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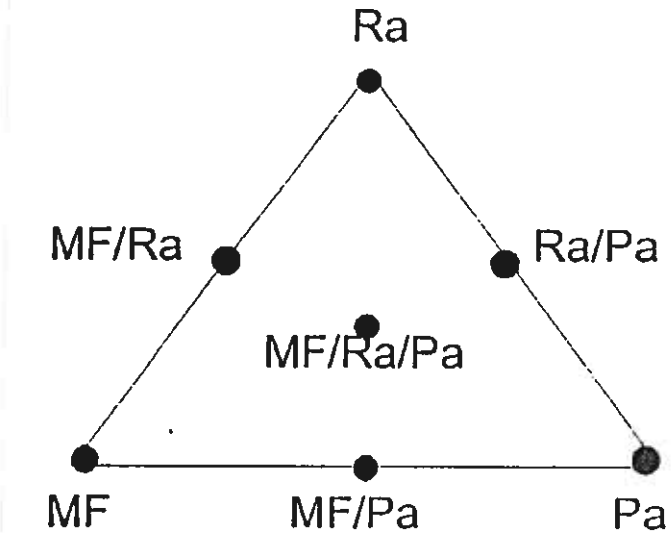

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Original article

Influence of milk treatment and ripening conditions on quality of Raclette cheese

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Abstract — The influence of ripening temperature (11, 14, 17, 20 °C) and ripening time (60, 90 days) on sensory properties and melting quality of Raclette cheeses made from raw milk, pasteurised milk and microfiltered milk has been investigated using the 'special cubic model' experimental design. With increased ripening temperature substantial acceleration of ripening was achieved. The higher ripening temperature led to higher counts of propionibacteria in raw milk cheeses, and, independent of the milk treatment, to higher concentration of free short chain acids, accelerated proteolysis, higher aroma intensity, decrease in water content and higher firmness. Raw milk Raclette should be ripened at ≤ 11 °C for 90 days, whereas pasteurised milk Raclette can be ripened at ≤ 14 °C for 90 days and microfiltered milk Raclette at 17 °C for 60 days in order to achieve comparable sensory properties and melting quality.

Raclette cheese / milk treatment / pasteurization / microfiltration / accelerated ripening / melting quality

1. INTRODUCTION

Raclette cheese is a Mountain cheese of Swiss origin; in the past it has been manufactured exclusively from raw milk in the Alps in Wallis during the summer months. As the popularity and therefore the demand for this cheese variety increased because of catering trade, Raclette cheese is being now produced from raw and pasteurised milk during the whole year in lowland regions. At present Raclette is the most important semi-hard cheese in Switzerland and belongs, besides Emmentaler and Gruyère, to the most often manufactured cheese varieties with a volume of 11600 *t* per year. Raclette cheese is consumed in a melted form as "racler" (means to scrape, to shed) and has to possess specific properties such as no fat separation as oiling off, proper break

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off of the melted body and the perception of toughness, but not rubberiness like chewing gum, in the mouth [12, 13]. The commercial Raclette cheeses from raw or pasteurised milk show significant sensory differences. In general, cheeses made from pasteurised milk are considered milder whereas raw milk cheeses develop a more intense flavour. The raw milk microorganisms appear to be the primary factor for the differences between raw milk Raclette and Raclette made from pasteurised milk [15].

A technology based on crossflow microfiltration, a pressure-driven filtration using a membrane pore size of 1.4 µm, has been introduced by Holm et al. [8] and Piot et al. [31] with the aim to remove very efficiently bacteria and spores from milk. On average, the content of bacteria in the milk is reduced to few hundred counts / mL, independent of the initial level of the bacterial population [36].

The microfiltration process for debacteriazation, marketed as the "Bactocatch" process [26, 29, 37] has proved to be suitable for manufacturing Grevé and Herrgårds cheese [25], Comté-type cheese [7], Swiss-type cheese [6, 9, 10] and Cheddar cheese [28, 33]. These investigations showed that the indigenous flora of milk can be significantly reduced by microfiltration, however, with the result that the overall aroma intensity of the cheeses compared to raw milk cheeses is less pronounced.

Raw milk Raclette cheese is usually ripened at 11 °C for 90 days. At higher ripening temperatures, propionibacteria are involved in undesirable secondary fermentation. Bouton et al. [7] found that Comté cheese made from microfiltered milk had a lower concentration of propionic acid than cheese made with raw milk. The reduction of propionibacteria by microfiltration allows the acceleration of ripening by increasing the ripening temperature without the risk of propionic acid fermentation. To our knowledge, no investigations have been recorded in the literature characterising ripening of Raclette produced from MF milk at elevated temperatures.

The purpose of this study was to investigate the influence of ripening temperature at four levels (11, 14, 17, 20 °C) and ripening time at two levels (60, 90 days) on sensory properties and melting quality of Raclette cheese made from raw milk, pasteurised milk and microfiltered milk using a 'special cubic model experimental design'.

2. MATERIALS AND METHODS

2.1. Cheese manufacture

Raw milk was separated into cream and skim milk at 30 °C. A third of the skim milk was microfiltered at 40 °C. A microfiltration unit from Tetra Alcross M (MFS-7 pilot plant, Tetra Pak Filtration Systems, Lund, Denmark) with Sterilox membrane (pore size of 1.4 µm, surface area of 1.4 m^2, flux of 300 $L \cdot h^{-1} \cdot m^{-2}$, concentration factor 20:1) was used. Cream and MF retentate were separately high temperature treated (HTT) at 121 °C for 4 s and remixed with MF skim milk at 40 °C in a sterilised cheese vat to standardise the fat content (3.5%). Non-microfiltered raw and pasteurised skim milk was mixed with HTT cream in the same way. The pasteurisation of skim milk was carried out in the cheese vat (Fig. 1).

Raclette cheeses were produced in the pilot plant of the FAM (Swiss Federal Dairy Research Institute, Liebefeld, Bern, Switzerland) according to the following manufacturing protocol: 70 L cheesemilk was placed in a sterilised steel cheese vat, inoculated with 2 g mesophilic starter culture (*Lactococcus lactis* subsp. *lactis* and subsp. *cremoris*, MA011, Texel, Winkler, Switzerland) and pre-ripened at 28 °C for 45 min. The milk was than adjusted to 32 °C and 12 mL Rennet (Standard Labextrakt, Winkler, Switzerland), diluted in 1 L water, added. After 30 min, when the coagulum reached the desired consistency, it was cut to grains of 10–20 mm diameter; 30 L water

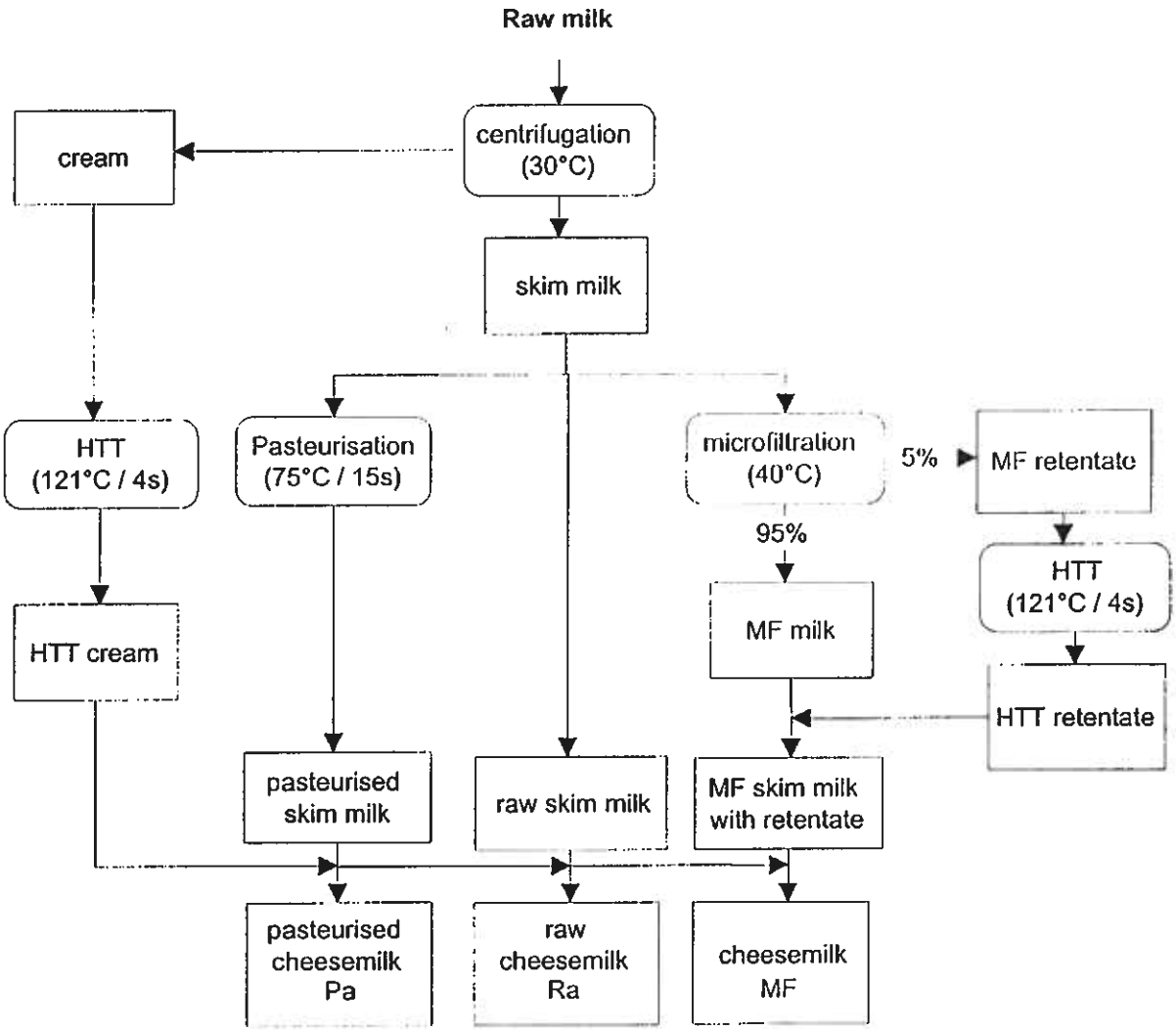

Figure 1. Preparation of milk for cheesemaking.

of 30 °C was added, the mixture heated to 38 °C in 15 min and stirred for additional 15 min at 38 °C. A part of the whey was drained off and the curd was pressed in a mould at 6 bar for 15 min and subsequently at 8 bar for 30 min. The cheese remained in the mould overnight. The temperature decreased from 35 °C to 25 °C and the pH was in 5.2–5.1 range. Afterwards, the cheeses were placed in a saturated NaCl brine of 11–12 °C for 24 h. Ripening conditions were 11, 14, 17, 20 °C or 60 and 90 days at 95% relative humidity.

Cheeses were made according to the experimental design from 100% raw, past. or MF milk, from 50/50 combinations of each, or from 1/3 1/3 1/3 mixture of all three milk types. All cheeses were manufactured in duplicate for each of the ripening conditions (11, 14, 17, 20 °C) and analysed after 60 and 90 days of ripening for microbial flora, glycolysis, lipolysis and proteolysis, sensory properties and melting quality.

2.2. Microbiological analysis

The cheesemilk, as well as the cheeses at the end of maturation, were examined for their microflora. Enterobacteriaceae were determined on VRBG agar (1 day, 37 °C) [1]. Enterococci were analysed on kanamycin aesculin azide agar medium (2 days, 37 °C) [30]. Propionibacteria were analysed on lactate agar (10 days, 30 °C) [17].

Psychrotrophs were analysed on standard methods agar incl. 1.0 g skim-med milk powder per litre (10 days, 6.5 °C) according to [22]. Salt tolerant bacteria were analysed on mannite-NaCl agar (2 days, 37 °C) [36]. Facultatively heterofermentative Lactobacilli were anaerobically analysed on agar with mannite (3 days, 38 °C) [24].

2.3. Chemical analysis

Total nitrogen (TN), pH 4.6 soluble nitrogen (SN4.6) and non protein nitrogen (NPN) as the 12% TCA soluble nitrogen, were determined by the Kjeldahl method according to [20] with a Büchi B-435 digestion unit and a Büchi B-339 distillation unit (Flawil, Switzerland). The SN4.6 and NPN fractions were prepared according to the method of Collomb et al. [8] and the results expressed in % total nitrogen. After isolation from cheese by steam distillation, free short chain acids (acetic and propionic) were determined by gas chromatography using a flame ionisation detector [5]. The water content was analysed gravimetrically [19], the fat content according to Gerber-van-Gulik method [23] and NaCl was calculated from Chloride determined potentiometrically [21].

2.4. Sensory analysis and melting quality

After 60 and 90 days of ripening, the sensory characteristics of the model cheeses were judged by a group of six cheese experts of the FAM according to a standard protocol. The experts applied the standard grading method concerning flavour (score: worst 1 to best 6), texture (score: worst 1 to best 6), preference (score: lowest 1 to highest 6) and intensity of aroma (score: lowest 2 to highest 8). The melting qualities of the model Raclette were judged by a panel of five cheese experts of the FAM according to a protocol regarding separation of fat (score slight 1 to strong 5), viscosity (liquid 1 to viscous 7), consistency (short 1 to long 7) and firmness (soft 1 to solid 7). In addition, the softening and dropping points were measured with an automatic Mettler-Thermosystem 800 with the Dropping point cell FP 83 [16].

2.5. Simplex lattice experimental design

"Mixture designs", such as the simplex lattice experimental design, are suitable for situations where different excipients are mixed to obtain optimal characteristics. To optimise the composition of a three component mixture, the simplex experimental design is a triangle [27].

The experimental design of the study contained three components: raw milk (x_1), pasteurised milk (x_2) and microfiltered milk (x_3) with seven points (variants) constituting a special cubic model design [27]. The distribution of the experimental points in the ternary diagram is shown in Figure 2. The design demands a total of 7 cheeses to be produced. Since the pilot plant equipment consisted of eight vats, the variant 7 was manufactured in duplicate. Each day, the eight treatment combinations were allocated to the vats at random.

The reason for the application of the special cubic model design was to differentiate between the chemical and microbiological effects of the milk treatment. The model allows to determine the dependence of an 'optimum point' from milk treatment, ripening temperature and ripening time.

2.6. Statistical analysis

The special cubic model design can be expressed as a graph in a triangle form determined by seven points of cheeses made from differently treated milk. Each axis of the graph represents the cheeses of one of the three milk treatments with the mixture composition from 0 to 100%. Based on the seven determined variants (points) the software SYSTAT (Systat for Windows, Version

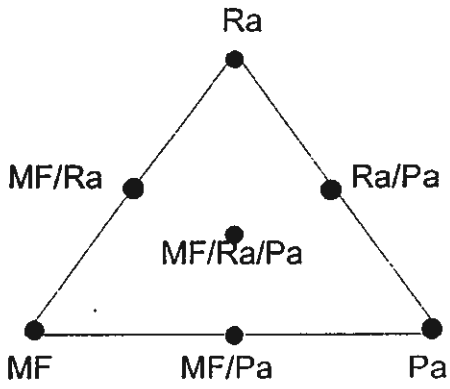

Figure 2. Principle of 'special cubic model design' for cheesemaking from raw milk (Ra), pasteurised milk (Pa), microfiltered milk (MF).

7.0.1, SPSS, Chicago 1997) calculated the corresponding curves in the simplex lattice diagram. The size (diameter) of each of the seven points represents the mean value.

3. RESULTS AND DISCUSSION

3.1. Cheese composition

The gross compositions of the cheeses after 60 and 90 days of ripening are summarised in Table I. No significant difference was found between the cheeses of different milk treatments ripened at the same temperature. To evaluate the overall influence of ripening temperature and time the average of all cheeses is shown. At elevated ripening temperature and longer ripening time the water content decreased as a result of water evaporation. The fat in dry matter of all cheeses ranged between 512 and 519 $g \cdot kg^{-1}$, the NaCl content between 18 and 21 $g \cdot kg^{-1}$. Schär et al. [35] found that in Walliser Raclette cheese of good quality the cheeses lost during ripening (stored at 11 °C) up to 30 g water per kg cheese until the stadium of full maturity at 120 days. This was due to the influence of salt adsorption during brining and the evaporation of water through the rind during maturation. According to Eberhard et al. [12, 13] the mean NaCl content of 21.8 $g \cdot kg^{-1}$ indicated cheeses of good melting quality whereas with NaCl content of 24.2 $g \cdot kg^{-1}$ the melting quality was poor.

3.2. Microbiological analyses

The standardised cheesemilk for the manufacture of the Raclette cheeses was analysed for its bacterial counts (Tab. II). The pasteurised (Pa) and microfiltered (MF) cheesemilk contained counts of

Table I. Mean chemical composition ($g \cdot kg^{-1}$) of all Raclette cheeses at different ripening temperatures after 60 and 90 days.

Age [days]	Ripening temperature [°C]	Chemical composition		
		Water content	Fat content	NaCl
60	11	416.6 ± 9.7	301.1 ± 8.6	18.7 ± 2.2
	14	408.9 ± 8.9	303.1 ± 7.4	19.3 ± 2.2
	17	400.5 ± 8.9	308.1 ± 6.8	20.1 ± 2.0
	20	398.9 ± 4.8	310.5 ± 7.0	19.2 ± 2.2
90	11	410.1 ± 9.9	306.1 ± 9.2	19.0 ± 1.9
	14	401.3 ± 9.8	309.3 ± 9.1	19.7 ± 2.3
	17	388.2 ± 6.1	313.8 ± 7.0	20.4 ± 1.5
	20	392.9 ± 8.3	314.5 ± 8.4	19.5 ± 1.7

Each value is the mean of 16 replicates ± standard deviation.

psychrotrophs and salt tolerant bacteria at a maximum level of 100 cfu·mL^{-1}; enterococci, facultatively heterofermentative lactobacilli (FHL) and propionibacteria were below the detection limit of 10 cfu·mL^{-1}. The raw (Ra) cheesemilk was of good bacterial quality. All mixed cheesemilk (Ra, Pa, MF milk) showed counts according to those in the milk components. These results are in agreement with Demarigny et al. [9] and Beuvier et al. [6] who found absence of, or only low counts of enterococci, FHL and propionibacteria in MF and Pa cheesemilk.

Changes in the numbers of enterococci, FHL and propionibacteria in the cheeses at four different ripening temperatures after 60 and 90 days of ripening are shown in Figure 3. With respect to the counts of enterococci, FHL and propionibacteria the Raclette cheeses after 60 and 90 days could be divided into two groups: (a) cheeses made from raw milk or with raw milk added and (b) cheeses made from pasteurised and microfiltered milk or their combinations. For cheeses from the 1st group, enterococci counts ranged between 10^6 and 10^7 cfu·g^{-1}, irrespective of the added amount of raw milk. Cheeses from Pa and MF milk contained less than 10^2 cfu·g^{-1}. In none of the cheeses an additional growth for enterococci at higher ripening temperature or longer ripening time was detected. In a previous, study Walliser Raclette cheese of good quality showed a mean value for enterococci of 1.3×10^4 cfu·g^{-1} and 4.3×10^4 cfu·g^{-1}, resp. [35], after 60 days and 130 days of ripening, whereas the enterococci count for pasteurised Raclette cheese after 120 days of ripening was below the detection limit of 10 cfu·g^{-1} [17]. In all cheeses made with raw milk, the count of FHL was at a constant level of 10^8 cfu·g^{-1} regardless of the ripening temperature or time. FHL concentration of MF cheeses was lower than in Pa cheeses (below 10^3 cfu·g^{-1} and 10^5 cfu·g^{-1}, resp.). In contrast to counts of enterococci and FHL the propionibacteria counts in cheeses with raw milk increased at ripening temperature above 11 °C whereas in MF and Pa cheeses the count remained on the same level. At 17 °C and 20 °C of ripening the growth of propionibacteria in raw milk cheeses was significantly enhanced thus increasing the risk of secondary fermentation. Schär et al. [35] found that propionibacteria counts above 10^6 cfu·g^{-1} indicated secondary fermentation. In MF and Pa cheeses propionibacteria were not detectable after 60 days; after 90 days at 17 °C and 20 °C, the counts were slightly increased to

Table II. Bacterial populations (log10 cfu·mL^{-1}) in raw (Ra), pasteurised (Pa), microfiltered (MF) cheesemilk and its mixtures, mean values ± standard deviation.

	Standardised cheesemilk				
	Entero-cocci	Fac. het. lactobacilli	Psychro-trophs	Propioni-bacteria	Salt tolerant bacteria
Ra milk	2.0 ± 0.4	2.2 ± 0.2	3.0 ± 0.7	1.1 ± 0.6	3.8 ± 0.3
Pa milk	nd	nd	1.0 ± 0.5	nd	1.3 ± 0.5
MF milk	nd	nd	1.0 ± 0.4	nd	1.2 ± 0.5
Ra / Pa milk	1.9 ± 0.2	1.9 ± 0.1	2.9 ± 0.4	0.9 ± 0.2	3.4 ± 0.1
Pa / MF milk	nd	nd	1.0 ± 0.5	nd	nd
Ra / MF milk	2.1 ± 0.3	2.0 ± 0.5	3.1 ± 0.9	0.9 ± 0.3	3.4 ± 0.5
Ra / Pa / MF milk	1.9 ± 0.2	1.9 ± 0.4	2.7 ± 0.3	1.1 ± 0.3	3.1 ± 0.2

nd: not detectable i.e. below the detection limit of 10 cfu·mL^{-1}. Each value is the mean of four replicates.

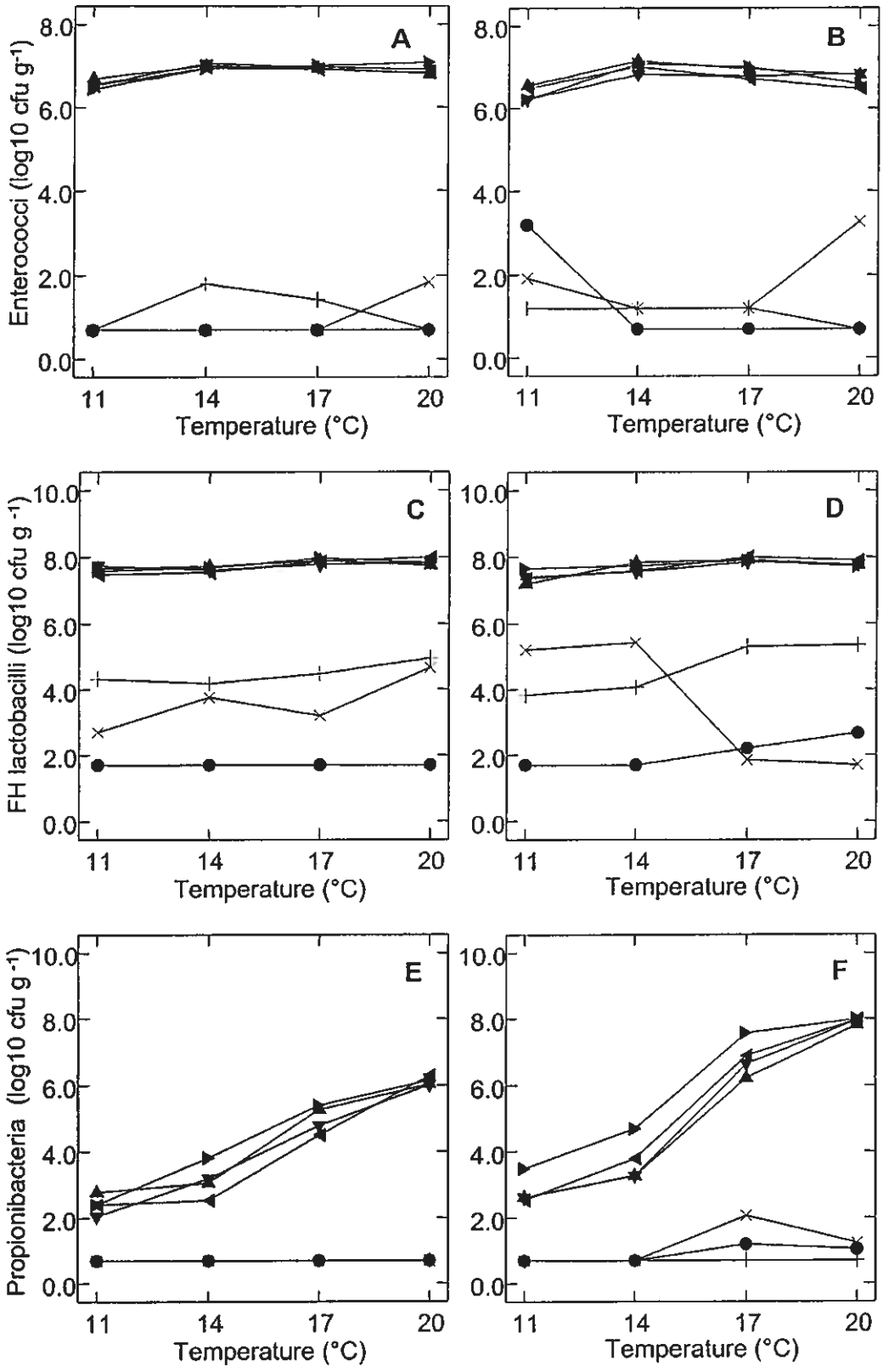

Figure 3. Counts of enterococci after 60 days (**A**) after 90 days (**B**), facultatively heterofermentative (FH) lactobacilli after 60 days (**C**) and after 90 days (**D**), propionibacteria after 60 days (**E**) and after 90 days (**F**) at different ripening temperatures in Raclette cheeses made from raw, pasteurised and microfiltered milk and its mixtures. ▶ raw milk (Ra), + pasteurised milk (Pa), ● microfiltered milk (MF), ◀ Ra/Pa (50:50%), ▲ Ra/MF (50:50%), ▼ Ra/Pa/MF (33:33:33%), × Pa/MF (50:50%). Means of two replicates.

100 cfu·g^{-1}. These results are opposite to those of Demarigny et al. [9] and Beuvier et al. [6] who found that microfiltration and pasteurisation only delayed the growth of enterococci, FHL and propionibacteria in cheeses. In their studies, these three bacterial populations in MF and Pa cheeses after 6 weeks were 10 to 100 fold lower than in Ra cheeses. They concluded that the presence of these microorganisms in MF and Pa cheeses may have been the result of contamination during cheese manufacture.

3.3. Free short chain acids

Again, the cheeses could be divided into two groups: cheeses made from raw milk or with raw milk added and cheeses made from pasteurised and microfiltered milk and their combinations. The concentration of FSCA in cheeses were higher when the indigenous raw milk flora was present. The concentrations of acetic and propionic acids are summarised in Figure 4. The amount of acetic acid was highly affected by elevated ripening temperatures: after 60 days the acetic acid may have originated mainly from the fermentation of citric acid and after 90 days at 17 °C and 20 °C additionally from the fermentation of lactic acid by propionibacteria. This was confirmed by the increased amount of propionic acid in the same period. MF and Pa cheeses showed no secondary fermentation. Similarly, Gallmann [14] found significant differences regarding acetic and propionic acids between Raclette cheeses made from raw and pasteurised milk after 120 days of ripening as a consequence of indigenous bacterial count.

3.4. Proteolysis

The protein and peptide breakdown in all cheeses was highly affected by ripening temperature and time (Fig. 5). After 60 days MF cheeses showed the lowest SN4.6 fraction as indication for the proteolysis "into the width" (SN4.6/TN) whereas the proteolysis "into the depth" (NPN/TN) was almost independent of milk treatment. After 90 days the differences between cheeses with raw milk and MF/Pa cheeses increased with higher ripening temperature. The enhanced proteolysis at elevated temperatures after 90 days can be explained by the fact that secondary fermentation has occurred in cheeses with raw milk as a consequence of high concentrations of propionibacteria. The acceleration of proteolysis at higher ripening temperatures is a well known phenomenon [2, 4, 16, 32]. Temperature adjustments during ripening of Cheddar cheese resulted in manipulation of specific proteolytic activities [2, 4]. The proteolytic activities reflected by breakdown products soluble in 12% TCA (NPN) were enhanced at higher temperatures, due to the increased activity of proteolytic enzymes. This observation is in good agreement with our results.

3.5. Sensory evaluation

Sensory characteristics of cheeses were analysed after 60 and 90 days. The results for attributes 'preference' and 'intensity of aroma' are shown in detail in Figures 6 and 7. Each axis of the graph represents the cheeses of one of the three milk treatments with the mixture composition from 0 to 100% at defined ripening temperature and time.

With respect to 'preference', Raclette cheeses could again be divided in the same two groups as before, i.e. those made from or with raw milk and those made using pasteurised and microfiltered milk (Fig. 6). The 'preference' attribute was affected more by the elevated ripening temperature than by the ripening time. For all cheeses the scores of 'preference' decreased with elevated temperature and enhanced proportion of raw milk. After 60 days the Pa cheeses ripened at 11 °C and 14 °C were scored higher than MF cheeses. After 90 days MF and Pa cheeses were judged in the same range. The

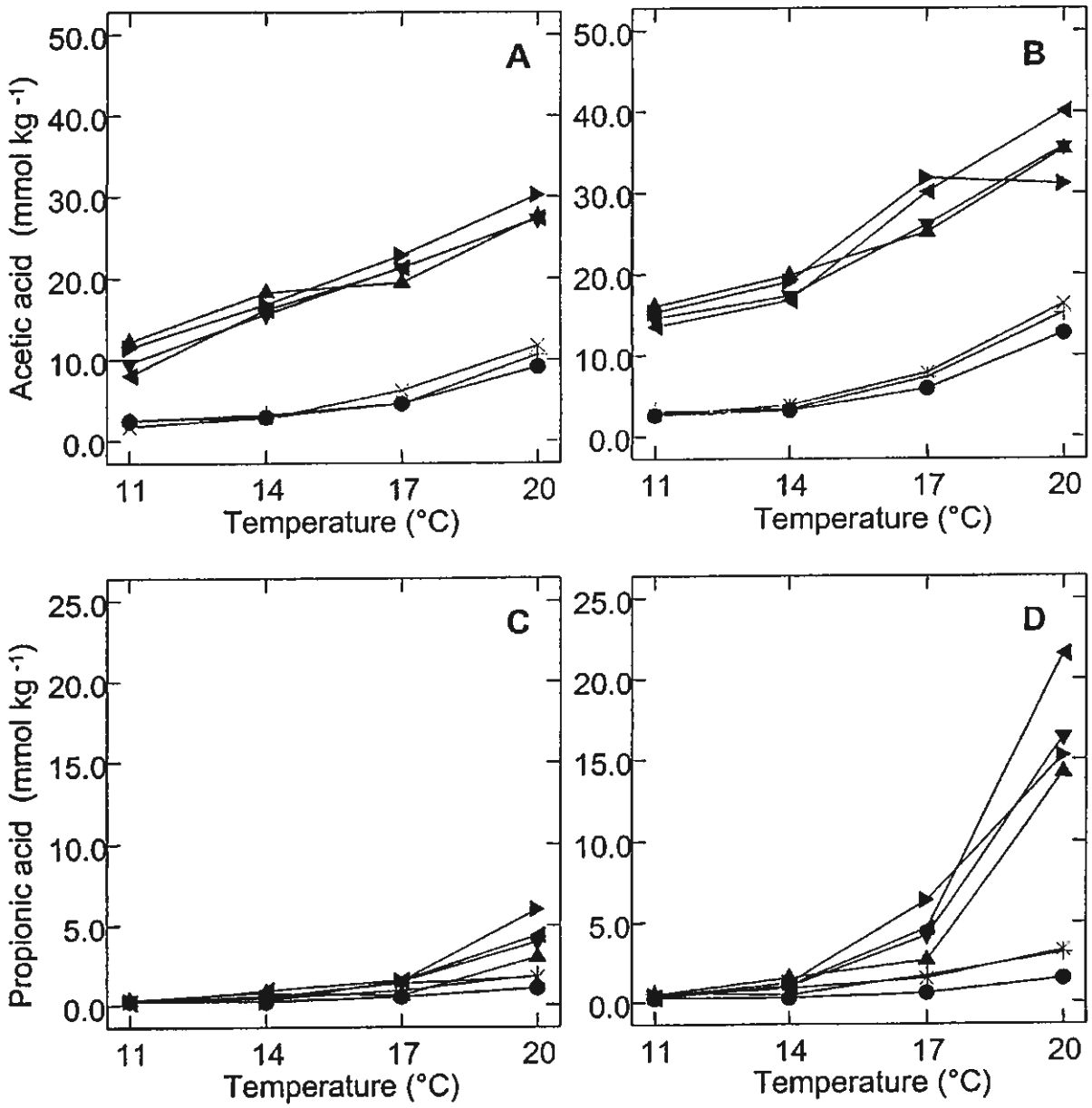

Figure 4. Concentration of acetic acid after 60 days (**A**) after 90 days (**B**), propionic acid after 60 days (**C**) and after 90 days (**D**) at different ripening temperatures in Raclette cheeses made from raw, pasteurised and microfiltered milk and its mixtures. ► raw milk (Ra), + pasteurised milk (Pa), ● microfiltered milk (MF), ◄ Ra/Pa (50:50%), ▲ Ra/MF (50:50%), ▼ Ra/Pa/MF (33:33:33%), × Pa/MF (50:50%). Means of two replicates.

graph curves connecting points of equal values were moving at elevated ripening temperature to an obvious distinction between cheeses made with raw milk and cheeses from MF and Pa milk. Cheeses with scores below 4.0 were considered as defective because of off-flavours and eye formation. Cheeses made with raw milk and at 17 and 20 °C ripening temperatures for 90 days exhibited off-flavour as a consequence of secondary fermentation. These cheeses showed an off-flavour already after 60 days, however, without detectable signs of propionic acid fermentation.

It can be concluded that the maximum temperature at which Raclette cheeses can be ripened without significant decrease

in the attribute 'preference' is about 14 °C (60 days) or 11 °C (90 days) for cheeses from or with raw milk and 17 °C (60 and 90 days) for MF and Pa cheeses.

The low 'preference' scores at elevated temperature, especially for cheeses made with raw milk, were mainly due to the 'intensity of aroma' being atypical for Raclette cheese (Fig. 7). Cheeses with scores for 'intensity of aroma' of 5 were in the range of normal maturity and, above 5, on the limit of being over mature. At elevated ripening temperatures the graph curves indicated higher scores of 'intensity of aroma'. The 'intensity of aroma' of MF cheeses was scored to be lower at 11, 14 and 17 °C after

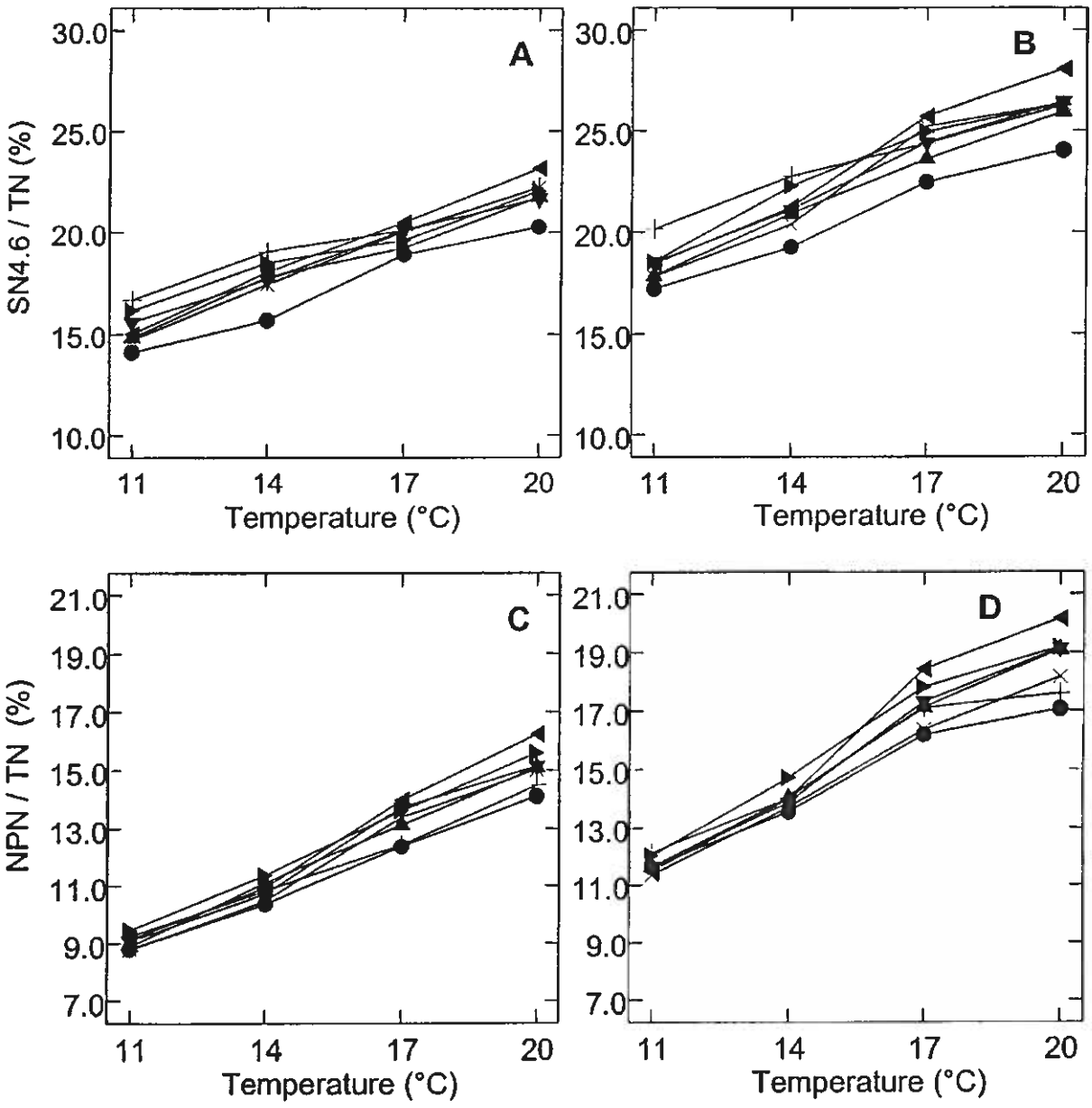

Figure 5. Development of soluble nitrogen at pH 4.6 (SN4.6 in % of total nitrogen (TN)) after 60 days (**A**) after 90 days (**B**), non protein nitrogen (NPN in % of total nitrogen (TN)) after 60 days (**C**) and after 90 days (**D**) at different ripening temperatures in Raclette cheeses made from raw, pasteurised and microfiltered milk and its mixtures. ▶ raw milk (Ra), + pasteurised milk (Pa), ● microfiltered milk (MF), ◀ Ra/Pa (50:50%), ▲ Ra/MF (50:50%), ▼ Ra/Pa/MF (33:33:33%), × Pa/MF (50:50%). Means of two replicates.

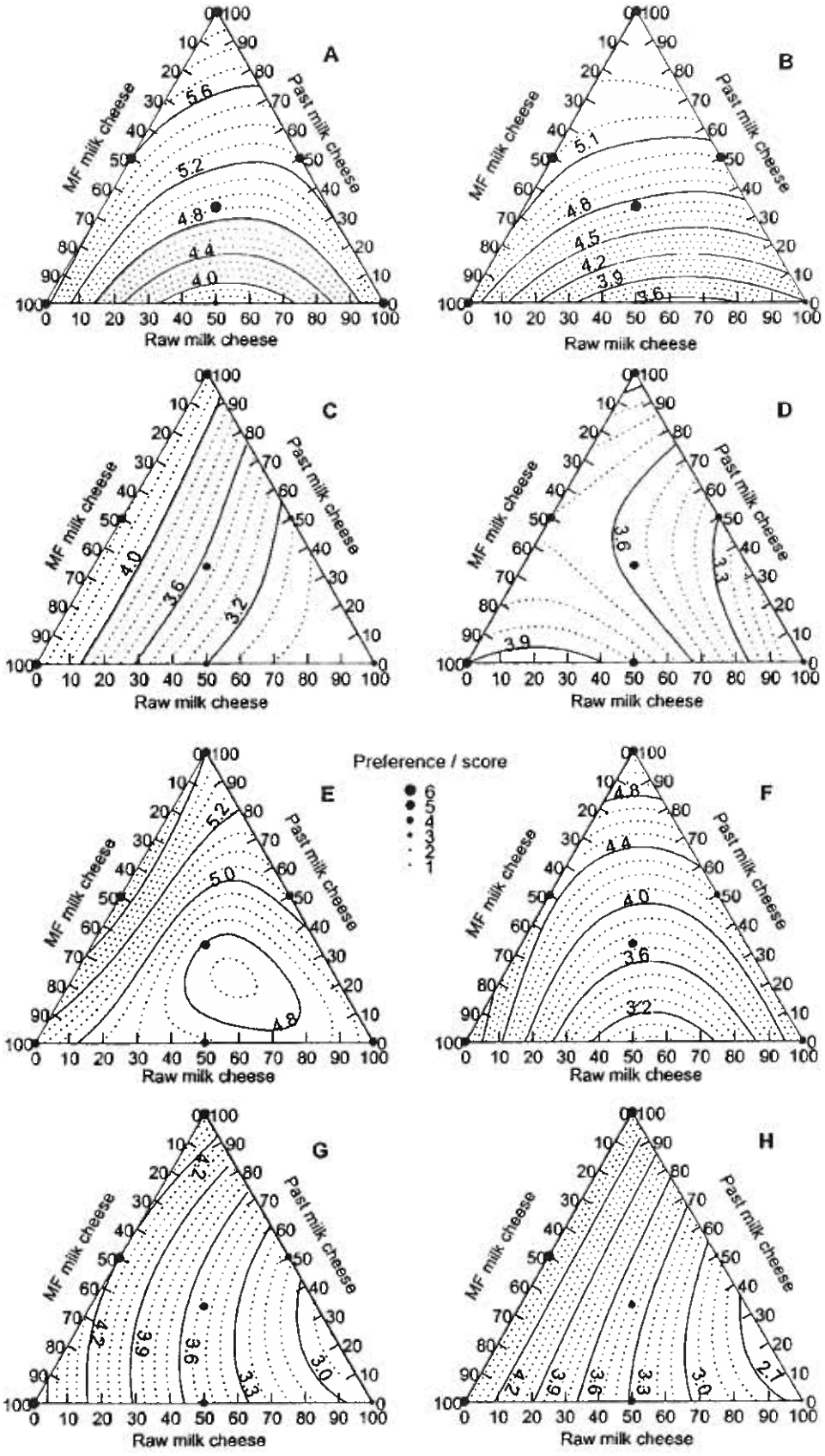

Figure 6. Sensory 'Preference' attribute of Raclette cheese from microfiltered, pasteurised and raw milk ripened for 60 days at 11 °C (**A**), at 14 °C (**B**), at 17 °C (**C**), at 20 °C (**D**) and for 90 days at 11 °C (**E**), at 14 °C (**F**), at 17 °C (**G**), at 20 °C (**H**). Means of two replicates.

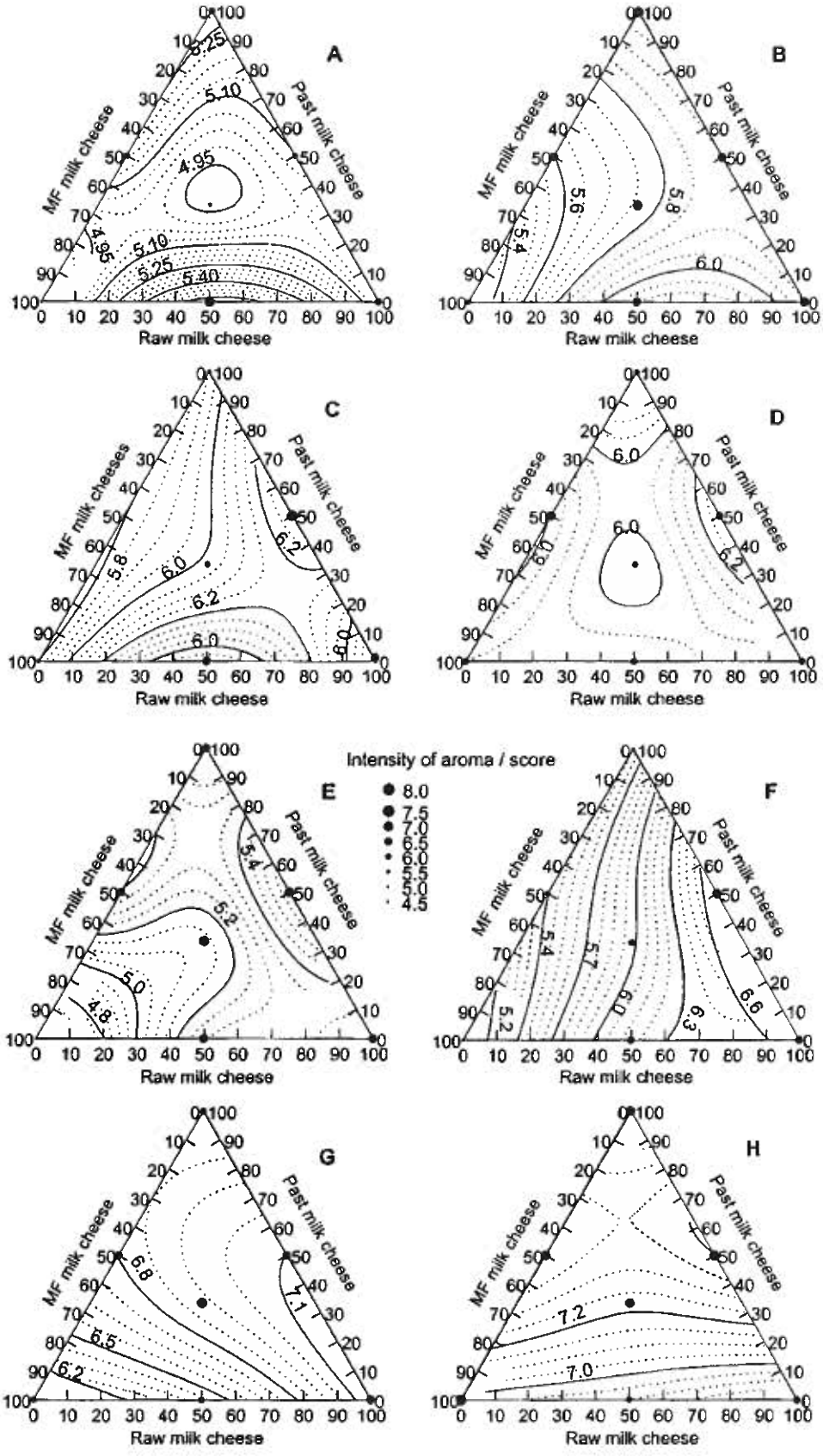

Figure 7. Sensory 'Intensity of aroma' attribute of Raclette cheese from microfiltered, pasteurised and raw milk ripened for 60 days at 11 °C (**A**), at 14 °C (**B**), at 17 °C (**C**), at 20 °C (**D**) and for 90 days at 11 °C (**E**), at 14 °C (**F**), at 17 °C (**G**), at 20 °C (**H**). Means of two replicates.

60 and 90 days, i.e. MF cheeses were less mature than cheeses made with raw and Pa milk. But at 20 °C, MF cheeses reached almost the same level of maturity as raw milk and Pa cheeses.

The ripening study showed that at higher ripening temperatures the rate of flavour development was accelerated. The same observation was made by Aston et al. [2–4] with Cheddar cheese, however using only pasteurised milk.

3.6. Melting quality

Raclette cheese is mainly consumed in a melted form. The melting properties of the cheeses were characterised by sensory attributes including 'fat separation', 'viscosity', 'consistency' and 'firmness' of the melted cheeses and by 'softening and dropping point' using an automatic dropping point measuring instrument.

The fat separation such as oiling off was determined visually. Figures 8A, 8B show the average results for Raclette cheeses of different milk treatment and different ripening temperature after 60 and 90 days. Cheeses without fat separation are denoted by the value of 1. With longer ripening time the fat separation increased, especially in cheeses made with raw milk. It is known, that in raw milk Raclette cheese fat separation occurs more often than in cheese made from pasteurised milk [13].

Viscosity and consistency were tested using a fork; the viscosity by stirring the melted cheese in the pan and the consistency by lifting the Raclette cheese and assessing the break off of the molten mass. The viscosity of all cheeses decreased, i.e. after melting the cheeses were less viscous with longer ripening time (Figs. 8C, 8D). However, when taking the average for all ripening temperatures the viscosity of raw milk, MF and Pa cheeses after 60 and 90 days was comparable. Generally with longer ripening time the consistency of all cheeses was judged to be 'shorter' (Figs. 8E and 8F). After 60 days the average difference between raw milk, MF and Pa cheeses was small. After 90 days the consistency of the melted cheeses with raw milk was judged to be "longer" than the consistency of MF and Pa milk cheeses.

Eberhard et al. [12, 13] analysed the composition and physical properties of raw and pasteurised milk Raclette cheeses of good and of insufficient melting quality, and found that the average score indicating good melting quality was below 4.8 for viscosity, consistency and firmness. They concluded that proteolysis "into the width" (SN4.6/TN) led to more viscous and longer texture of melted cheeses, whereas the proteolysis "into the depth" (NPN/TN) led to shorter consistency of melted cheeses.

In this study the average score for viscosity and consistency were below 4.8, and therefore in the required range for good melting quality. Another important sensory parameter is the perception of firmness of the melted cheeses in the mouth during chewing. Figure 8G shows that all cheeses with score above 4.8 for firmness after 60 days were firm and tough in perception. Figure 8H shows that after 90 days cheeses became softer and were divisible again into two groups: cheeses made from or with raw milk and those made with pasteurised and microfiltered milk, the latter having a score lower than 4.8. Cheeses made with raw milk were firmer, scoring still above 4.8 thus indicating insufficient melting quality.

To investigate the influence of different milk treatments on melting quality in more detail, further parameters such as softening and dropping point were measured. Figure 9 shows softening and dropping point of Raclette cheeses from different milk treatments regarding the ripening temperature and time. The softening point of all cheeses increased with elevated ripening temperature and time. The dropping point increased also with elevated temperature but not necessarily with longer ripening time.

According to Eberhard et al. [12, 13] the softening point below 58 °C and the

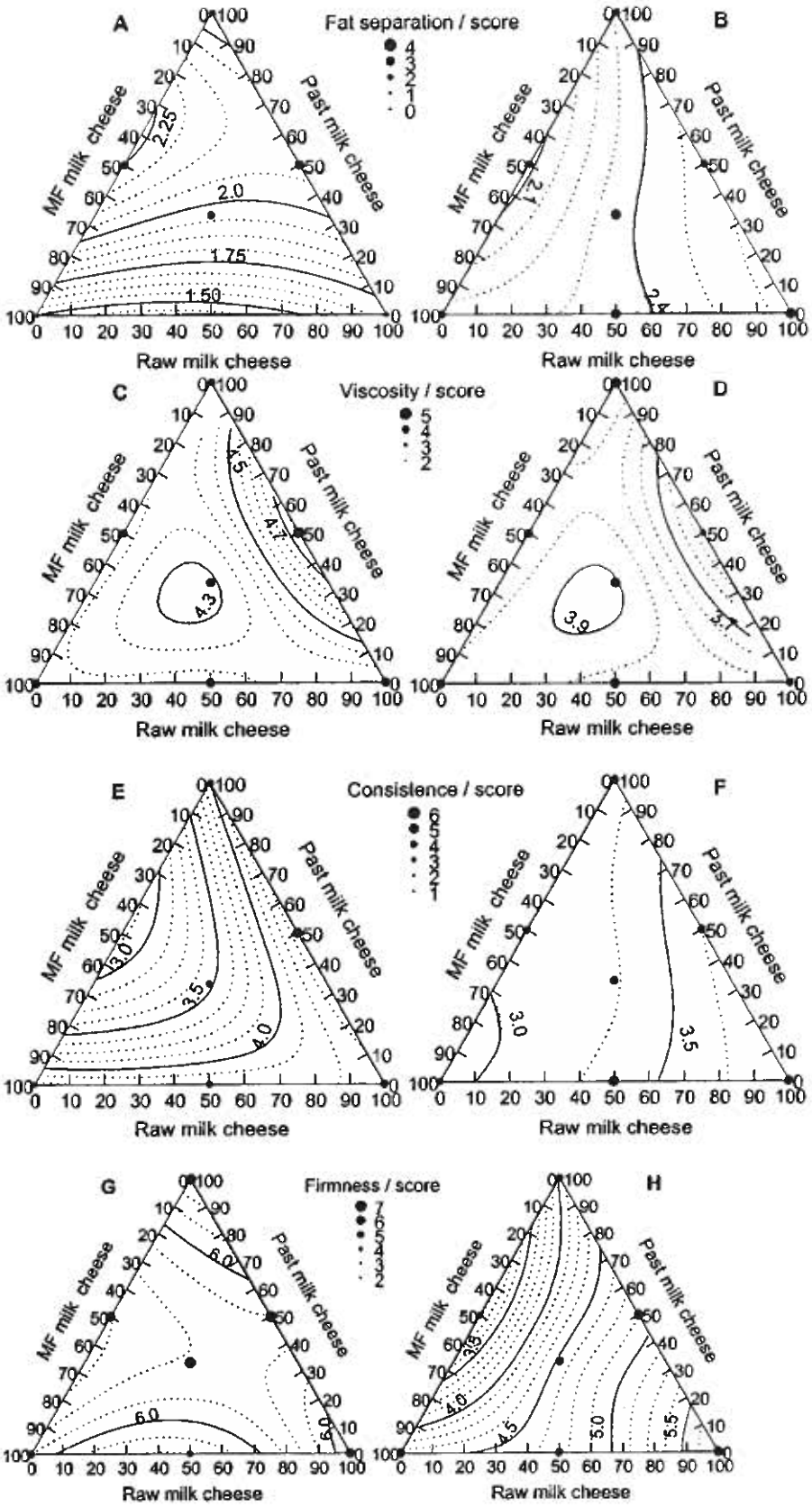

Figure 8. Sensory analysis of melted Raclette cheeses from microfiltered, pasteurised and raw milk. Fat separation after 60 days (**A**), after 90 days (**B**), viscosity after 60 days (**C**) and after 90 days (**D**), consistence after 60 days (**E**) and after 90 days (**F**), firmness after 60 days (**G**) and after 90 days (**H**). Means of eight replicates.

dropping point below 65 °C are typical for cheeses of good melting quality, which contain more water, more non protein nitrogen and have higher pH, and less fat, calcium and lactic acid compared to cheeses with a poor melting quality. Rüegg et al. [34] found that increased intensity of proteolysis was responsible for lower softening points and therefore better melting properties.

As shown in Figure 9, the influence of ripening temperature at 17 °C and 20 °C for 60 and 90 days on softening and dropping point in all cheeses was significant. This can be mainly explained by the fact that at elevated ripening temperatures the moisture content decreased whereas the extent of proteolysis increased. The influence of fat in dry matter and the NaCl content was negligible. It can be concluded that cheeses of all three milk treatments can be ripened at 11 and 14 °C for 60 and 90 days without impairment of the softening and dropping point. At 17 °C for 60 days only MF cheeses showed a dropping point lower than 65 °C and were in the required range for good melting quality.

4. CONCLUSION

The elimination of indigenous raw milk flora by microfiltration leads to significantly reduced concentration of free short chain acids in MF Raclette cheeses which developed less intense flavour compared to raw milk Raclette cheeses. The indigenous raw milk flora in MF cheeses could be reconstructed by addition of a proportion (e.g. one third) of raw milk to MF cheesemilk. Higher ripening temperatures were less

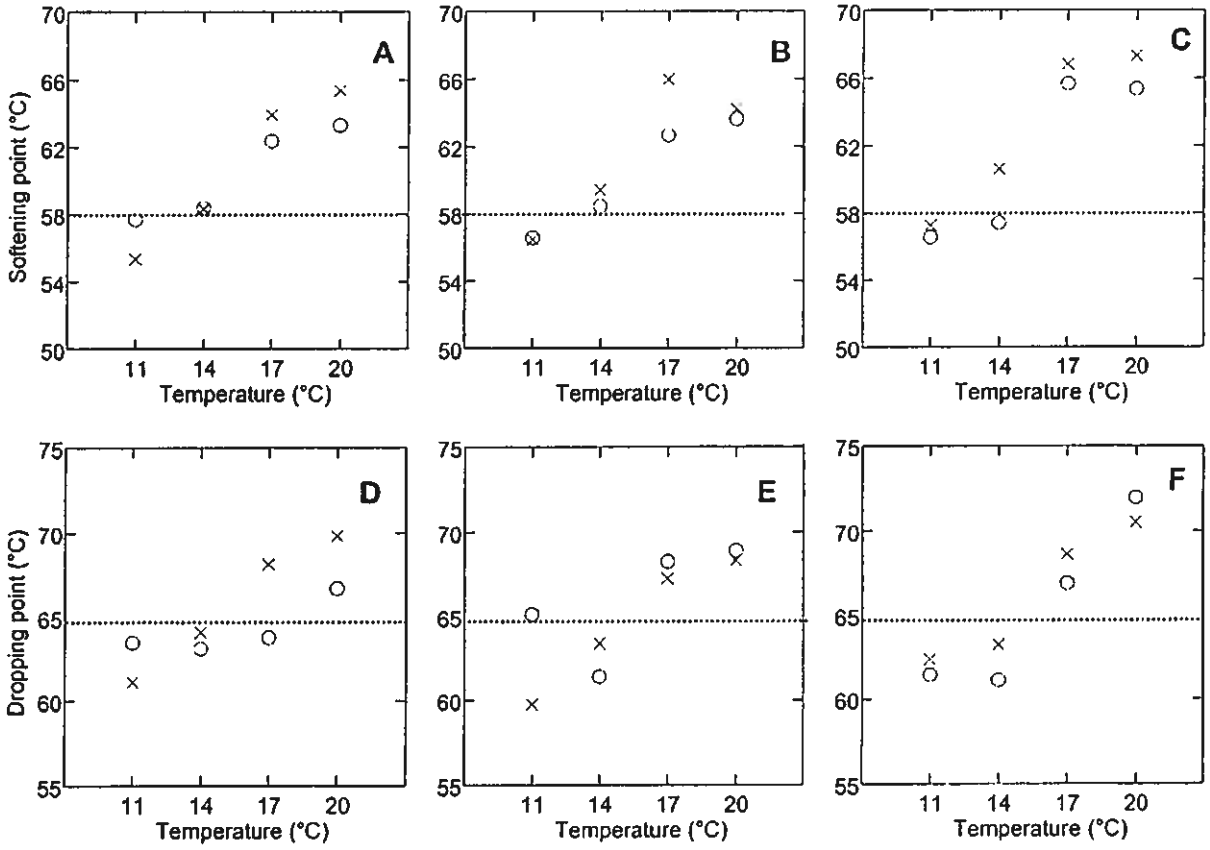

Figure 9. Softening point of Raclette cheeses made from microfiltered milk (**A**), pasteurised milk (**B**) and raw milk (**C**), and dropping point of Raclette cheese made from microfiltered milk (**D**), pasteurised milk (**E**) and raw milk (**F**) after 60 (×) and 90 days of ripening (○). Upper limit of good melting quality (·····). Means of two replicates.

effective than the addition of raw milk, but were the most promising way to accelerate the ripening of MF cheese. At elevated ripening temperatures above 11 °C the concentration of free short chain acids and the proteolysis in MF cheeses were enhanced, thus leading to increased intensity of aroma. In order to achieve good sensory and melting quality, MF cheeses could be ripened at 17 °C for 60 days which is an option for ripening acceleration. In cheeses with raw milk the elevated ripening temperatures caused secondary fermentation as well as flavour defects because of the increased counts of propionibacteria. Cheeses made from pasteurised milk were comparable to those made from MF milk. In Pa and MF cheeses the count of propionibacteria was below the detection limit and at elevated ripening temperatures no secondary fermentation occurred. However, the Pa Raclette cheese could be ripened only at ≤ 14 °C for 90 days because the melting quality decreased at higher ripening temperature.

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