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Original article

Effect of dairy production systems on the sensory characteristics of Cantal cheeses: a plant-scale study

Claire AGABRIEL[a*], Bruno MARTIN[b], Cécile SIBRA[a], Jean-Claude BONNEFOY[b], Marie-Christine MONTEL[c], Robert DIDIENNE[c], Sophie HULIN[d]

[a] Unité Élevage et Production des Ruminants (soutenue par l'INRA), ENITA, 63370 Lempdes, France
[b] Unité de Recherches sur les Herbivores, INRA, 63122 St-Genès-Champanelle, France
[c] Laboratoire de Recherches Fromagères, INRA, 36 route de Salers, 15000 Aurillac, France
[d] Comité Interprofessionnel des Fromages du Cantal, 52 avenue des pupilles de la nation, BP 124, 15000 Aurillac, France

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Abstract – A study was conducted to verify whether bulk milk produced according to specific conditions of production would lead to distinctive cheeses. Milk from two groups of farms that mainly differ in their level of intensification of dairy cow and forage area management was processed into cheese in the same Cantal dairy plant, during 4 periods of 3 consecutive days each. The milk chemical composition differed little between the two producing groups whereas the differences were greater between the processing periods because of the combined effects of the season, the mean lactation stage of the herds and cow feeding. Major chemical and microbiological differences were noted in ripened cheeses according to the cheesemaking period, especially between cheeses made in the winter and in the summer. The cheesemaking period and ripening time (6, 13 and 23 weeks) accounted for most of the variance noted in all the sensory characteristics of the cheeses, whereas the production system had a far lesser impact. With regards to odour and aroma, the spring and winter cheeses differed from the autumn and summer ones. With time, the cheeses became softer and melted more and tasted saltier and more pungent. The stronger characteristics were enhanced whereas milder flavours lost power, a trend that was more marked in the winter cheeses. On average, the cheeses made from the more extensive farms were more elastic and slightly less bitter and pungent. They were also characterised by their globally less intense odour and aroma characteristics. The differences between the two production systems were noticeable in cheeses made in the winter or spring and the most significant after 13 weeks of ripening. For other periods or other ripening time, the cheeses made from the 2 groups of farms were very close.

dairy production systems / Cantal cheese / sensory characteristics / ripening time / season

Résumé – Effet des systèmes de production sur les caractéristiques sensorielles des fromages Cantal : étude à l'échelle d'une entreprise. Afin de vérifier si des laits de mélange de plusieurs

* Corresponding author: agabriel@enitac.fr

exploitations, identifiées pour présenter des conditions de production différentes, conduisent à des fromages distincts, une étude a été réalisée dans une laiterie produisant du Cantal. Le lait de deux groupes d'exploitations, se distinguant principalement par le niveau d'intensification de la conduite des vaches laitières et des surfaces fourragères, a été transformé en fromage au cours de 4 périodes de 3 jours consécutifs. Les différences de composition chimique du lait ont été faibles entre les deux groupes de producteurs mais plus importantes entre les périodes de fabrication en raison des effets combinés de la saison, du stade de lactation moyen des troupeaux et de leur alimentation. Des différences physico-chimiques et microbiologiques importantes ont également été observées sur les fromages affinés selon la période de fabrication, particulièrement entre les fromages fabriqués en été et en hiver. Pour l'ensemble des caractéristiques sensorielles des fromages affinés, la période de fabrication et la durée d'affinage (6, 13 et 23 semaines) expliquent la plus grande part de la variance observée, l'effet du système de production étant nettement moindre. Sur le plan des odeurs et des arômes, les fromages de printemps et d'hiver se sont différenciés des fromages d'été et d'automne. En vieillissant, les fromages sont devenus plus fondants et onctueux et leur saveur plus piquante et salée. Les caractères plus « corsés » se sont développés au détriment des caractères plus « doux », tendance plus marquée pour les fromages d'hiver. En moyenne, les fromages issus des exploitations les plus extensives ont été légèrement plus élastiques, moins amers et piquants et leurs odeurs et leurs arômes ont été légèrement moins intenses. Les écarts entre les fromages des deux systèmes de production étaient sensibles pour les fromages fabriqués durant l'hiver et le printemps plus particulièrement après 13 semaines d'affinage. Pour les autres périodes ou durées d'affinage, les fromages issus des 2 groupes d'exploitations étaient très proches.

système de production laitier / fromage Cantal / caractéristiques sensorielles / durée d'affinage / saison

1. INTRODUCTION

The characteristics of ripened cheeses depend both on the cheesemaking technology and on the chemical and bacterial composition of milk. The latter are partly linked to the conditions of milk production, and to animal feeding in particular. In the case of certain cheeses with a Protected Denomination of Origin (PDO), for which milk modifications are restricted or even forbidden, the production conditions may have very notable effects on the physicochemical and sensory characteristics of ripened cheeses.

Early studies involved the respective influences of the animals' physiological or genetic characteristics (breed and/or lactoprotein genetic variants) and of their feeding on the sensory quality of ripened cheeses [4, 7, 14, 18, 19]. Original results have been experimentally obtained on the effects of forage preservation methods [18] and the floristic composition of dry [19] or grazed forages [2, 3] which lead to the most important effects with hard cooked cheeses. These experimental results are important to outline and to understand the proper effect of the factors studied individually. Nevertheless, at the farm level, they are associated in the production system and these results deserve to be confirmed when factors are combined. So far, few studies have been conducted on bulk milk [17], especially within a homogeneous pedoclimatic area where the farmers' strategies regarding the evolution of milk production differ.

Therefore, the aim of this study was to determine whether bulk milk collected from groups of farms with different conditions of milk production would lead to cheeses with specific sensory characteristics. It could help the professionals in their decisions about cheese valorisation and about the evolution of the specification, particularly for cheeses with a PDO.

2. MATERIALS AND METHODS

2.1. Farm description

Fifty-eight farms were located in a homogeneous soil and climate area, on the Saint-Flour plateau (Cantal, France) with a

Table I. Characteristics of the two farm groups in 1998.

Farm groups (n)	**A** (26)	**B** (11)
Herds		
Number of dairy cows	25	43
Milk yield (L·cow^{-1}·year^{-1})	3736	5398
Areas		
Usable farm area (ha)	53	83
Main forage area (ha)	49	67
Stocking rate of main forage area (LU·ha^{-1})	0.8	1.14
Dairy cows feeding		
Forage fed in winter (number of farms)		
Hay based	25	0
½ hay +½ fermented grass	1	3
Fermented grass-based	0	8
Duration of summer supplementation (d)	22	102
Concentrate given in the winter (kg·cow^{-1}·d^{-1})	3.3	5.2
Concentrate given in the summer (kg·cow^{-1}·d^{-1})	2.1	3.8
Calving period (number of herds)		
Winter (February-March-April)	13	1
Summer (August-September-October)	0	3
Autumn (November-December-January)	1	1
Distributed	12	6
Stable and milking equipment (number of farms)		
Traditional stable, milking bucket	18	2
Traditional stable, milking pipeline machine	7	7
Free-stall housing, milking parlour	1	2

LU: Livestock unit.

mean elevation of 1060 m and their milk was delivered to the same dairy plant of Valuejols. The cows' breeds were Montbéliarde (58%) or Prim'Holstein (42%). Four distinctive farm groups were identified by preliminary surveys on dairy herd husbandry, stocking rate, forage area management, production means and farm changes since their creation. The two extreme groups (A and B) were chosen for the study. The main differences between the two groups of farms were the level of intensification of dairy cow management (performance and feeding) and of forage areas (stocking rate and forage method) as well as production means [1] (Tab. I). Group A included farms with small, low-producing herds, half of which calved in the winter. The grazing area was small, little stocked and utilised in a rather extensive manner. Winter rations were based on hay and the cows ate almost exclusively grass during the grazing period. Concentrate supplementation was minimal throughout the year. These farms were otherwise scarcely equipped (few, low-power tractors, many traditional stables without mechanical cleaning out, milking bucket).

Group B farms had opposite characteristics: larger, higher-producing herds with calvings distributed over the year in more than half of the farms. Forage areas included more intensively used temporary meadows, with higher stocking rates. Winter rations were predominantly based on fermented forages (wrapped haylage) and the cows were fed with preserved forage during half of the grazing season on average, supplemented throughout the year by a larger proportion of concentrate feeds. These farms were better equipped (tractors, many tethered stables with mechanical cleaning out and a milking pipeline machine).

Additional telephone surveys were conducted throughout the duration of the study, which made it possible to verify that the differences noted between the two groups during the main surveys were maintained. In particular, they confirmed that apart from the summer period, the rations differed greatly between the two farm groups.

2.2. Milk collection and cheesemaking

During four periods of three consecutive days (summer: 10-11-12 August 1999; autumn: 12-13-14 October 1999; winter: 28-29-30 March 2000; spring: 7-8-9 June 2000) the milk produced over 24 h in each group of farms was collected and processed separately. During those 24 cheesemaking experiments, 5100 to 7350 L of semi-skimmed raw milk (to obtain comparable fat/protein ratios in both vats, i.e. 1.13 in the summer and 1.05 to 1.08 otherwise) were processed by the same cheesemaker. Lactic starters (Flora Danica MSP, Sochal, Levallois-Perret, France, 2U/1000L) and surface fungal flora (Monilev and Penbac, Laboratoire Interprofessionnel de Production, Aurillac, France) were added to the milk and it was left to rennet at a temperature of 30.8 to 32.2 °C. Rennet clotting time was visually observed and varied from 14 to 18 min. The curd was cut into grains of 6 mm mean diameter after 4 to 14 min firming. The curd was then transferred into a pre-pressing tank where most of the lactoserum was discarded. The curd was pressed and cut into 4–5 kg lumps and overturned nine times until a 52% mean (50.9–52.9%) dry matter was obtained. The cake was then left to mature for 2.30 h in a room at approximately 18 °C. These lumps were turned over three hours later to balance cooling. The cake was ground and dry salted 20 h after rennet addition. The amount of salt added equalled 2% of the cake weight. The cheeses were moulded after 2 h of maturation in salt at a mean temperature of 18 °C. These cheeses were compressed for 24 h, during which they were overturned 5 times (0.26 to 0.52 bar per cm^2 increasing pressure was applied on the first day and 0.65 bar per cm^2 pressure was applied on the second day). Milk composition and cheesemaking parameters were recorded. Three cheeses from each vat were identified and left to ripen in the cells at 8 °C, one for 6 weeks, another for 13 weeks and the third one for 23 weeks.

2.3. Sample collection and testing

2.3.1. Milk

Milk samples were collected from each cheesemaking vat just before the starter addition. Fat and protein (infrared spectroscopy according to IDF 141B standard), somatic cell count (IDF 148A Somacount Bentley), lipolysis (copper soap method IDF 265), urea (dimethyl amino benzaldehyde colorimetric method, [16]), spores of butyric acid bacteria [6], total flora at 30 °C (IDF 100B FMAR) and staphylococci coag+ (V08057-2/NF V08100) were assessed in the fresh milk.

The other microbiological analyses were performed on frozen milk by INRA Aurillac. The following microorganisms were identified and counted: thermophilic streptococci (M17, 48 h at 42 °C); lactobacilli (MRS pH 5.2 deep gelose, 3 days at 30 °C); dextrane-producing leuconostocs (MSE, 24 or 48 h at 30 °C); faecal and other enterococci (Slanetz and Bartley medium, 2 days at 42 °C in aerobiosis); yeasts (OGA, 3–5 days at 25 °C); pseudomonas (CFC medium, 3–5 days at 25 °C); micrococci

(Baird Parker, modified, 48 h at 37 °C); enterobacteria (VRBG, 24 h at 30 °C).

2.3.2. Cheeses

Upon cellar entrance (3 days after cheesemaking), pH (at 20 °C) and dry matter (by dessication at 102 °C for 24 h) were determined and fat (acido butyrometric method IDF 5B/1986) and chloride contents (titrimetric method, IDF 17A/1972) were assessed after 6 and 23 weeks of ripening time, lipolysis rate after 13 and 23 weeks and proteolytic rate (280 nm optical density of cheese aqueous phase [12]) after 23 weeks of ripening. The microbial populations that were identified and numbered in the milk were also investigated in the cheeses (except spores of butyric acid bacteria) at the cellar entrance and at the various ripening stages, as were citrate+ bacteria (Nickels Leesment medium). At the end of each ripening period, the sensory characteristics of the cheeses were assessed by a panel (68/72 cheeses were assessed: for 2 days in the summer the cheeses were not assessed at 6 weeks). The panel was composed of 12 members trained to assess the intensity of each of the 69 sensory descriptors of Cantal cheese commonly used by the "*Comité Interprofessionnel des Fromages du Cantal*" (respectively 7, 8, 27, 27 descriptors for texture, taste, odour and aroma) scored on a structured scale from 0 to 7.

2.4. Data analysis

Data were processed using SAS software (Version 8.6, SAS Institute, Inc., Cary, NC).

Data concerning milk and soft cheeses were processed by analysis of variance (GLM procedure) by introducing in the model the cheesemaking period (per), the farm group (sys) and the interaction. Data concerning ripened cheeses were processed using the Proc MIXED procedure. The period, the ripening time (age), the farm group and the interactions (period × ripening time, farm group × period, farm group × ripening time, farm group × period × ripening time) were the factors considered in the model. Since the characteristics of ripened cheeses at different times are correlated, ripening time was considered as the repeated factor. The assessor effect was also introduced into the model for the sensory data.

For sensory data, in order to describe the interactions between factors (farm group × period or farm group × ripening time), the effect of the farm group was also evaluated by successive analyses of variance completed within each period – ripening time (12 variance analysis for each descriptor introducing the farm group, the assessor and the interaction into the model). In order to describe the interaction ripening time × period, for each descriptor and cheese, the difference between 6 and 23 weeks of ripening was also compared by analysis of variance introducing the period, the assessor and the interaction into the model.

3. RESULTS

3.1. Milk characteristics

Marked differences in milk composition were observed according to the cheesemaking period because of the combined effects of the season, herd mean lactation stage and feeding (Tab. II). The milk used for summer cheesemaking had the lowest pH and protein content (6.73 and 30.8 g·kg^{-1}, respectively) and the highest somatic cell count and urea concentration values (240 000 cells·mL^{-1} and 314 mg·L^{-1}). In contrast, winter milk exhibited a low somatic cell count (136 000 cells·mL^{-1}) and the highest lipolysis (1.25 meq·100 g^{-1} FM) and pH (6.81). Autumn milk was characterised by the highest protein content (34.3 g·kg^{-1}). Microbiologically, summer and spring milks contained more total flora and enterococci. Spring milk was characterised by a low lactobacilli content.

Table II. Effects of production system and cheesemaking period on vat milk characteristics.

	Production system		Cheesemaking period				Statistical significance			
	A	B	Summer	Autumn	Winter	Spring	sys	per	sys × per	SD
Physicochemical characteristics										
Fat content (g·L^{-1})	34.2	35.0	34.9ab	35.9b	33.3a	34.3ab	ns	*	ns	1.36
Protein content (g·L^{-1})	31.8	32.2	30.8a	34.3c	31.1a	31.8b	+	***	**	0.51
Fat/Protein ratio	1.07	1.09	1.13b	1.05a	1.08a	1.08ab	ns	*	ns	0.04
Cells (1000·mL^{-1})	203	170	240c	190b	136a	181b	*	***	ns	31
Lipolysis[1]	0.98	0.90	0.85a	0.79a	1.25b	0.87a	+	***	ns	0.1
Urea (mg·L^{-1})	256	288	314b	248a	257a	269a	**	**	ns	25
pH	6.77	6.77	6.73a	6.76b	6.81d	6.79c	ns	***	ns	0.02
Microbiological characteristics (UFC·mL^{-1} – log10)										
Total flora	4.7	4.5	4.6ab	4.4a	4.3a	5.0b	ns	*	ns	0.32
Staphylococci coag+	2.5	2.4	2.4	2.6	2.2	2.6	ns	ns	ns	0.31
Therm. streptococci	4.0	3.6	4.2a	3.9ab	3.7ab	3.4b	*	+	ns	0.47
Lactobacilli	2.7	2.6	3.1b	2.6ab	2.7b	2.2a	ns	*	ns	0.46
Leuconostocs	2.1	1.9	2.1	2.0	1.9	2.0	ns	ns	ns	0.43
Faecal enterococci	2.7	2.4	2.7	2.4	2.6	2.6	+	ns	ns	0.42
Other enterococci	2.3	2.8	3.1b	2.4ab	1.8a	2.8b	ns	+	ns	0.80
Yeasts	2.4	2.4	2.4	2.3	2.4	2.5	ns	ns	*	0.17
Pseudomonas	4.1	3.9	4.0	4.0	3.6	4.4	ns	ns	ns	0.61
Micrococci	3.2	2.9	3.2	3.1	3.1	3.0	*	ns	ns	0.30
Enterobacteria	2.7	2.5	2.7bc	2.3a	2.5ab	2.9c	ns	*	+	0.32
Spores of butyric acid bacteria (spores·L^{-1})	2.6	2.5	2.9	2.3	2.6	2.5	ns	ns	ns	0.38

A: small, low-producing herds with calvings in winter; B: large, high-producing herds with calvings over the year; sys: farm group effect; per: cheesemaking period effect; sys × per: interaction between farm group and cheesemaking period.
SD: standard deviation; statistical significance: ns: no signification, +: $P < 0.1$, *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$; a, b, c: within the same row, values with different letters are statistically different.
[1] Lipolysis as meq·100 g^{-1} fat matter – meq = milliequivalent 0.28 g oleic acid.

The differences in chemical composition according to the production system were not as marked as between the cheesemaking periods. Milk from the A group farms tended to contain fewer proteins (–0.4 g·kg^{-1}, $P < 0.1$), especially during the winter period (–1.7 g·kg^{-1}). It also contained less urea (–32 mg·L^{-1}, $P < 0.01$), especially in the summer (–58 mg·L^{-1}). In contrast, somatic cell count and lipolytic rate were slightly higher. Also, milk from this group was slightly richer in most microbial populations although the differences were always under 0.5 log cfu·mL^{-1} and were only significant for thermophilic streptococci and micrococci (Tab. II). In addition, we observed no

Table III. Effects of production system, cheesemaking period and ripening time on cheese characteristics during the cheesemaking process.

	Production system		Cheesemaking period				Statistical significance			
	A	B	Summer	Autumn	Winter	Spring	sys	per	sys × per	SD
Physicochemical characteristics										
Cheeses out of cake pressing										
Dry matter (%)	51.4	52.1	52.2	51.2	52.1	51.6	ns	ns	ns	1
pH	6.67	6.66	6.66b	6.68bc	6.70c	6.62a	ns	**	ns	0.02
Cheeses before grinding										
Temperature (°C)	18.5	18.3	18.4ab	19.4b	18.6b	17.2a	ns	*	ns	1.12
Dry matter (%)	51.7	52.1	52.8c	51.5ab	52.4bc	50.9a	ns	*	ns	1.05
pH	5.22	5.23	5.30b	5.13a	5.29b	5.19a	ns	**	ns	0.07
Cheeses after grinding										
Temperature (°C)	21.4	21.4	19.6a	23.6c	22.0b	20.5a	ns	***	ns	0.94
Dry matter (%)	51.9	52.9	52.8	52.2	52.7	51.9	+	ns	ns	1.39
pH	5.17	5.19	5.24b	5.12a	5.23b	5.13a	ns	*	ns	0.07
Cheeses at cellar entrance										
Dry matter (%)	59.1	59.2	58.5a	59.1a	60.5b	58.4a	ns	**	ns	0.89
pH	5.14	5.14	5.17	5.11	5.13	5.15	ns	ns	ns	0.06
Lactic acid ($g \cdot kg^{-1}$)	13.8	13.4	12.7a	14.9b	13.4a	13.4a	ns	*	ns	1.1
Lactose ($g \cdot kg^{-1}$)	2.2	2.5	4.2b	0.8a	1.9a	2.6ab	ns	*	ns	1.68
Microbiological characteristics (UFC·mL^{-1} – log10)										
Cheeses at cellar entrance										
Therm. streptococci	7.7	7.8	8.2c	8.3c	7.6b	6.9a	ns	***	ns	0.42
Lactobacilli	6.0	5.9	6.0b	6.2b	6.0b	5.5a	ns	*	+	0.32
Micrococci	6.5	6.6	6.8b	6.9b	6.2a	6.4a	+	***	+	0.19
Staphylococci	6.3	6.4	6.5b	6.7b	6.2a	6.0a	ns	***	ns	0.22
Faecal enterococci	6.5	6.2	6.6	6.3	6.4	6.3	*	ns	ns	0.31

A: small, low-producing herds with calvings in winter; B: large, high-producing herds with calvings over the year; sys: farm group effect; per: cheesemaking period effect; sys × per: interaction between farm group and cheesemaking period.
SD = standard deviation; statistical significance: ns: no signification, +: $P < 0.1$, *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$; a, b, c: within the same row, values with different letters are statistically different.

difference in the count of spores of butyric acid bacteria in particular according to the system.

3.2. Cheese characteristics during the cheesemaking process

During cheesemaking, acidification was slightly faster in the autumn and spring than in the other seasons and cheese drip-drying was more thorough in the winter (Tab. III). In contrast, acidification and drip-drying did not differ according to the production system.

At the time of cellar entrance, the level of thermophilic streptococci, lactobacilli, micrococci and staphylococci coag+ were significantly higher in the summer and autumn cheeses than in the winter and spring ones (Tab. III). Only faecal enterococci were higher in the cheeses from the A farms.

3.3. Physicochemical and microbiological characteristics of ripened cheeses

Marked physicochemical differences were noted according to ripening time and depending on the cheesemaking period, entailing higher pH, increased lipolysis, dry matter and chloride contents (Tab. IV). Summer cheeses differed from those made in the winter insofar as they had higher pH, fat in dry ratio and proteolysis but lower lipolysis and dry matter content. Cheeses made in the autumn or spring were characterised by low pH, lipolysis, fat in dry ratio and dry matter content.

No significant difference was noted between the cheeses from the two production systems. However, the cheeses from B farms exhibited slightly higher pH, lipolysis and proteolysis.

The microbial content of ripened cheeses varied widely from one cheesemaking period to the other: summer-made cheeses contained more of most microbial populations, unlike those made in the winter (Tab. IV). Cheeses made in the autumn and spring were in between. Depending on the system, the differences were smaller: in ripened cheeses from A farms, faecal enterococci were higher whereas the staphylococci coag+ population was lower.

3.4. Sensory characteristics of ripened cheeses

The mean rating level of texture and taste descriptors (4.1, 1.2 respectively) was higher than that of the odour and aroma descriptors (0.4); the rating range was smaller and the frequency of null ratings was greater in the odour and aroma descriptors. Except for the intensity, the mean score was higher or equal to 0.8 for 5 odour descriptors (butter 1.7, fermented cream 1.5, fresh cream 1.0, stable 0.9 and vanilla 0.9) and 3 aroma descriptors (fermented cream 1.5, butter 1.3 and stable 0.8). Respectively 9 odour and 12 aroma descriptors presented a very low mean score (≤ 0.25).

Overall, the cheesemaking period and ripening time accounted for most of the variance recorded in all sensory analysis results (respectively 52 and 47 descriptors significantly different with $P < 0.05$). The production system effect was much lower (12 descriptors significantly different with $P < 0.05$).

3.4.1. Effect of the cheesemaking period

The texture of the summer cheeses was the softest, the least firm and brittle, with the least noticeable microstructure (Tab. V). The taste of spring cheeses was the most bitter and persistent, whereas that of the summer and above all the autumn cheeses was generally less marked. With regards to odour and aroma, the spring and winter cheeses were globally stronger (intensity, fermented cream, stable, malt). The autumn cheeses exhibited the weakest butter aroma whereas the winter cheeses exhibited the strongest hazelnut and vanilla flavour characteristics.

3.4.2. Effect of ripening time

With time, the texture of the cheeses became less firm, stickier, softer and melted more and their taste became more pungent, persistent and salty (Tab. V), especially in the winter-made cheeses. Odour and aroma intensity increased, as well as the "stronger" features (fermented cream, alliaceous, stable, cheese mite and spicy), whereas the softer flavour characteristics (butter, fresh cream, hazelnut and vanilla) decreased (Tab. V). The interactions observed between the ripening time and the cheesemaking period show that the effect of ripening time was the least important for the cheeses made in the autumn and the most pronounced for the cheeses made in the winter (for 23/52 odour or aroma descriptors the gap between 6 and 23 weeks of ripening was

Table IV. Effects of production system, cheesemaking period and ripening time on the characteristics of ripened cheeses.

	Production system		Cheesemaking period				Ripening time			Statistical significance						
	A	B	summer	autumn	winter	spring	6 w	13 w	23 w	sys	per	age	sys × per	sys × age	per × age	sys × per × age
Physicochemical characteristics																
pH	5.34	5.37	5.46b	5.30a	5.32a	5.34a	5.24a	5.29b	5.53c	+	***	***	ns	ns	ns	ns
Dry matter (%)	60.0	60.1	59.3a	60.0a	60.9b	59.9a	59.5		60.5	ns	**	***	ns	ns	ns	ns
Fat/dry	51.5	51.0	52.6b	50.5a	51.1a	51.0a	51.5		51.0	ns	***	+	ns	ns	ns	ns
HFD (%)	57.9	57.6	59.1c	57.4ab	56.8a	57.7b	58.4		57.1	ns	***	***	ns	ns	ns	ns
Chlorides (%)	1.7	1.8	1.6a	1.7ab	1.8ab	1.8b	1.6		1.8	ns	+	**	ns	ns	*	ns
Lipolysis (meq·100 g^{-1} fat)[1]	3.2	3.5	3.0a	3.2a	4.0b	3.2a		2.8	3.8	ns	**	***	*	ns	ns	ns
Proteolysis (index)	16.9	18.3	21.1b	16.0a	15.4a	17.9ab			17.6	ns	*	/	ns	/	/	/
Microbiological characteristics (UFC·mL^{-1} – log10)																
Staphylococci coag+	4.4	4.8	4.9b	4.3a	4.2a	5.0b	5.8c	4.9b	3.0a	**	***	***	ns	+	*	ns
Thermophile streptococci	7.1	7.2	7.4b	7.5b	6.9a	7.0a	7.6c	7.3b	6.7a	ns	***	***	+	ns	***	ns
Lactobacilli	7.5	7.4	7.7b	7.6bc	7.3a	7.4ab	7.4	7.5	7.5	ns	***	ns	ns	ns	ns	ns
Leuconostocs	5.5	5.5	5.7b	5.3a	5.4ab	5.6b	5.8b	5.6b	5.1a	ns	*	***	***	ns	ns	ns
Faecal enterococci	6.3	6.1	6.3	6.3	6.1	6.2	6.2a	6.1a	6.4b	**	ns	*	**	ns	**	ns
Other enterococci	5.5	5.8	6.4c	5.7b	4.9a	5.7b	6.0b	5.6ab	5.4a	ns	***	*	ns	ns	ns	ns
Yeasts	4.5	4.4	4.8b	4.1a	4.3ab	4.4ab	4.8b	4.4ab	4.0a	ns	ns	**	ns	ns	ns	ns
Pseudomonas	5.3	5.6	6.0b	4.6a	5.5b	5.7b	6.2c	5.4b	4.8a	ns	***	***	+	ns	ns	ns
Micrococci	5.1	5.1	5.4b	5.1ab	4.8a	5.0a	6.2c	5.1b	4.0a	ns	*	***	ns	ns	ns	ns
Enterobacteria	4.8	5.1	5.5b	4.0a	5.1b	5.3b	5.8c	5.0b	4.2a	ns	***	***	ns	ns	ns	ns
Citrate+ bacteria	7.5	7.4	7.7c	7.3ab	7.2a	7.5bc	8.2c	7.5b	6.7a	ns	**	***	+	ns	**	ns

A: small, low-producing herds with calvings in winter; B: large, high-producing herds with calvings over the year; w: week; sys: farm group effect; per: cheesemaking period effect; age: ripening time effect; sys × per: interaction between farm group and cheesemaking period; Sys × age: interaction between farm group and ripening time; per × age: interaction between cheesemaking period and ripening time; sys × per × age: interaction between farm group, cheesemaking period and ripening time.
Statistical significance: ns: no signification, +: $P < 0.1$, *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$; a, b, c: within the same row, values with different letters are statistically different.
HFD: humidity on fat-depleted cheese; [1] lipolysis as meq·100 g^{-1} fat matter – meq = milliequivalent 0.28 g oleic acid.

significantly higher for the winter cheeses than for the autumn ones). Spring cheeses were in-between.

3.4.3. Effect of the production system

Twelve sensory descriptors differed significantly between the two systems although the differences never exceeded 0.5 points. Cheeses made from group A farms were on average more elastic and slightly less salty, bitter and pungent (Tab. V). They were also characterised by their globally less intense odour and aroma characteristics, such as butter odour, yoghurt, fermented cream and peppery aroma in particular.

Nevertheless, the effect of the production system was different according to the period and/or the ripening time. For flavour attributes, this effect was smaller in the summer and autumn cheesemaking periods, when respectively 13 and 14 descriptors differed significantly ($P < 0.05$) according to the farm group, and was greater for cheeses made during the other two periods when 20 and 19 descriptors differed significantly ($P < 0.05$). In those cheeses made in the winter and spring, differences according to farm groups occurred at 6 weeks (10 significantly different descriptors ($P < 0.05$)) and were the most significant after 13 weeks of ripening (21 significantly different descriptors ($P < 0.05$)). They practically disappeared at 23 weeks (8 significantly different descriptors ($P < 0.05$)), when a very wide variability between cheeses was recorded, regardless of the production system. At 13 weeks, cheeses from the A farms were mainly characterised in the winter by their stronger hazelnut odour and their smaller butter odour and in the spring by their less intense stable flavour, cheese mite odour, fermented cream and alliaceous aroma.

4. DISCUSSION-CONCLUSION

In this study, the sensory characteristics of the cheeses varied mainly according to ripening time and to the season of production.

The effect of ripening time is well-known [5]. Texture evolution and time-related fading of the mild flavour attributes to the benefit of stronger features were consistent with the time-related increases in pH, lipolytic and proteolytic indices [11]. These changes are linked to sugar, protein and fat catabolism being all the more important as ripening time is longer [9].

The effect of the cheesemaking period, less marked than the precedent, was more surprising. It is not just a seasonal effect stricto sensu: the differences observed are probably linked to the seasonal changes in the chemical and microbiological characteristics of milk, to the cheese plant environmental conditions and to certain technological parameters that may have evolved from one cheesemaking season to the other. Thus, the less firm texture of summer cheeses could be linked both to their lower dry matter content and higher fat content (linked to the fat to protein ratio being standardised at 1.13 vs. 1.05–1.08 during other periods) as well as to higher urea concentration in milk [13]. It is certainly also partially explained by the type of forage fed to cattle (pastured or preserved grass) [20] and by the changes in the cows' physiological condition [7].

The faster changes observed during the ripening of winter, and to a lesser extent, spring cheeses, confirm the empirical knowledge whereby cheeses made in the summer are more adapted to longer ripening, unlike winter-made cheeses, which must be marketed faster, before the early occurrence of strong and unpleasant sensory features. This faster evolution was not due to the ripening conditions, which were rigorously identical during the various periods. It resembled those described with late-lactation milk [7] or high somatic cell count milk [10]. But these factors cannot be incriminated in this study insofar as their seasonal fluctuations were minimal. The fast evolution during the ripening of winter and spring cheeses could, however, be linked to a slower acidification during winter cheesemaking and to the lower concentration of

Table V. Effects of production system, cheesemaking period and ripening time on the sensory characteristics of ripened cheeses (descriptors with mean score ≥ 0.25).

	Production system		Cheesemaking period				Ripening time			Statistical significance						
	A	B	summer	autumn	winter	spring	6 w	13 w	23 w	sys	per	age	sys × per	sys × age	per × age	sys × per × age
Texture																
Elastic	5.3	5.0	4.7a	5.0b	5.4c	5.5c	5.2b	5.5c	4.8a	***	***	***	ns	ns	***	ns
Firm	3.4	3.2	3.0a	3.4b	3.6c	3.1a	3.7c	3.2b	3.0a	+	***	***	***	+	***	***
Brittle	2.9	2.9	2.4a	3.0b	3.1b	3.2b	2.9a	3.0a	2.8b	ns	***	*	ns	ns	ns	*
Sticky	4.0	4.0	4.0ab	3.9a	3.9a	4.2b	2.9a	4.2b	4.9c	ns	**	***	ns	ns	***	ns
Microstructure	3.5	3.4	2.7a	3.6b	4.0c	3.6b	3.8c	3.4b	3.2a	ns	***	***	***	**	***	*
Melting	4.5	4.4	4.5a	4.5a	4.3a	4.7b	3.8a	4.6b	5.1c	ns	***	***	+	ns	***	ns
Soft	4.6	4.7	4.8b	4.6ab	4.5a	4.7bc	3.8a	4.8b	5.3c	ns	**	***	***	*	***	ns
Taste																
Salty	2.4	2.6	2.5b	2.3a	2.6b	2.7b	2.2a	2.5b	2.8c	*	***	***	ns	ns	**	ns
Acid	0.6	0.8	0.5a	0.5a	0.9b	0.9b	0.7	0.7	0.7	+	***	ns	ns	ns	ns	ns
Bitter	0.7	0.8	0.6ab	0.4a	0.6b	1.5c	0.6a	0.6a	1.0b	*	***	***	ns	ns	**	ns
Pungent	1.1	1.4	1.3ab	1.1a	1.3b	1.4b	0.9a	1.2b	1.7c	*	*	***	ns	ns	***	ns
Persistence	3.5	3.6	3.3b	3.1a	3.8c	3.9c	3.1a	3.4b	4.1c	ns	***	***	ns	ns	***	ns
Odour																
Odour intensity	3.5	3.8	3.2a	3.3a	4.1c	3.9b	3.4a	3.6b	3.9c	***	***	***	ns	ns	***	*
Butter	1.5	2.0	2.0b	1.8b	1.7ab	1.5a	2.1b	1.6a	1.5a	***	*	**	ns	ns	***	+
Fresh cream	1.0	1.0	1.0	0.8	1.0	1.0	1.3c	1.0b	0.6a	ns	ns	***	ns	ns	ns	+
Yoghurt	0.3	0.3	0.5b	0.3a	0.3a	0.2a	0.5b	0.2a	0.2a	ns	*	**	ns	ns	ns	ns
Fermented cream	1.4	1.4	1.0a	1.1a	1.7b	1.8b	0.8a	1.3b	2.0c	ns	***	***	*	ns	***	ns
Grass	0.3	0.4	0.4	0.3	0.4	0.3	0.3	0.4	0.4	ns	ns	ns	ns	ns	ns	ns
Hay	0.2	0.2	0.3	0.2	0.3	0.2	0.2	0.3	0.3	ns	ns	ns	ns	ns	ns	ns
Alliaceous	0.5	0.5	0.5a	0.3a	0.7b	0.4a	0.4a	0.3a	0.7b	ns	***	***	ns	ns	***	ns

Table V. Continued.

	Production system		Cheesemaking period				Ripening time			Statistical significance						
	A	B	summer	autumn	winter	spring	6 w	13 w	23 w	sys	per	age	sys × per	sys × age	per × age	sys × per × age
Hazelnut	0.5	0.6	0.5a	0.4a	0.7b	0.5a	0.8c	0.6b	0.3a	ns	*	***	ns	ns	***	*
Vanilla	0.9	0.9	0.8a	0.9a	1.1b	0.8a	1.2c	0.9b	0.6a	ns	*	***	ns	ns	***	ns
Caramel	0.3	0.3	0.3a	0.3a	0.5b	0.3a	0.5b	0.3a	0.2a	ns	*	***	*	ns	*	ns
Toasted onion	0.3	0.3	0.1a	0.3a	0.5b	0.3ab	0.2a	0.3a	0.5b	ns	**	***	ns	ns	***	ns
Stable	0.8	0.9	0.5a	0.5a	1.3c	1.0b	0.3a	0.8b	1.4c	ns	***	***	*	ns	***	ns
Cheese mite	0.3	0.4	0.2a	0.3ab	0.5c	0.4bc	0.1a	0.4b	0.5b	ns	*	***	ns	ns	ns	*
Manure	0.3	0.3	0.2a	0.1a	0.4b	0.4b	0.0a	0.2a	0.6b	ns	***	***	ns	ns	**	ns
Spicy	0.4	0.3	0.2	0.3	0.4	0.4	0.2a	0.3a	0.5b	ns	+	**	ns	ns	***	ns
Cellar/mould	0.3	0.2	0.1a	0.2a	0.4b	0.4b	0.2a	0.1a	0.5b	ns	**	***	ns	*	***	ns
Malt	0.3	0.4	0.1a	0.2a	0.6b	0.5b	0.3ab	0.2a	0.5b	ns	***	*	*	ns	*	**
Aroma																
Aroma intensity	3.5	3.7	3.3a	3.4a	3.8b	3.9b	3.1a	3.5b	4.2c	*	***	***	ns	ns	***	ns
Butter	1.2	1.3	1.2ab	1.0a	1.4b	1.4b	1.5b	1.2a	1.1a	ns	*	**	ns	ns	***	ns
Fresh cream	0.5	0.5	0.5	0.5	0.5	0.6	0.7b	0.6b	0.3a	ns	ns	***	ns	ns	ns	ns
Yoghurt	0.2	0.3	0.3	0.2	0.2	0.3	0.4b	0.2a	0.2a	*	ns	*	ns	ns	+	ns
Fermented cream	1.3	1.6	1.2a	1.2a	1.7b	1.6b	0.9a	1.4b	2.0c	*	***	***	ns	ns	***	ns
Hay	0.3	0.2	0.3	0.3	0.3	0.2	0.3	0.2	0.3	ns	ns	ns	ns	ns	ns	ns
Alliaceous	0.6	0.6	0.4ab	0.5a	0.8b	0.5a	0.5a	0.6a	0.8b	ns	**	*	ns	ns	+	ns
Hazelnut	0.4	0.3	0.3a	0.4a	0.6b	0.4a	0.6b	0.4b	0.1a	ns	**	***	ns	ns	***	ns
Vanilla	0.4	0.3	0.2a	0.3a	0.5b	0.4ab	0.5c	0.4b	0.2a	ns	*	***	ns	ns	***	ns
Toasted onion	0.4	0.4	0.3	0.4	0.6	0.4	0.3a	0.4a	0.6b	ns	ns	***	ns	ns	ns	ns
Smoked	0.4	0.3	0.2a	0.4b	0.2a	0.4b	0.3ab	0.2a	0.4b	ns	*	+	ns	ns	*	ns
Stable	0.8	0.8	0.6ab	0.6a	1.2c	0.8b	0.4a	0.6b	1.4c	ns	***	***	ns	+	***	ns
Meat	0.2	0.3	0.2	0.2	0.3	0.3	0.1a	0.2a	0.4b	ns	ns	***	ns	ns	ns	ns
Cheese mite	0.5	0.5	0.4	0.6	0.5	0.6	0.3a	0.4a	0.9b	ns	ns	***	*	ns	ns	ns
Spicy	0.5	0.6	0.7b	0.2a	0.6b	0.7b	0.4a	0.4a	0.9b	ns	***	***	ns	ns	*	ns
Peppery	0.3	0.4	0.5b	0.1a	0.4b	0.4b	0.3b	0.1a	0.6c	**	***	***	ns	ns	***	ns
Cellar/mould	0.2	0.3	0.1a	0.3b	0.4c	0.2ab	0.2ab	0.2a	0.3b	+	**	*	**	ns	**	ns

A: small, low-producing herds with calvings in winter; B: large, high-producing herds with calvings over the year; w: week; sys: farm group effect; per: cheesemaking period effect; age: ripening time effect; sys × per: interaction between farm group and cheesemaking period; sys × age: interaction between farm group and ripening time; per × age: interaction between cheesemaking period and ripening time; sys × per × age: interaction between farm group, cheesemaking period and ripening time.
Statistical significance: ns: no signification, +: $P < 0.1$, *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$; a, b, c: within the same row, values with different letters are statistically different.

lactic acid bacteria (thermophilic streptococci, lactobacilli), micrococci and staphylococci coag+ at the time of cellar entrance. Indeed, limited growth of this flora has often been associated with globally stronger cheeses [8].

Compared with ripening time, the effect of the production system on the sensory characteristics of cheeses was much weaker. Such a low influence of production factors compared to that of technological factors has already been noted in other situations [21]. The globally stronger flavour and less elastic texture of cheeses originating from B farms were consistent with the trends of their chemical composition: slightly higher pH and proteolytic and lipolytic levels on the average [9]. These differences could not be due to the cheesemaking technology because the technological parameters, the acidification and drying kinetics were identical in both groups. Indeed, they reflected milk characteristics and, beyond that, the production conditions in the two groups of dairy farms where the milk came from. Winter is the season when husbandry practices, feeding in particular, differ the most between the groups of farms. The varied composition in winter diets (proportions of dried or fermented forage) probably played a determinant role and was reflected by sharper sensory differences between cheeses originating from the two groups [20]. From the microbiological standpoint, in the course of cheesemaking or during ripening, slightly higher concentrations of micrococci, pseudomonas and staphylococci coag+ in group B cheeses could be the cause for developing a globally stronger aroma [15]. Also, other unavailable composition information (native enzymes, other microbiological characteristics) could help to understand the seasonal variations and differences between the systems.

The interaction noted between ripening time and production systems constitutes a new result insofar as ripening time measurements have rarely been taken into consideration for understanding the effect of milk production factors on the sensory characteristics of cheeses. In younger cheeses, the absence of any production system effect is probably linked to the high predominance of the butter, fresh cream or vanilla features directly derived from the cheesemaking starters used for the Cantal technology (Didienne, personal communication) and to the limited development of other sensory characteristics. In contrast, the sensory characteristics of older cheeses became too remote at 23 weeks of ripening for mean differences to have any statistical significance. The ripening time most appropriate to evidence the influence of upstream factors therefore appears to be 13 weeks.

To conclude, this study shows that on the scale of bulk milk and even within relatively close production systems (grass-based) significant differences can be found in the sensory characteristics of cheeses. Differences between systems are season-related, hence due in part to the type of grass fed to the cattle (pastured or preserved), and also to the composition of the diet in the winter. These results underline the interactions that exist between upstream factors and the cheese ripening time.

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