COMPARISON OF SOME HIGHLAND AND LOWLAND GRUYERE-TYPE CHEESE OF SWITZERLAND: A STUDY OF THEIR POTENTIAL PDO/AOC/AOP CHARACTERISTICS

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SUMMARY

This study compares the specificity and characteristics of two Swiss hard (Gruyère) cheese varieties manufactured at different altitudes: i) L'Etivaz cheese manufactured at L'Etivaz with 2 production sites (L'Etivaz 1 & L'Etivaz 2, 1300-2100 m); ii) Gruyère cheese manufactured at Montbovon (1000 m) and at Grangeneuve (600 m). These four production sites were studied during summer 1995, from the beginning of June until mid-September. Observations were carried out at each site: botanical composition of the pastures; chemical composition of the grass; chemical composition of milk, cream and cheese which was ripened over 8-9 months, as well as sensory and rheology properties of cheese. The grass composition was markedly different but the cheese production methods were similar excepted for milk heating (with open log fire producing some smoke in highland or in steam heated vats in lowland factories). All cheese loaves (n = 49) matured in the same ripening cellar under identical conditions. This study clearly highlights numerous differences of composition (heavy metals, fatty acids, triglycerides, volatile components including terpenoids, polyaromatic hydrocarbons and as well as flavour) between highland and lowland milk products.

INTRODUCTION

In regions with high production costs, agriculture needs to produce food of superior quality. The products can be labelled according to the specific conditions which characterise their origin and methods of manufacture. These regions can be designated for producing cream, butter, yoghurts and cheeses with PDO (Protected Designation Origin; in French: AOC/AOP). In the production area of hard cheese such as a L'Etivaz, a type Swiss Gruyère, the relationship between grass quality and cheese is not well known. 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. Pastures rich in dicotyledons are mostly located in the highlands while those rich in gramineae are mainly found in the lowlands. Both types of grass yield cheeses with different flavours. Terpenoids in plants are products of secondary metabolism and may be considered as potential biochemical indicators or markers to characterise cheeses originating from the highlands (1,2). A previous study (3) confirmed these results showing a significantly higher occurrence of terpenoid and aliphatic hydrocarbons in Swiss Gruyère and L'Etivaz highland cheeses than in the corresponding lowland cheeses.
The first aim of this work was to study the relationship between pasture (as starting material),

milk or cream (intermediates) and ripened cheese (final product) composition within the framework of PDO labelling. The second aim was to determine the influence of cheese manufacturing technologies: heating the milk on an open log fire in alpine cabins or in vats in lowland factories. The third aim was to determine the sensorial differences (flavour, i.e. odour and taste) between highland and lowland cheese varieties. A series of publications is currently in progress. The first paper (4) describes in detail the project and deals with the outlines, goals, procedures, study sites and techniques adopted in this work. It also briefly describes the meteorological conditions, the soil characteristics, those of the pasture and herds of cows as well as the method of cheese manufacture used at each site. A second paper (5) describes the occurence of terpenoids in various highland and lowland plant species. A third paper (6) shows that the polyaromatic hydrocarbons of alpine cheeses cheese are derived from smoke.

MATERIALS AND METHODS

Grass, milk and cheese samples were collected on the four production sites (1) from the beginning of June until mid-September 1995 at different altitudes: i) L'Etivaz cheese manufactured at L'Etivaz with 2 production sites (1300-2100 m); ii) Gruyère cheese manufactured at Montbovon (1000 m) and at Grangeneuve (600 m) according to traditional production technologies (on an open log fire in the highlands or in a steam heated vat in lowland factories). All cheese loaves (n = 49) matured in the same ripening cellar under identical conditions. Various analytical methods were applied to analyse the following constituents: i) dry matter, total nitrogen, phenolic compounds, non volatile terpenoids, earth alkaline and heavy metals, fibrous matter, carbohydrates, volatile compounds (GC-MS & FID) in grass, milk and cheese; ii) fat, colour (L, a, b according to Hunter), lactose, carotenoid and fatty acid composition in milk or cream or cheese; iii) water soluble nitrogen, non protein nitrogen, polyaromatic hydrocarbons, sodium chloride, volatile fatty acids, organic acids (L & D lactic, citric), free amino acids, biogenic amines, quality tests (appearance, taste, shelf-life), sensorial analyses (sensory panel) and rheological measurements in cheese. All these methods are described in detail in the series of above mentioned papers.

RESULTS AND DISCUSSION

Table 1 highlights the great diversity of highland plant species compared with that of lowlands. Figure 1 shows the distribution of monoterpenoids in all collected plant species that may account for some differences observed within cheese itself. The heavy metal, fatty acid, and triglyceride (TG) composition of milk (Table 2) as well as the volatile compounds of cheese (Table 3) varied significantly between highland and lowland production sites. Moreover, the heating technique explains the presence of some characteristic components such as polycyclic aromatic hydrocarbons (Table 4) which were not found in cheese produced in modern, more industrial lowland vats heated with hot steam. All these factors explain the statistically significant flavour differences (Table 5) which discriminate between highland and lowland cheeses. Another previous study (7) also confirmed these results.

CONCLUSIONS

This study shows that highland grass, with a highly diversified botanical composition, produces milk and cheese with a significantly different chemical composition than lowland grass. The

cheese manufacturing methods used at each site such as the use of raw milk (with a specific microbial flora) as well as various heating technologies (artisanal manufacture in alpine cabins using a smoking open log fire or steam to heat the milk in lowland factories) also explain the potential PDO/AOC/AOP characteristics of both highland and lowland cheese types. For consumers, who are not primarily interested in analytical results, flavour (odour and taste) characteristics are some of the main criteria for choosing cheese types. The highland cheese manufactured in L'Etivaz differs from the lowland cheese produced in Grangeneuve by having significantly higher values in flavour intensity (odour and taste) which are generally described in terms of "pungent", "salted", "animal" and "acid".

Table 1: Summary of the observations on botanical composition

Location Altitude (m)	L'Etivaz 1 1400-1900	L'Etivaz 2 1300-2100	Montbovon 900-1200	Grangeneuve 600-650
Method	Point quadrate method			Visual estimation
Number of observations	26	29	31	21
Number of plant species:				
- Total (per unit, all observations)	188	196	192	10
- Mean (per observation)	50	57	54	6
- Min. (per observation)	31	35	39	5
- Max. (per observation)	72	79	83	10

Table 2: Chemical composition of milk

Compound		L'Etivaz 1		L'Etivaz 2		Montbovon		Grangeneuve	
	n=	11		13		12		13	
		x	s	x	s	x	s	x	s
Zinc	mg/kg	3.51^{B}	0.28	3.39^{B}	0.34	3.13^{A}	0.12	3.13^{A}	0.34
Manganese	mg/kg	21.1^{B}	6.6	19.8^{AB}	3.9	21.1^{B}	4.8	15.1^{A}	2.4
Iron	µg/kg	210.6^{B}	43.0	184.1^{B}	39.3	202.0^{B}	43.9	149.0^{A}	39.8
Caproic acid	%	2.21^{A}	0.16	2.28^{A}	0.11	2.27^{A}	0.10	2.62^{B}	0.14
Capric acid	%	2.42^{A}	0.30	2.44^{A}	0.24	2.34^{A}	0.23	2.95^{B}	0.30
Oleic acid	%	29.3^{B}	1.8	29.1^{B}	1.3	29.2^{B}	1.1	24.1^{A}	1.7
Linoleic acid	%	2.56^{C}	0.22	2.92^{D}	0.24	2.33^{B}	0.10	1.92^{A}	0.23
TG 34	%	5.08^{A}	0.42	5.06^{A}	0.37	5.13^{A}	0.30	6.23^{B}	0.49
TG 36	%	9.74^{A}	0.42	9.70^{A}	0.39	9.89^{A}	0.35	11.56^{B}	0.60
TG 50	%	12.4^{B}	0.8	12.2^{B}	0.65	11.8^{B}	0.37	10.5^{A}	0.57
TG 52	%	12.6^{B}	1.25	12.8^{B}	0.97	12.6^{B}	0.92	9.6^{A}	1.23
TG 54	%	7.48^{B}	0.93	7.78^{B}	0.84	7.64^{B}	0.73	4.83^{A}	0.87

Caption: x = mean value; s = standard deviation;
Production sites: A<B<C<D (= significantly different contents) or AB = A and B overlap by using an univariate discriminant analysis;
% = percent of the sum of all free fatty acids (fat composition);
TG = triglycerides (number of carbon atoms on the sides chains); % = percent of the sum of all triglycerides.

Table 3: Volatile compounds of cheese (peak heights, arbitrary unit) found by multivariate backward discriminant analysis

Volatile compound	n=	L'Etivaz 1 11		L'Etivaz 2 13		Montbovon 12		Grangeneuve 13	
		x	s	x	s	x	s	x	s
2-Butanol *		6900^{C}	7450	1180^{B}	1410	253^{A}	250	369^{A}	1027
Benzene *		287^{B}	139	365^{AB}	193	167^{A}	102	143^{A}	77
Heptane *		319^{A}	79	333^{A}	62	282^{A}	161	302^{A}	89
2-Methyl-1-butanol*/**		568^{B}	244	704^{AB}	466	3490^{C}	1500	234^{A}	74
Hexanal *		946^{A}	361	1400^{A}	443	1260^{A}	827	2010^{A}	870
(E)-3-Octene*		492^{A}	170	867^{B}	255	861^{B}	244	1420^{B}	823
Octane *		513^{A}	118	517^{A}	71	539^{A}	167	566^{A}	170
α-Pinene*/**		2110^{C}	1410	1330^{C}	478	590^{B}	266	n.d.^{A}	
β-Pinene *		3280^{C}	3980	1100^{C}	1480	194^{B}	103	n.d.^{A}	
p-Cymene */**		170^{B}	125	95^{A}	74	94^{AB}	43	n.d.^{A}	
Limonene **		235^{AB}	224	197^{AB}	116	84^{AB}	58	n.d.^{A}	

Caption: see table 3; *) α (to remove) = 0.01; **) α (to remove) = 0.001; n.d. = non detected.

Table 4: Content of some polyaromatic hydrocarbons (µg/kg) in cheese

Compound	Statistical parameter (n=)	L'Etivaz 1 11	L'Etivaz 2 13	Montbovon 12	Grangeneuve 13
Anthracene	minimum	0.20	0.20	nd	nd
	lower quartile	0.30	0.30	nd	nd
	median	0.40	0.30	nd	nd
	upper quartile	0.40	0.50	nd	nd
	maximum	0.90	1.00	nd	0.20
Phenanthrene	minimum	1.70	1.20	0.80	0.80
	lower quartile	2.30	2.00	0.95	1.20
	median	2.60	2.40	1.20	1.40
	upper quartile	3.00	3.60	1.55	1.60
	maximum	4.90	6.00	1.80	3.00
Pyrene	minimum	0.30	0.20	0.30	nd
	lower quartile	0.40	0.30	0.30	0.20
	median	0.50	0.60	0.35	0.30
	upper quartile	0.70	0.60	0.50	0.40
	maximum	0.70	0.70	0.60	0.70

n = number of cheeses considered; nd = not detected (detection limit: 0.1µg/kg).

Table 5: Chemical and sensorial parameters of cheese

Parameter		L'Etivaz 1		L'Etivaz 2		Montbovon		Grangeneuve	
	n=	11		13		12		13	
		x	s	x	s	x	s	x	s
Odour intensity	7 point sc.	3.71^{B}	0.21	3.51^{AB}	0.31	3.53^{AB}	0.37	3.26^{A}	0.18
Odour animal	% sens.p.	73^{B}	47	62^{B}	51	42^{A}	51	8^{A}	28
Taste intensity	7 point sc.	4.11^{B}	0.28	4.11^{B}	0.34	4.01^{AB}	0.41	3.61^{A}	0.25
Taste animal •	% sens.p.	82^{B}	40	62^{B}	51	67^{B}	49	23^{A}	44
Saltiness	7 point sc.	3.77^{B}	0.37	3.62^{A}	0.33	3.47^{A}	0.37	3.21^{A}	0.40
Sweetness	7 point sc.	1.78^{A}	0.21	1.82^{AB}	0.17	2.44^{C}	0.37	1.95^{B}	0.21
Acidity	7 point sc.	3.16^{B}	0.19	3.15^{B}	0.19	2.87^{A}	0.28	2.94^{AB}	0.35
Pungent	7 point sc.	73^{B}	47	54^{B}	52	42^{A}	51	15^{A}	38
Acetic acid	mmol/kg	22.4^{B}	3.80	18.2^{B}	5.25	34.7^{C}	9.38	6.4^{A}	1.34
Formic acid	mmol/kg	2.52^{C}	0.46	1.85^{B}	0.61	1.77^{B}	0.55	0.98^{A}	0.40
Sum of free a.a.	g/kg	49.7^{BC}	3.22	49.2^{B}	4.69	53.9^{C}	4.15	40.7^{A}	7.71

Caption: 7 point sc. (=scale) with 1 for the lowest value and 7 for the highest value by tasting and smelling; sens.p. = sensory panel; a.a. = amino acid.

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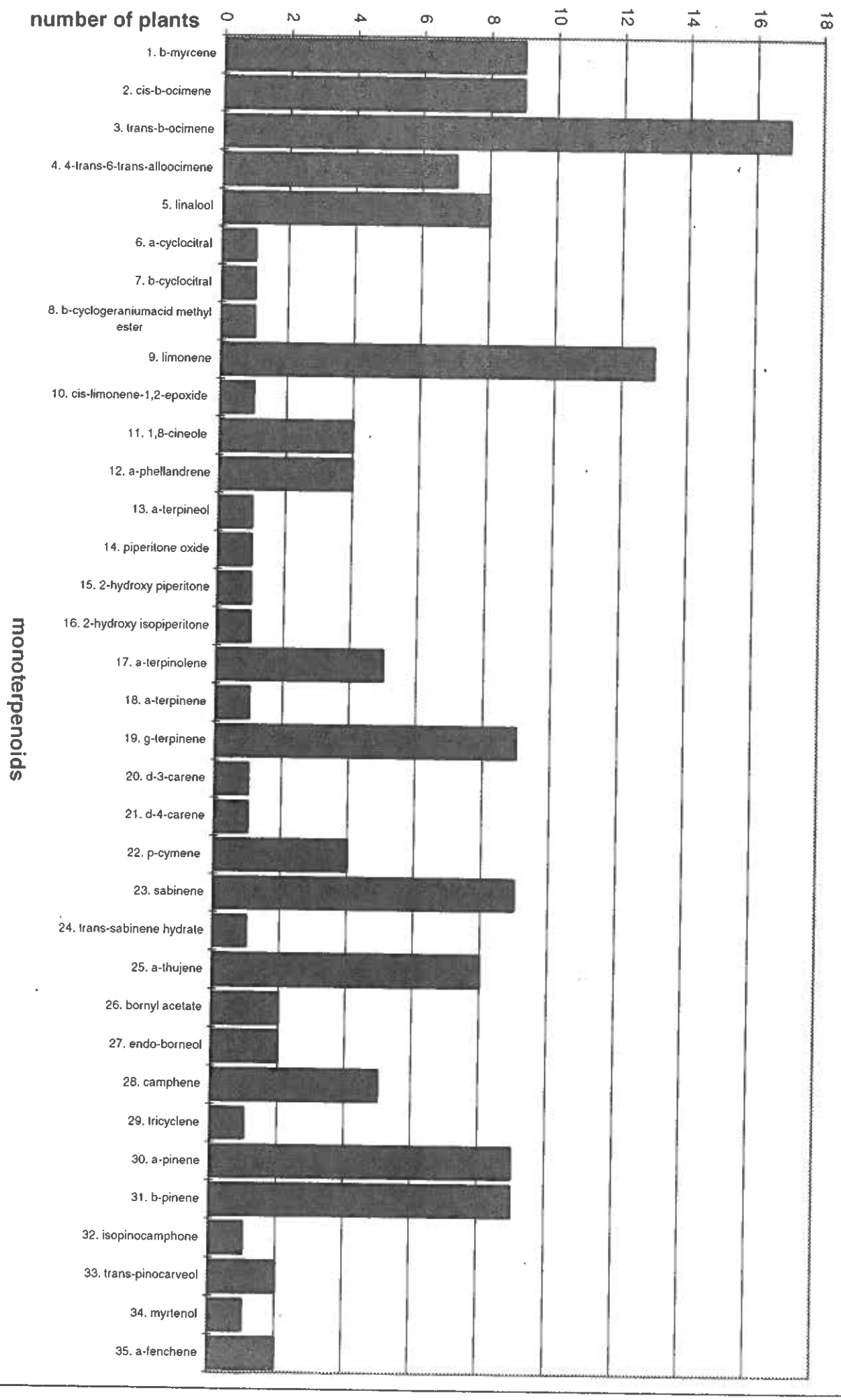
Figure 1. Distribution of terpenoids in all collected plant species (n=21)


number of plants
0
2
4
6
8
10
12
14
16
18
monoterpenoids
1. b-myrcene
2. cis-b-ocimene
3. trans-b-ocimene
4. 4-trans-6-trans-alloocimene
5. linalool
6. a-cyclocitral
7. b-cyclocitral
8. b-cyclogeraniumacid methyl ester
9. limonene
10. cis-limonene-1,2-epoxide
11. 1,8-cineole
12. a-phellandrene
13. a-terpineol
14. piperitone oxide
15. 2-hydroxy piperitone
16. 2-hydroxy isopiperitone
17. a-terpinolene
18. a-terpinene
19. g-terpinene
20. d-3-carene
21. d-4-carene
22. p-cymene
23. sabinene
24. trans-sabinene hydrate
25. a-thujene
26. bornyl acetate
27. endo-borneol
28. camphene
29. tricyclene
30. a-pinene
31. b-pinene
32. isopinocamphone
33. trans-pinocarveol
34. myrtenol
35. a-fenchene