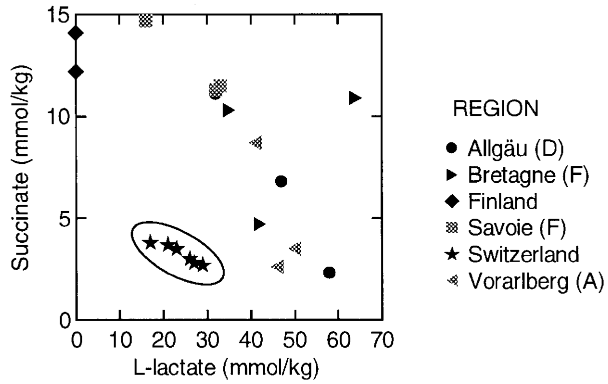

Fig. 3 Discrimination of the Emmentaler Switzerland™ according to L-lactate and succinate

Microbial composition

Table 5 lists the microbial composition of the Emmentalers from the six regions. In general, the microbial counts in Emmentaler Switzerland™ were significantly lower than in cheeses from other regions. All investigated microorganisms were significantly lower in "Switzerland" than in "Savoie." The OHL were significantly

Table 5 Microbial composition of the 20 Emmentaler cheese samples investigated expressed in $\log_{10}$

Region (n=)	ANOVA	AL (3)		BR (3)		CH (6)		FI (2)		SA (3)		VO (3)	
		x	s_x	x	s_x	x	s_x	x	s_x	x	s_x	x	s_x
Enterococci (cfu/g)	*	**5.18**[AB]	0.89	**3.3**[AB]	2.3	**2.1**[B]	2.3	**3.7**[AB]	2.4	**6.30**[A]	0.26	**5.51**[AB]	0.13
Fac. het. Lb (cfu/g)	*	**8.12**[AB]	0.26	**8.69**[AB]	0.92	**7.63**[B]	0.35	**7.62**[AB]	0.14	**9.1**[A]	1.1	**8.09**[AB]	0.30
Obligate het. Lb (cfu/g)	**	**7.7**[A]	1.0	**6.03**[A]	0.58	**2.7**[B]	2.3	**5.70**[AB]	0.00	**6.7**[A]	1.0	**6.37**[A]	0.58
Propionic acid b. (cfu/g)	ns	**8.31**	0.10	**9.12**	0.70	**8.13**	0.35	**7.99**	0.53	**9.4**	1.3	**8.44**	0.23
Salt tolerant b. (cfu/g)	*	**4.27**[AB]	0.86	**2.50**[B]	0.51	**2.5**[B]	2.0	**3.4**[AB]	2.3	**5.97**[A]	0.91	**5.05**[AB]	0.43
Lb. helveticus (strains/g)	***	>7[A]	n.c.	>5.8[A]	n.c.	<3.5[B]	n.c.	>5.8[A]	n.c.	>7[A]	n.c.	>7[A]	n.c.

see Table 3
n.c.=not calculated

Table 6 Sensory analyses and colour measurement of the 20 Emmentaler cheese samples investigated

Region (n=)	ANOVA	AL(3)		BR(3)		CH(6)		FI(2)		SA(3)		VO(3)	
		x	s_x	**x**	s_x	**x**	s_x	**x**	s_x	**x**	s_x	**x**	s_x
Adhesivity	ns	**3.58**	0.48	**2.85**	0.65	**3.15**	0.35	**2.45**	0.35	**3.12**	0.22	**3.17**	0.49
Friability	ns	**3.18**	0.42	**3.14**	0.48	**2.85**	0.37	**2.85**	0.35	**2.75**	0.17	**2.69**	0.32
Elasticity	ns	**3.79**	0.45	**4.19**	0.38	**4.30**	0.28	**4.55**	0.21	**4.44**	0.10	**4.04**	0.21
Firmness	ns	**3.70**	1.06	**4.18**	0.59	**3.59**	0.39	**4.50**	0.85	**3.82**	0.36	**3.40**	0.26
Aroma int.	ns	**3.47**	0.46	**2.97**	0.33	**3.06**	0.32	**3.10**	0.28	**3.27**	0.05	**2.97**	0.34
Odour int.	ns	**3.03**	0.64	**3.14**	0.19	**3.24**	0.24	**3.60**	0.71	**3.16**	0.17	**2.96**	0.04
Bitterness	*	**2.00**^{A}	0.20	**1.54**^{C}	0.17	**1.81**^{ABC}	0.17	**1.95**^{ABC}	0.35	**2.02**^{AB}	0.19	**1.67**^{ABC}	0.08
Saltiness	**	**2.66**^{A}	0.13	**2.27**^{AB}	0.30	**2.04**^{B}	0.27	**2.25**^{AB}	0.07	**2.41**^{AB}	0.05	**1.99**^{B}	0.12
Acidity	*	**2.65**^{A}	0.26	**2.13**^{B}	0.25	**2.05**^{B}	0.16	**2.30**^{AB}	0.28	**2.16**^{B}	0.22	**2.00**^{B}	0.16
Sweetness	ns	**2.45**	0.10	**2.59**	0.10	**2.64**	0.21	**2.90**	0.00	**2.61**	0.33	**2.49**	0.07
L-value[a]	ns	**68.9**	0.45	**69.3**	1.8	**68.9**	1.6	**68.8**	0.57	**67.6**	2.2	**69.4**	1.0
a-value[a]	***	**–2.18**^{B}	0.24	**–2.62**^{C}	0.19	**–2.22**^{B}	0.15	**–1.65**^{A}	0.07	**–2.47**^{BC}	0.23	**–2.32**^{BC}	0.10
b-value[a]	***	**16.63**^{AB}	0.81	**15.57**^{B}	0.45	**15.92**^{B}	0.94	**18.40**^{A}	0.00	**13.87**^{C}	0.40	**16.30**^{B}	0.26

see Table 3
[a] according to Hunter

lower in “Switzerland” compared to all other regions except for “Finland.” “Switzerland” showed the lowest concentrations of ECOC. These observations may be explained by research carried out at the Swiss Federal Dairy Research Station. In the 1970s, starter cultures with specifically low values of ECOC, OHL and STB were selected in order to reduce undesirable fermentations. The concentration of PSB was also among the lowest in “Switzerland.” The high propionate concentration of these samples indicates however that a part of the PSB must have already died out.

All foreign cheeses contained *Lb. helveticus*. In “Switzerland,” the content was below the detection limit of the method applied except for one sample where this species was detected at a level at least one order of magnitude below that of foreign cheeses. In foreign countries, *Lb. helveticus* is commonly used because of its ability to shorten the ripening period. In Switzerland, this bacteria is no longer used in starter cultures, in order to avoid secondary fermentation because of its strong proteolytic activity. Its presence in one Swiss sample may be due to contamination from the environment. The importance of such contamination is not known and further analyses will be necessary to check the occurrence of this contamination.

Lb. helveticus is the single thermophilic lactic acid bacterium producing both L- and D-lactate from lactose. Therefore the absence of this species should induce a decrease of the L/D-lactate ratio. This ratio in Emmentaler Switzerland™ was, however, not significantly different from the others (Table 4).

Sensory analyses

The results of the sensory analyses are listed in Table 6. The observations on texture did not show any difference between the regions of origin. The same was true for the aroma and the odour intensity. “Allgäu” was the most salty, “Switzerland” and “Vorarlberg” were the least salty, in good agreement with the potentiometric chloride measurements carried out (Table 3). “Bretagne” was significantly less bitter than “Allgäu” and “Savoie.” “Allgäu” was significantly more acid than all others except “Finland.”

The low number of differences in sensory tests explained the difficulty of the panel in determining if a sample originated from Switzerland or not. It must however be pointed out that the panel was not specifically trained on young Emmentaler.

Colour measurements

The parameters (a) and (b) presented considerable differences (Table 6). The Finnish Emmentaler was significantly redder and yellower than the others. “Savoie” on the other hand was significantly less yellow than the others and “Bretagne” more blue. This cannot be explained by the different maturation time of the samples analysed. Namely a decrease in lightness (L), and a slight increase on both reddish (a) and yellowish (b) have been observed [55]. “Finland” and “Bretagne” are, however, the youngest cheese in this study. A possible explanation may be found in the forage. “Finland” uses grass silage whereas “Bretagne” feeds maize silage. In the other regions, silages are not permitted.

Conclusion

Cheese is a living system continuously undergoing microbial, enzymatic and chemical modifications. Therefore, analyses of organic compounds or living microorganisms are only valid for a defined ripening time and data collected on young cheeses may not be valid for more mature samples. For all foreign Emmentaler cheese types, we focused our investigations on cheese samples with a ripening time corresponding to that offered in the stores (i.e. 2.5–4 months). In Switzerland, loaves ripened for 4 to 6 months are considered to be young cheeses. We limited however our investigation to 4 months Emmentaler Switzerland™ as the risk of confusion is the highest with such young cheeses.

Due to the low number of samples examined, the statistical values presented here are only an indication. General chemical parameters such as fat, fat in dry matter, sodium chloride as well as the pH-value showed significant differences. The concentration of organic acids such as L- and D-lactate, succinate, pyruvate, acetate, propionate, butyrate, capronate and total volatile acid content also were significantly different. The current alkaline phosphatase values (AP) showed too large a variation within a region to be valuable as markers of geographic origin. However, more consistent results of AP could probably be obtained if the samples are taken directly under the rind.

The microbiological ecology of the samples offered very promising results. ECOC, FHL, OHL and STB were all present at significantly lower concentrations ($p<0.05$) in the Emmentaler Switzerland™ than in the foreign cheeses pooled in one group. The presence of *Lb. helveticus* in high amounts in Emmentaler cheese samples appeared to be a reliable indicator of foreign origin since the raw milk starter mixtures used in Switzerland do not contain this species. The importance of possible contamination from the environment must, however, still be investigated. The absence of *Lb. helveticus* does not prove Swiss origin.

Most of the sensory analyses did not show significant differences. Exceptions were the criteria of "bitterness," "saltiness" or "acidity." Cheese from Finland could be easily identified by the colour measurement.

The following analyses were less promising for indication of geographical origin and won't be included in further works: vitamins A and E, water in fat-free matter, citrate, propionic acid bacteria and sensory analyses.

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