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Impact of ripening strains on the typical flavour of goat cheeses

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Abstract

The strong and characteristic "goat" flavour is one of the most important quality components of French cheeses made from goat milk. This study was designed in order to evaluate the impact of different ripening strains on this typical flavour. Goat milk was incubated with selected ripening strains (yeasts and moulds), and two types of cheeses were produced: Sainte-Maure cheese (lactic coagulation technology) and Camembert-type cheese (lactic-rennet coagulation technology). Sensory evaluation of the cheeses was performed by trained panellists, and physico-chemical parameters (including lipolysis) were measured. The results showed that cheeses made with *Geotrichum candidum* as a ripening agent were characterised by a strong typical flavour, whereas the use of *Penicillium candidum* was detrimental for the sensorial quality of cheeses. These results were related to the lipolytic and flavouring activities of the different strains, which displayed considerable quantitative and qualitative variations.

Keywords: Goat cheeses; Ripening strains; Flavour; Lipolysis

1. Introduction

The characteristic flavour of goat cheeses is one quality component of particular importance to cheese producers. Several aroma compounds responsible for the specific "goat" flavour have been identified: 3-methylbutanoic acid, octanoic acid, 4-methyloctanoic acid, 4-ethyloctanoic acid, and nonanoic acid (Ha & Lindsay, 1991; Le Quéré, Pierre, Riaublanc, & Demaizières, 1998). Among them, 4-met-C8 and 4-et-C8 have been found to be principally responsible for the goat flavour, since they are perceived even at very low concentrations (Brennand, Ha, & Lindsay, 1989).

These fatty acids, as well as others in cheese, are produced by lipolysis, which could be considered at three distinct levels: (i) initial milk lipolysis (spontaneous lipolysis); (ii) lipolysis induced by milking practices, storage and technological operations; (iii) microbial lipolysis generated notably by ripening strains. Among the processing steps, ripening, and notably the nature of the ripening strains, is of considerable importance for the development of the sensorial characteristics of soft surface-ripened cheeses made from cow milk (Molimard & Spinnler, 1996), but there is a lack of information concerning the contribution of yeasts and moulds to the biosynthesis of flavour compounds in goat cheeses.

This study was designed to get a better knowledge of the relationships between ripening strains, lipolysis and goat flavour of cheeses. We have studied the effect of several yeasts and moulds on the sensorial characteristics of surface-ripened soft goat cheeses (lactic and Camembert-type cheeses). The sensory evaluation of the cheeses was performed by trained panellists, and physico-chemical parameters (including lipolysis) were measured. The results indicated that a control of the typical flavour of goat cheeses could be achieved through the choice of suitable ripening strains.

2. Materials and methods

2.1. Ripening strains

All ripening strains were purchased from TEXEL (Dangé St Romain, France), and CHR HANSEN (Arpajon, France) except the two strains of *Yarrowia lipolytica* that were kindly provided by INRA Dairy Research Laboratory (Aurillac, France). The source and identification codes of the ripening strains are given in Table 1. The supplier's recommendations concerning the

Abbreviations: DH: *Debaryomyces hansenii*; FDM: Fat in fry matter; GC: *Geotrichum candidum*; MNFS: Moisture in non-fat substance; PC: *Penicillium candidum*; RI: *Rhodosporidium infirmominiatum*

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Table 1
Source and identification codes of the ripening strains

Strain	Code	Supplier
Penicillium candidum		
Penicillium candidum	PC1	TEXEL
Penicillium candidum	PC2	TEXEL
Penicillium candidum	PC3	TEXEL
Penicillium candidum	PC4	TEXEL
Penicillium album	PA	CHR HANSEN
Geotrichum candidum		
Geotrichum candidum	GC1	TEXEL
Geotrichum candidum	GC2	TEXEL
Geotrichum candidum	GC3	TEXEL
Geotrichum candidum	GC4	CHR HANSEN
Geotrichum candidum	GC5	CHR HANSEN
Geotrichum candidum	GC6	CHR HANSEN
Yeasts		
Rhodosporidium infirmominiatum	RI	TEXEL
Kluyveromyces lactis	KL1	TEXEL
Kluyveromyces lactis	KL2	CHR HANSEN
Debaryomyces hansenii	DH1	CHR HANSEN
Debaryomyces hansenii	DH2	TEXEL
Yarrowia lipolytica	YL1	INRA
Yarrowia lipolytica	YL2	INRA
Others		
Micrococcus	MS	TEXEL
Aromatisation mix	A	TEXEL

inoculation doses of the commercial strains were followed (between 10^5 and 10^6 CFU/L). The strains of *Y. lipolytica* were suspended in a culture media at a concentration of 1000 spores/mL, and milk was then inoculated at 10^5 CFU/L.

2.2. Goat milk and cheeses

Goat milk (bulk milk from two consecutive milkings) was collected at a local dairy farm.

Two types of surface-ripened soft goat cheeses were produced corresponding to the usual industrial practices for France: lactic cheeses (Sainte-Maure-type) and Camembert-type cheeses, as described in Fig. 1. Cheeses were analysed at two different ripening stages: fresh cheeses before ripening at day 2 and ripened cheeses at day 30.

2.3. Physico-chemical and microbiological analyses

The dry matter was obtained after drying to constant weight at 102°C. The titrable acidity (° Dornic) was determined in milk using NaOH 0.111 M and phenolphthalein as an indicator.

Protein content in milk was obtained by an infrared analysis using a Milkoscan apparatus (International Dairy Federation 141B, 1996). The relative amount of the different caseins in goat milk (αs1, αs2, β, κ) was calculated using reverse phase HPLC, as described by Jaubert and Martin (1992).

Fat was measured in milk by the butyrometric method (International Standard Organisation 2446, 1976) and in cheese by the Heiss method (Heiss, 1961).

Somatic cells counts were obtained according to the IDF method (International Dairy Federation 148A, 1995) with a Fossomatic apparatus and total microflora was counted on PCA (International Dairy Federation 100B, 1991c). Yeasts and moulds were counted according to the IDF method (IDF 94B, 1991d).

The lipolysis level was determined in milk by the BDI method (IDF, 1991a) and in cheeses by a procedure similar to the one described by Delacroix-Buchet, Degas, Lamberet, and Vassal (1996). Cheeses were mixed with an equal weight of sand and H_2SO_4 4 M was added to the mixture in order to obtain a pH < 2. Fat matter was extracted by centrifugation for 30 min at 3900 g and 55°C. Fat acidity was titrated according to the IDF procedure (IDF, 1991b). For milk and cheeses, the lipolysis level was expressed in g Oleic Acid/100 g Fat (g OA/100 g). Only a few percentage of short chain fatty acids is counted via the BDI method (Deeth, Fitz-Gerald, & Wood, 1975), whereas high level recovery are obtained for all the fatty acids by the method used for the evaluation of lipolysis in cheeses (i.e. around 50% for C4 and 100% for C6 to C20; G. Lamberet, Personal Communications).

2.4. Sensory evaluation

Sensorial characteristics of goat milks and cheeses (fresh and ripened) were evaluated by 12 trained panellists in separate booths, using white light, in an air-conditioned room (18°C). Cheeses were cut in identical portions (~30 g) and presented with their rinds. Each Camembert-type cheese was divided in 8 parts, and lactic cheeses were cut in cylindrical slices (2 cm large) after having eliminated the ends. The samples were presented in a monadic manner according to a balanced design. The descriptor's intensities were rated on a continuous linear scale ranking from 0 (no perception of the descriptor) to 10 (very intense perception of the descriptor) and recorded using FIZZ software (Biosystemes®, Couternon, France).

The nature of the descriptors was defined by the trained panellists in preliminary studies (unpublished data). The sensory attributes were for milk: overall intensity of the flavour, goat and rancid flavours; for fresh cheeses: overall intensity of the odour, goat odour, overall intensity of the flavour, goat, acid, bitter, alcohol, metallic/oxidised, pungent, rancid, and soap flavours; for ripened cheeses, overall intensity of the odour, goat odour, overall intensity of the flavour, goat, acid bitter, ammonia, mushroom, metallic/oxidised, mouldy, pungent, rancid, and soap flavours.

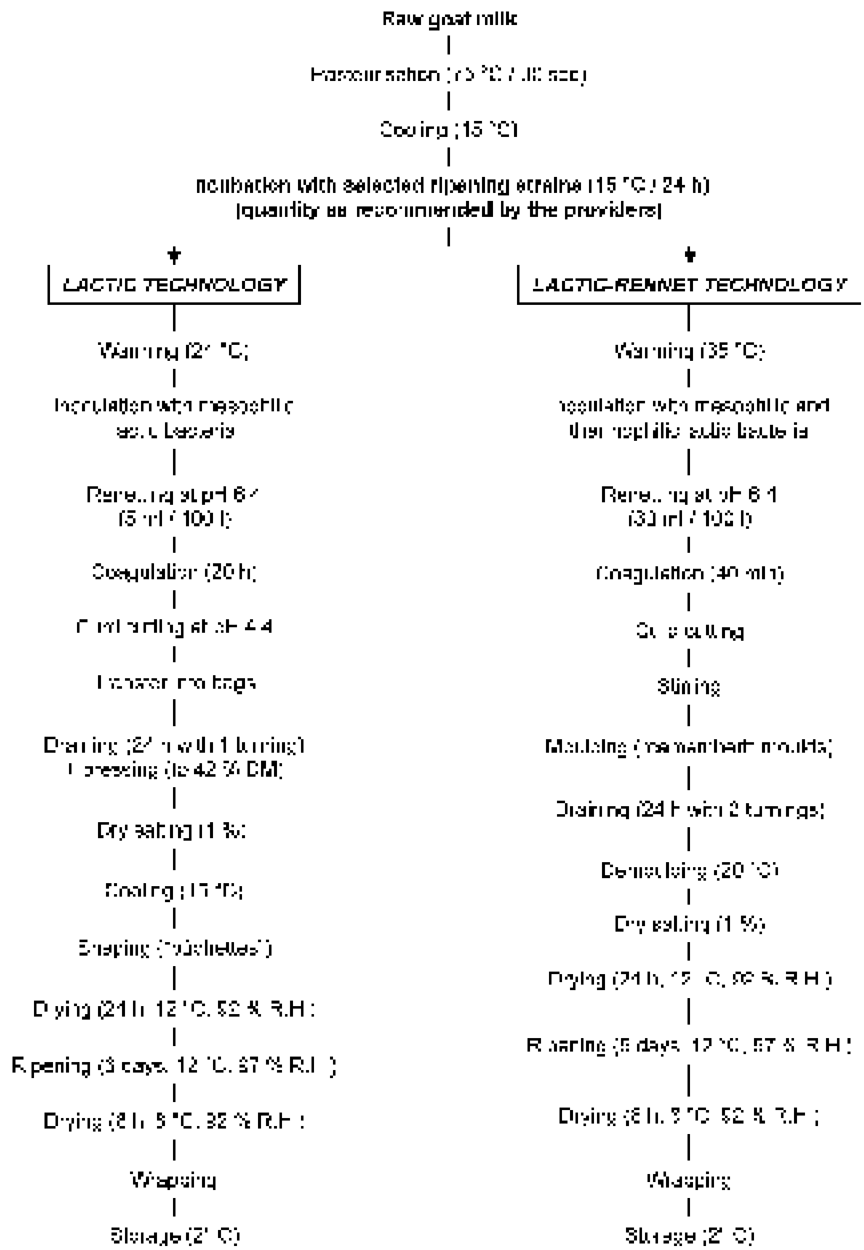

Fig. 1. Process schemes for cheese-making.

In a previous study, the intensities of defect descriptors which corresponded to the perception limit of flavour defects in ripened cheeses were defined by the trained panellists (unpublished results). For pungent, bitter and soap, these threshold intensities were 2.36, 2.03 and 1.44, respectively.

2.5. Statistical analysis

The sensorial analysis data were submitted to an analysis of variance using FIZZ software (Biosystemes®, Couternon, France). A fixed model with two factors (product and judge) was applied.

A principal component analysis was performed on the entire group of ripened cheeses (lactic + Camembert-type), using STATITCF software (ITCF, version 3, Boigneville, France). The normalised scores of sensorial descriptors and lipolysis were used as active and supplementary variables, respectively.

3. Results and discussion

3.1. Selection of ripening strains

Of the 20 ripening strains tested, there were 5 *Penicillium candidum* (or *album*) and 6 *Geotrichum*

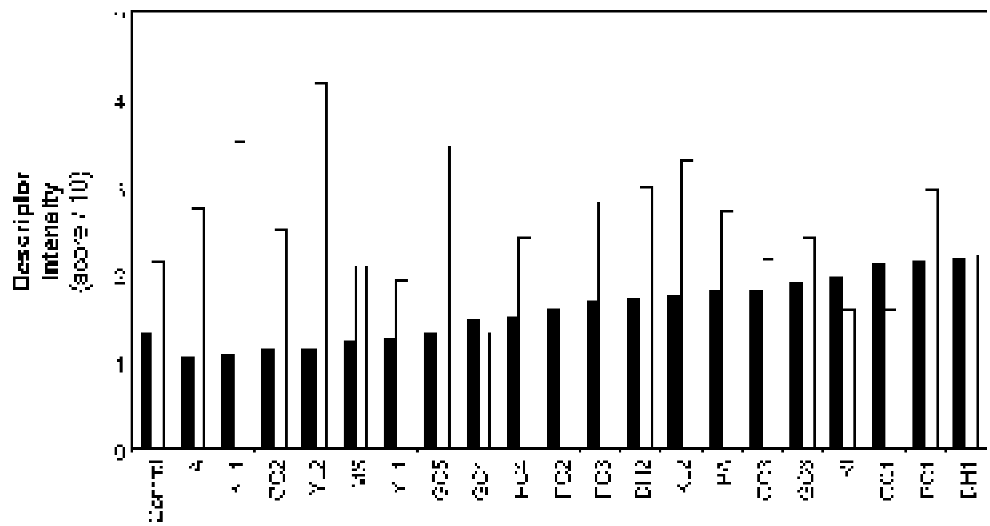

Fig. 2. Screening of the flavouring aptitudes of ripening strains in pasteurised goat milk. Mean of two replicate determinations (white bars: rancid taste intensity; black bars: goat flavour intensity; codes for ripening strains are given in Table 1).

candidum, which are commonly used for goat cheese ripening. Seven yeasts were also tested: 2 *Kluyveromyces lactis*, 2 *Debaryomyces hansenii*, 1 *Rhodosporidium infirmominiatum* and 2 *Yarrowia lipolytica*. According to the survey of Nahabieh and Schmidt (1990), *Debaryomyces hansenii* is the dominant yeast in goat cheeses and *Yarrowia lipolytica* is found almost exclusively in goat cheeses. However, *Yarrowia lypolytica* was also isolated from several varieties of mould-ripened and smear-ripened cheeses made from bovine milk (Eliskases-Lechner, 1998). Additionally, a *Micrococcus* strain and an aromatisation mix were tested.

These different ripening strains were selected according to their ability to develop goat flavour in pasteurised goat milk (72°C, 15 s) after an incubation period at 15°C for 24 h, without giving rise to a marked rancid taste. The variation of lipolysis was also evaluated after the incubation period. The results concerning the evaluation of goat flavour and rancid taste of milk after incubation with the various strains are shown in Fig. 2.

For the experiments on cheeses, the strains GC1, PC1, RI and DH1 were selected since they were associated with the greatest increases of the goat flavour intensity (Fig. 2). PC1 and GC1 were used as principal strains for the manufacture of all cheeses. These two strains are widely used for the manufacture of soft surface-ripened goat cheeses, notably for their role in the development of the superficial rind of cheeses during ripening. DH1 and RI were used in some cases in association with PC1 and GC1, in order to evaluate the impact of such microbial cocultures on the flavour of goat cheeses.

Additionally, the results of this screening phase showed that a marked rancid taste was perceived in milks incubated with KL1, KL2, YL2, and GC5 (Fig. 2). As previously shown by Woo and Lindsay (1984), the appearance of a rancid taste in milk products may be due to an important production of C4 to C8 fatty acids that come from an excessive fat hydrolysis. According to Viljoen (1998), the lipolytic activities of *K. lactis* and *Y. lypolytica* are extremely high. In this study, a two-fold increase in the lipolysis level of milk was actually observed after incubation with YL2 (0.32 g OA/100 g fat) and KL2 (0.34 g OA/100 g fat) as compared to the control milk (0.16 g OA/100 g fat). However, it seems tenuous to link the observed rancid taste to the variation of the lipolysis level of milk since only a few percentage of short chain fatty acids is counted via the BDI method, which was used in this study for the measurement of lipolysis in milk (Deeth et al., 1975).

3.2. Experiments on cheeses

Lactic and Camembert-type cheeses were produced as described in Fig. 1. Pasteurised goat milk was distributed in basins (40 L) before cheese-making operations, and 8 combinations of the selected ripening strains were tested simultaneously: (GC1); (PC1); (GC1 + DH1); (GC1 + RI); (PC1 + DH1); (PC1 + RI); (GC1 + PC1); (GC1 + PC1 + DH1).

3.2.1. Milk composition

The mean physico-chemical and microbiological composition of pasteurised goat milk used for lactic and Camembert-type cheese production is given in Table 2. The results indicated that the lipolysis level in milks was low and that yeasts and moulds were almost absent from the two batches of milk. This was necessary to avoid any interference in the experiments due to the quality of the raw material. The relative amounts of the different caseins, determined by reverse phase HPLC, indicated that the milk of the chosen flock was not unusual concerning the αs1 casein genetic polymorphism, i.e. the αs1 casein represented 16.7% of the total casein. This criteria should be taken into account in sensorial studies concerning goat milk since it has been postulated that there is a relationship between the genetic polymorphism of αs1 casein in milk and the flavour of goat cheeses (Delacroix-Buchet et al., 1996; Lamberet, Degas, Delacroix-Buchet, & Vassal, 1996; Pierre, Le Quéré, Famelart, Riaublanc, & Rousseau, 1998). The fat and protein contents of the milk used for Camembert-type cheeses were higher compared to those found for the one used for lactic cheeses. Although these milks were taken from the same flock, Camembert-type cheeses were produced six weeks after lactic cheeses, and the observed compositional changes in milk were ascribed to the known effect of the lactation period on goat milk composition (Lopez, Luna, Laencina, & Falagan, 1999; Zeng, Escobar, & Popham, 1997).

3.2.2. Physico-chemical and sensorial changes during cheese ripening

The physico-chemical characteristics of cheeses at day 2 and day 30 are shown in Tables 3 and 4 for lactic and Camembert-type cheeses respectively.

These results showed that the pH increase during ripening was similar for both types of cheeses. However, the final pH was markedly higher for the Camembert-type cheeses (Table 4). Concerning technological parameters such as fat in dry matter (FDM) or moisture in non-fat substance (MNFS), the obtained results corresponded to those usually found for these types of cheeses.

The sensorial evaluation (including the lipolysis level) of fresh and ripened cheeses are shown in Figs. 3A and B for lactic and Camembert-type cheeses, respectively. Fresh cheeses were characterised by a low lipolysis level, which increased drastically during ripening. This increase was much more pronounced for lactic cheeses

Table 2
Physico-chemical and microbiological composition of pasteurised goat milk (same flock) used for cheese making (mean of two replicate determinations)

		For lactic cheeses		For Camembert-type cheeses
pH		6.75		6.53
Acidity	°Dornic	15		20
Protein	g/L	33.9		37.7
α_{s1} casein content	% of total casein		16.7	
α_{s2} casein content	% of total casein		13.8	
κ casein content	% of total casein		15.2	
β casein content	% of total casein		54.3	
Fat	g/kg	38.9		44.6
Lipolysis	g OA/100 g fat	0.26		0.16
Somatic cells count	log cells/mL	6.42		6.22
Total germs	log CFU/mL	4.68		4.72
Yeasts and moulds	log CFU/mL	0.32		0.32

Table 3
Physico-chemical characteristics of lactic cheeses ($n = 8$)[a]

	pH	DM (g/kg)	Fat (g/kg)	FDM (%)	MNFS (%)
At day 2					
Mean	4.32	42.8	22.1	51.6	73.4
SD	0.04	0.6	0.2	0.4	0.6
CV (%)	1.02	1.3	0.8	0.7	0.8
min	4.24	42.2	22.0	51.0	72.3
max	4.36	44.0	22.5	52.2	74.1
At day 30					
Mean	5.52	45.3	24.1	53.3	72.1
SD	0.13	1.3	1.2	2.5	1.7
CV (%)	2.29	2.8	4.8	4.8	2.4
min	5.36	43.5	22.0	50.6	69.3
max	5.71	47.7	25.0	56.1	73.9

[a] DM: dry matter; FDM: fat in dry matter; MNFS: moisture in non fat substance.

Table 4
Physico-chemical characteristics of Camembert-type cheeses ($n = 8$)[a]

	pH	DM (g/kg)	Fat (g/kg)	FDM (%)	MNFS (%)
At day 2					
Mean	5.36	46.1	23.3	50.7	70.3
SD	0.07	2.1	0.7	1.3	2.2
CV (%)	1.39	4.5	3.1	2.6	3.1
min	5.25	42.7	22.0	47.6	66.2
max	5.44	49.4	24.0	51.6	73.4
At day 30					
Mean	6.92	48.5	25.5	52.5	69.1
SD	0.11	1.6	1.0	1.2	1.5
CV (%)	1.55	3.3	3.9	2.3	2.2
min	6.76	46.1	24.0	50.2	67.3
max	7.06	50.9	27.0	54.2	71.9

[a] DM: dry matter; FDM: fat in dry matter; MNFS: moisture in non fat substance.

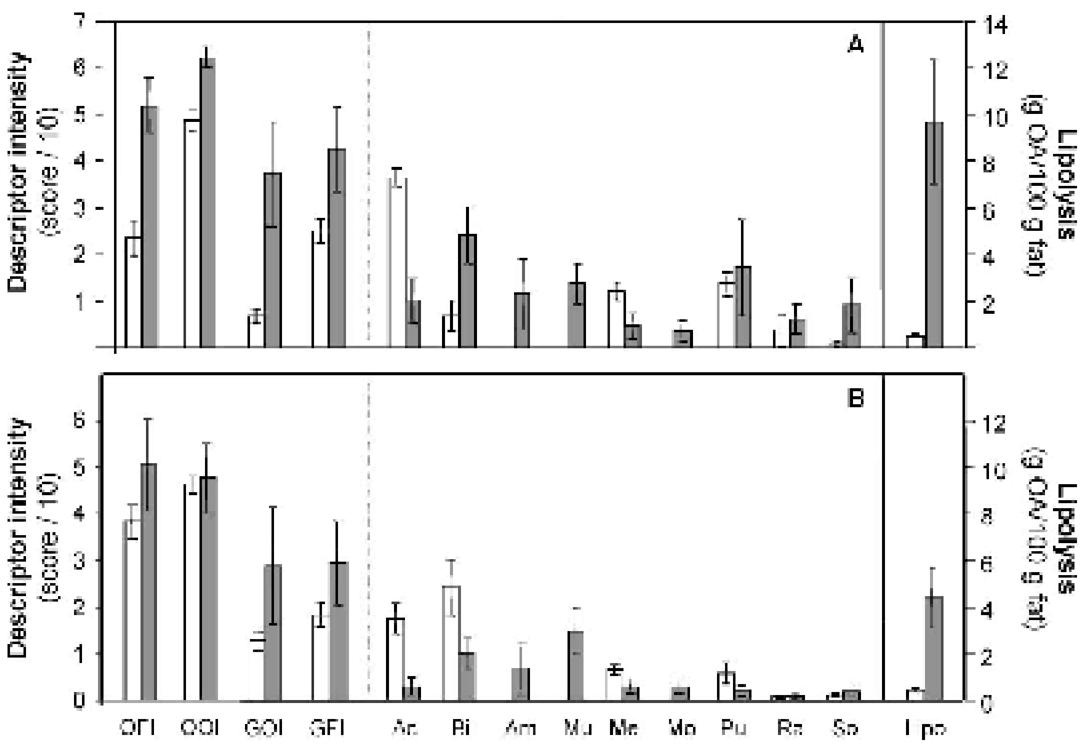

Fig. 3. Sensorial evaluation and lipolysis levels of lactic (A) and Camembert-type cheeses (B) (white bars: cheeses at day 2; grey bars: cheeses at day 30). Mean and standard deviations ($n = 8$). Abbreviation key: OFI: overall flavour intensity, OOI: overall odour intensity, GFI: goat flavour intensity, GOI: goat odour intensity, Ac: acid, Bi: bitter, Am: ammonia, Mu: mushroom, Me: metallic, Mo: mouldy, Pu: pungent, Ra: rancid, So: soap, Lipo: lipolysis level.

(Fig. 3A) as compared to Camembert-type cheeses (Fig. 3B). After ripening, the cheese flavour (overall intensity) increased for both types of cheeses and the odour (overall intensity) was enhanced only for lactic cheeses. For both lactic and Camembert-type cheeses, the goat odour and flavour intensities increased during ripening. The acid score was the highest for lactic cheeses, but ripening caused a reduction of the acid flavour for both types of cheeses, as a result of the utilisation of lactic acid by the surface flora. The fresh lactic cheeses were characterised by a low bitterness, which increased during ripening and was then above the unacceptable intensity for most of the cheeses. The opposite situation was observed for Camembert-type cheeses, starting at the fresh state with a marked bitterness that was reduced after ripening. The scores obtained for pungent, rancid and soap descriptors were the highest in lactic cheeses. They were very low for

Camembert-type cheeses and remained nearly unchanged after ripening.

These results indicated that the overall flavour, as well as the goat odour and goat flavour were higher in lactic cheeses, which could be partly due to the well known effect of pH on sensorial evaluation of milk products (Kuzdal-Savoie, 1980). Lipolysis level was also greater in lactic cheeses as compared to Camembert-type ones. The higher MNFS obtained in lactic cheeses (Table 3) could possibly facilitate the enzymatic activities of the surface flora and thus lead to an enhanced lipolysis in these cheeses. An excessive fat hydrolysis could explain the higher occurrence of flavour defects in lactic cheeses (notably bitterness, pungent and soap).

In addition, as indicated by the wide standard deviations, a noticeable dispersion of the sensorial parameters (including lipolysis) was obtained for ripened cheeses. The next step of this study was to clarify the origin of this variability, by evaluating the distinct flavouring patterns induced by the ripening strains in goat cheeses.

3.2.3. *Effect of the ripening strains on lipolysis and sensorial properties of goat cheeses*

There was no significant effect of the ripening strains on the sensorial characteristics of fresh cheeses, except for bitterness, which was significantly higher in fresh cheeses incubated with GC1 + PC1 + DH1 (data not shown). On the contrary, the sensorial properties of ripened cheeses were affected to a great extent by the nature of the ripening strains, as shown in Tables 5 and 6 for lactic and Camembert-type cheeses, respectively.

Lactic cheeses ripened with GC1 alone or GC1 associated with DH1 or RI showed the lowest lipolysis levels and the highest scores for goat odour and flavour intensities (Table 5). The goat flavour was more intense when GC1 was used in association with DH1 or RI. The intensity of defect descriptors were low, especially when the association (GC1 + RI) was used.

The utilisation of PC1 for ripening, alone or associated with DH1 or RI, was detrimental for the sensorial quality of lactic cheeses, leading to high lipolysis levels, low goat odour and flavour intensities, and to high acid, bitter, ammonia, pungent, and soap flavours (Table 5). According to Alhir, Marhakis, and Chandan (1990), low molecular weight triglycerides are a better substrate for the exo-cellular lipase of *P. candidum* than high molecular weight triglycerides. Thus, lipolysis by *P. candidum* could lead to the formation of short and medium chained fatty acids, which might be responsible for pungent and soap defects (Brennand et al., 1989). Furthermore, *P. candidum* is able to transform medium chained fatty acids in methyl-ketones through the β-oxidation pathway leading to mushroom and mouldy notes (Molimard & Spinnler, 1996). Concerning goat cheeses, some medium chained fatty acids are particularly responsible for the typical flavour (octanoic, 4-ethyloctanoic, 4-methyloctanoic). Thus, the β-oxidation of these aroma compounds by PC1 would limit the development of the goat flavour and lead to mushroom and mouldy flavours, due to the

Table 5
Sensorial characteristics of ripened lactic cheeses as a function of the ripening strains[a]

	GC1	GC1 + DH1	GC1 + RI	PC1	PC1 + DH1	PC1 + RI	PC1 + GC1	PC1 + GC1 + DH1	
pH	5.39	5.36	5.52	5.51	5.50	5.49	5.71	5.70	
Lipolysis	7.62	5.78	7.78	11.00	11.70	9.11	14.15	10.35	
									p
Odour									
Overall intensity	5.55ab	5.77a	5.42abc	4.59bc	4.38c	4.60bc	5.37abc	5.91a	**
Goat	4.80a	4.87a	4.83a	2.77bc	2.46c	2.29c	3.57abc	4.16ab	***
Flavour									*p*
Overall intensity	6.38	6.17	6.09	6.23	5.99	6.08	6.51	6.50	ns[b]
Goat	4.47ab	5.44a	5.64a	3.48b	3.33b	3.34b	3.96b	4.43ab	***
Acid	0.56bc	0.55bc	0.40c	1.05abc	1.25ab	1.46a	1.69a	1.10abc	*
Bitter[c]	2.16ab	2.53ab	1.58b	2.93a	3.11a	2.94a	2.55ab	1.58b	**
Ammoniac	0.25c	0.04c	0.50bc	1.70ab	1.26abc	1.78a	1.94a	1.66ab	***
Mushroom	0.98	0.92	0.74	1.38	1.81	1.98	1.52	1.54	ns
Metallic/oxidised	0.19	0.65	0.86	0.49	0.77	0.13	0.30	0.30	ns
Mouldy	0.41	0.06	0.13	0.74	0.20	0.37	0.57	0.38	ns
Pungent[c]	0.69bc	0.50c	0.39c	2.29a	2.48a	2.91a	2.44a	2.09ab	***
Rancid	0.26	0.75	0.35	0.51	1.26	0.45	0.62	0.70	ns
Soap[c]	0.66bcd	0.22cd	0.03d	1.56a	1.52a	0.97abc	1.35ab	0.93abc	**

[a] Means in the same row without a common following lettering are significantly different (*: $p<0.05$; **: $p<0.01$; ***: $p<0.001$).
[b] ns: not significant.
[c] The underlined values correspond to unacceptable intensities (flavour defect) as described under the Materials and Methods section.

Table 6
Sensorial characteristics of ripened Camembert-type cheeses as a function of the ripening strains[a]

	GC1	GC1 + DH1	GC1 + RI	PC1	PC1 + DH1	PC1 + RI	PC1 + GC1	PC1 + GC1 + DH1	
pH	6.87	6.85	6.90	6.76	6.87	7.01	7.06	7.05	
Lipolysis	4.72	4.25	3.96	3.01	4.33	2.68	6.02	6.36	
Odour									*p*
Overall intensity	5.64a	5.74a	5.60a	3.79b	4.22b	3.60b	5.76a	5.96a	***
Goat	4.28a	3.77a	3.91a	0.76c	1.85bc	1.84bc	2.98ab	3.66a	***
Flavour									*p*
Overall intensity	5.12a	5.12a	5.51a	3.87b	3.95b	3.85b	5.24a	5.51a	***
Goat	3.82a	3.09abc	3.72ab	1.47d	2.47cd	2.33cd	2.64bc	4.09a	***
Acid	0.42	0.17	0.61	0.16	0.41	0.03	0.15	0.44	ns[b]
Bitter	1.29	1.24	1.33	0.51	1.23	0.66	1.08	0.72	ns
Ammoniac	0.64abcd	0.15cd	1.13abc	0.11d	0.52bcd	0.08d	1.54a	1.23ab	***
Mushroom	1.19bcd	1.26abcd	1.10cd	2.08a	1.77abc	2.05ab	0.78d	1.56bcd	*
Metallic/oxidised	0.47	0.39	0.47	0.18	0.24	0.07	0.38	0.20	ns
Mouldy	0.20	0.53	0.03	0.46	0.29	0.22	0.25	0.30	ns
Pungent	0.06	0.18	0.33	0.07	0.16	0.21	0.21	0.45	ns
Rancid	0.20	0.04	0.04	0.03	0.04	0.05	0.13	0.20	ns
Soap	0.09	0.21	0.24	0.16	0.12	0.17	0.37	0.21	ns

[a] Means in the same row without a common following lettering are significantly different (*: $p<0.05$; **: $p<0.01$; ***: $p<0.001$).
[b] ns: not significant.

production of methyl-ketones. Although no significant differences were found, the scores for mushroom and mouldy notes were actually higher in cheeses ripened with *P. candidum*.

Results in Table 5 showed that the association (GC1+PC1) for lactic cheese ripening gave an intermediate goat flavour intensity but high scores for acid, bitter, ammonia, pungent and soap descriptors, probably due to high lipolysis levels. The use of the association (GC1+PC1+DH1) had little effects on the goat flavour but seemed to enhance slightly the sensorial quality of cheese (no flavour defects).

For Camembert-type cheeses (Table 6), the same tendencies were observed, although the scores obtained for most of the sensorial descriptors were lower than those found for lactic cheeses. Ripening with GC1 alone or GC1 associated with DH1 or RI gave Camembert-type cheeses with the best sensorial quality, i.e. high goat flavour intensity and no flavour defects. No differences were found between cheeses ripened with GC1 alone and cheeses ripened with GC1 associated with DH1 and RI.

Results in Table 6 showed that ripening with PC1 (alone or associated with DH1 or RI) led to lower goat flavour intensity and to the absence of flavour defects in Camembert-type cheeses. The score for mushroom was significantly higher in such cheeses ripened with PC1 alone, which could be related to the formation methyl-ketones through the β-oxidation of fatty acids (Molimard & Spinnler, 1996), as discussed above.

The Camembert-type cheeses ripened with the association (GC1+PC1) had higher lipolysis levels, but their sensorial characteristics were similar to those ripened with GC1. However the association (GC1+PC1+DH1) led to a more intense goat flavour (Table 6).

These results were further confirmed by a principal component analysis of the sensorial characteristics of ripened cheeses (Fig. 4). The cheese samples could be distinguished along the first dimension according to their lipolysis level, their overall flavour intensity and their flavour defects (pungent, rancid, soap, acid, bitter, ammonia). The second dimension was determined by the overall odour intensity, the goat flavour and odour intensities and by the mushroom and mouldy notes (Fig. 4A). The cheese samples were well discriminated on the first factorial plot and could be divided into four groups (Fig. 4B). Group L1 (lactic cheeses ripened with PC1 alone or PC1 associated with other strains) was distinguished by a high occurrence of flavour defects and a high lipolysis. Cheeses from group L2 (lactic cheeses ripened with GC1 alone or GC1 associated with DH1 or RI) were distinguished by a high typical taste and odour, with no flavour defects. Group C1 (Camembert-type cheeses ripened with PC1 alone or PC1 associated with DH1 or RI) was characterised by mushroom and mouldy notes, low typical taste, and low lipolysis level. Cheeses of group C2 (Camembert-type cheeses ripened with GC1 alone or GC1 associated with other strains) had a satisfactory typical taste, with no flavour defects. From a sensorial point of view, the

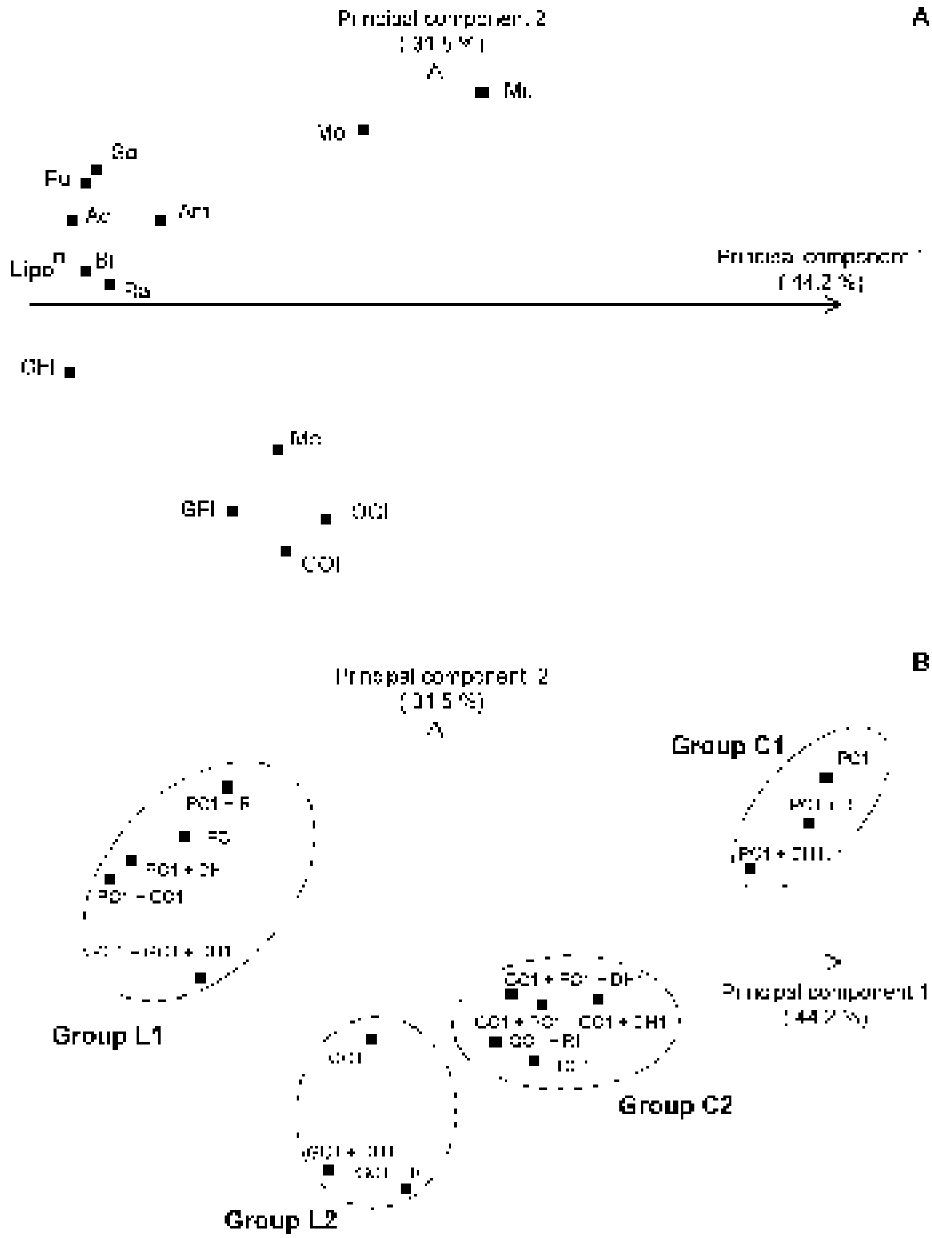

Fig. 4. Principal component analysis of the sensory data. (A) Correlation plot. (B) Plot of the cheese samples with the corresponding ripening strains (L1 and L2: lactic cheeses; C1 and C2: Camembert-type cheeses). The abbreviation key is the same as Fig. 3.

two groups of cheeses ripened with *G. candidum* (i.e. L2 and C2) were the more suitable products.

4. Conclusions

The results presented here indicate that the control of the sensorial quality of goat cheeses could be achieved by the choice of the ripening strains. Particularly, the use of *G. candidum* as a ripening agent for soft goat cheeses led to the development of a suitable typical flavour, and to satisfying overall sensorial characteristics. The flavouring aptitudes of mixed strains of surface flora have been recently investigated for surface-ripened cheeses made from cow milk (Molimard, Lesschaeve, Issanchou, Brousse, & Spinnler 1997; Martin et al., 1999), but there is a lack of information concerning goat cheeses. In this study, the use of microbial associations led in some cases to an improvement of the sensorial quality of ripened cheeses. However, a lot of work remains to be done to understand the impact of mixed cultures of ripening strains on the flavour of goat cheeses.

In addition, the obtained results pointed up the relationship existing between the lipolysis level and the typical flavour of goat cheeses. As shown by Fig. 5, a

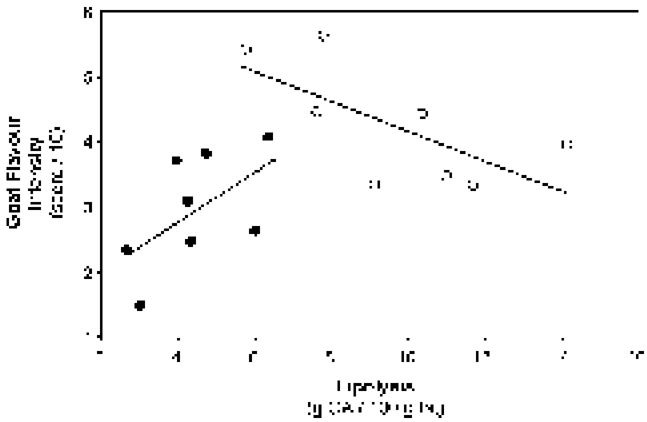

Fig. 5. Goat flavour intensity as a function of lipolysis level in ripened goat cheeses (closed circles: Camembert-type cheeses; open circles: lactic cheeses).

positive correlation between goat flavour and lipolysis was obtained for Camembert-type cheeses ($R = +0.65$) whereas it was negative for lactic cheeses ($R = -0.78$). This result clearly indicated that the technology used for cheesemaking exerts a major influence on this relationship. For each type of cheese, the best sensorial quality corresponds to a specific and optimal lipolysis level. The development of a suitable typical taste requires a certain level of lipolysis, but lipolysis should be controlled in order to limit the occurrence of flavour defects. For small and medium dairy enterprises, the use of the lipolysis level to monitor the sensorial quality of goat cheeses could be very useful, given the fact that the evaluation of the lipolysis is faster, easier and less expensive than a more accurate analysis of individual free fatty acids by gas chromatography. However, it should be kept in mind that this application must be tailored with respect to each technological scheme used for cheese making.

In that context, a better comprehension of the influence of the technological and physico-chemical parameters on the sensorial quality of goat cheeses would be useful. Therefore, future work on the sensorial quality of goat cheeses will be focused on the respective roles of pH, moisture and NaCl on the lypolysis and flavour development induced by ripening strains.

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