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Interlaboratory Comparison of Cheese Making Trials: Model Cheeses Made From Raw, Pasteurized and Microfiltered Milks

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An interlaboratory comparison on cheese making trials was conducted to examine the differences between model cheeses manufactured in pilot plants at six European laboratories. The experimental design (within each laboratory) for the model cheese was an unreplicated 2^3 full factorial design in one block of eight cheese vats. The three factors were the pasteurization of skimmed milk, microfiltration of skimmed milk and pasteurization of cream. Although the manufacture, sampling and analyses were generally standardized, the gross composition and sensorial properties of the cheeses differed greatly across the laboratories. Good statistical design and analysis of the experimental data aided in minimizing the effect caused by the technical difficulties experienced by some of the laboratories during the cheese making trials. Despite the problems encountered, all six laboratories noted similar effects between model cheeses that were produced from milk in which the initial load of indigenous flora was reduced by either pasteurization or microfiltration. The cheeses produced from milk in which the raw milk flora had been reduced had lower concentrations of D-lactate and a less intense aroma and odour. With few exceptions the individual laboratories observed similar effects, although these were less significant when compared with the overall effect.

Keywords: cheese; pasteurization; microfiltration; raw milk flora; experimental design; interlaboratory comparison

Introduction

Within the framework of an European Research Project, interlaboratory studies have been undertaken to evaluate the consistency of treatment effects on model cheeses produced in different laboratories. The importance of experimental design in such studies was discussed in earlier publications (1, 2, 3).

The first study involved six European laboratories (4) and the differences in the chemical, sensory and microbiological properties of a model cheese produced to a standard protocol at each site were evaluated. The experimental design encompassed two further objectives, the comparison of cheese made from raw milk with cheese made from pasteurized milk, and cheese made using just a starter against cheese made with an adjunct *Lactobacillus casei* culture, at different sites. A split plot design with blocking structure laboratory/day/vat and factorial treatment structure Laboratory.adjunct.milk was used (2, 4). In the first study it was observed that deviations from the manufacturing profile and inexperience with some of the manufacturing procedures of the model cheese resulted in differences in the gross composition of the cheese, which in turn influenced ripening. However, sound experimental design and a consistency in the gross composition of the cheese within individual laboratories allowed the effects of pasteurization and the addition of *Lactobacillus casei* adjunct to be clearly defined. It was found that the reduction of the natural

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milk flora and indigenous enzymes of raw milk by pasteurization influenced the microbial flora, extent of proteolysis, levels of D-lactate, some volatile fatty acids and the sensory properties of the mature model cheese. The addition of *Lactobacillus casei* adjunct to pasteurized milk did not result in a restoration of the properties of a raw milk cheese.

Experience gained from the design, planning, execution and evaluation of the first study was employed in a second study to investigate further the relative influence of the natural milk flora on the sensorial properties and biochemical characteristics of model cheeses. There were three main objectives to the second study. (i) to investigate the differences between model cheeses that are produced according to the same manufacturing protocol but in different pilot plants; (ii) to investigate the differences between model cheeses that are produced from milk with the reduction of the indigenous flora by pasteurization or by microfiltration (iii) to investigate whether results obtained in different laboratories using the same experimental design lead to the same conclusions.

Selection of the statistical model is discussed in this paper together with gross composition and sensory evaluation. Other chemical, biochemical, rheological and microbiological data obtained in the study will be published elsewhere.

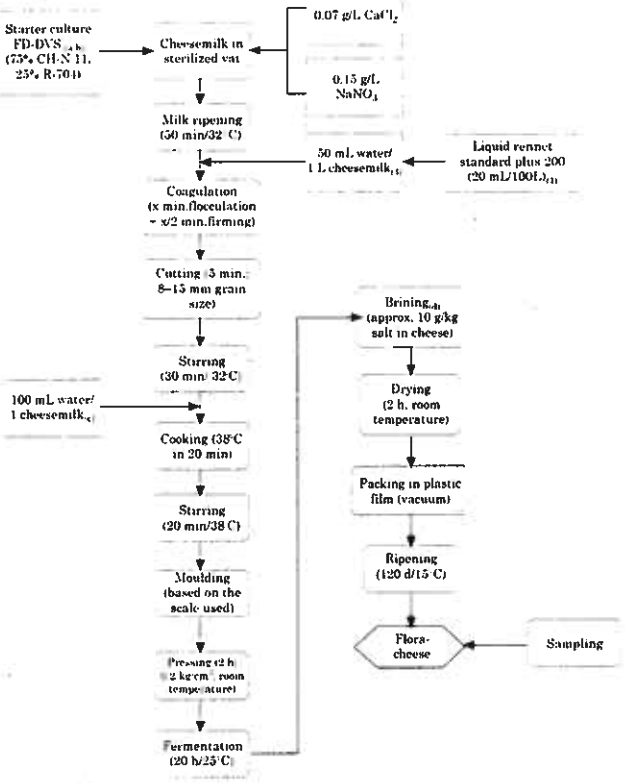

Fig. 1 Standard manufacturing protocol, (a) CHR.Hansen A/S Horsholm, Denmark (same batch for all); (b) dilution in sterile reconstituted skimmed milk; (c) cold distilled water; (d) brine: 200 g/kg NaCl, pH 5.3 (adjusted with lactate)

Materials and Methods

Cheese production and analyses

The trial was replicated in the pilot plants of six European laboratories. The cheesemaking protocol (**Fig. 1**), sampling and chemical analysis have been described in an earlier publication (4). The standardization of cheese manufacturing was undertaken as far as was possible

Table 1 Pilot plant facilities and milk composition at individual laboratories

Parameters		Laboratories					
		A	B	C	D	E	F
Milk:							
age	(h)	36–60	3–12	15	12–48	12–24	3–15
fat before skimming	(g/kg)	37.8	40.0	41.0	43.3	34.6	36.7
protein before skimming	(g/kg)	34.3	34.2	32.0	32.1	32.7	31.1
lactose before skimming	(g/kg)	45.4	n.d.	n.d.	47.9	n.d.	47.6
somatic cell count	[numbers/ml]	n.d.	n.d.	150 000	n.d.	n.d.	56 000
Milk quantity per vat	(L)	15	40	350	500	13	80
Number of vats		4	4	4	4	4	8
Size of vats	(L)	20	50	500	640	14	120
Chéese per vat		1	1	3	5	1	1
Average weight of cheese	(kg)	1.6	4.3	33	49	1.4	8.5
Size of cheeses	(cm)						
loaf, diameter/height		15/10	—	32/12	—	18/5	35/9
block, length/breadth/height		—	26/13/15	—	36/24/10	—	—
Microfiltration unit							
Pore size	(μm)	1.4	1.4	1.4	1.4	1.4	1.4
Concentration factor		n.d.	n.d.	10:1	15:1	20:1	10:1
Pasteurization							
milk: continuous or batch		c	c	c	c	c	c
cream: continuous or batch		c	c	c	c	b	b

n.d. = not determined.

Table 2 Experimental design within each laboratory for the model cheeses

Pasteurization of skimmed milk	Microfiltration of skimmed milk	Pasteurization of cream	Block (production Day)
Raw	Unfiltered	Raw	1
Raw	Unfiltered	Pasteurized	2
Raw	Microfiltered	Raw	2
Raw	Microfiltered	Pasteurized	1
Pasteurized	Unfiltered	Raw	2
Pasteurized	Unfiltered	Pasteurized	1
Pasteurized	Microfiltered	Raw	1
Pasteurized	Microfiltered	Pasteurized	2

Blocking factor confounded with 3 way interaction; skimmed milk pasteurization. Skimmed milk microfiltration. Cream pasteurization.

but the control of milk quality and pilot plant processing facilities were prohibitive. The details of the six pilot plant facilities are summarized in **Table 1**. The brining time was determined in a preliminary experiment to obtain a comparable salt content across all of the laboratories. The sensory evaluation of the cheeses was performed according to Berodier *et al.* (5). A modified starter culture system was used (75% CH-N11 & 25% R-704, Chr.Hansen, Denmark) to minimize eye formation, and to increase the extension of the ripening period to 4 mo to allow development of a more intense flavour. In comparison with the first trial (4) there were less technical errors. Laboratory A used only one of the two starter cultures, CHN11. The milk from laboratory A which had been microfiltered was subsequently shown to have been contaminated post-treatment. The microfiltration from this laboratory must therefore be examined with caution. Microbiological data on the milks is also available but will be published elsewhere.

Experimental Design and Statistical Evaluation

The statistical design (within each laboratory) for the model cheese was an unreplicated 2^3 full factorial design in two blocks of four cheese vats. The blocking factor (i.e. Production Day (DAY)) was confounded with the 3-way effect of the treatment factors, skimmed milk pasteurization (SP), Skimmed milk Microfiltration (MF), and Cream Pasteurization (CP), (**Table 2**).

The experimental design had 1 degree of freedom for the error term DAY. DAY was also a blocking factor at a higher error stratum than the treatment effects and was therefore not an appropriate error term. If it is assumed that the magnitude of low order interactions are greater than the magnitude of higher order interactions, the higher order interactions may be used in

Table 3 Analysis of variance for different laboratories

Error Stratum	Term	Degrees of Freedom
DAY	Residual = SP.MF.CP	1
DAY.VAT	SP	1
	MF	1
	CP	1
	SP.MF	1
	Residual (SP.CP + MF.CP) = Error	2
	Total	7

Table 4 Modified ANOVA for Entire Experiment

Error Stratum	Term	Degrees of Freedom
Laboratory	LABORATORY	5
Laboratory.vat	SP	1
	MF	1
	CP	1
	LAB.SP	5
	LAB.MF	5
	LAB.CP	5
	SP.MF	1
	SP.CP	1
	MF.CP	1
	SP.MF.CP = day	1
	Residual	20
	(LAB.SP.MF + LAB.SP.CP + LAB.MF.CP + LAB.SP.MF.CP) + error	
	Total	47

Table 5 Mean gross composition of the cheeses after 120 days (g/kg)

Parameters		Laboratories A	B	C	D	E	F	All Mean	Sig.
Moisture	(g/kg)	470	451	447	462	440	408	446	***
MNFS	(g/kg)	607	593	592	595	612	585	597	***
fat	(g/kg)	225	240	245	225	282	303	253	***
fat in dry matter	(g/kg)	426	437	443	417	503	512	456	***
protein	(g/kg)	249	232	253	239	246	246	244	***
salt in moisture	(g/kg)	43.8	40.6	38.2	51.7	19.5	41.5	39.2	***
lactates (L + D)	(mmol/kg)	162	157	165	158	147	163	159	***
L-lactate	(mmol/kg)	103	124	118	116	88	111	110	***
D-lactate	(mmol/kg)	59	33	47	42	59	52	49	**
pH-value		5.26	5.27	5.21	5.25	5.43	5.29	5.28	**

ns = not significant; * significant ($P < 0.05$); ** significant ($P < 0.01$); *** significant ($P < 0.001$).

place of the error term. Within each laboratory the study was analysed using the ANOVA in **Table 3**, however, this approach was unsatisfactory for two reasons: (i) the number of degrees of freedom for error is small and (ii) there are not enough replications to calculate all 2-way interactions (SP.MF, SP.CP, and MF.CP). Therefore the experiment can not be satisfactorily statistically analysed on a laboratory by laboratory basis.

Because the effect of laboratory is important, it is only regarded as a treatment factor although it should be regarded as a blocking factor because it was not randomized. Not all laboratories were able to comply with the requirement for blocking the experiment as required by the initial experimental design. Thus the analysis was modified and the data was treated as if each laboratory had produced eight vats of cheese on a single day. **Table 4** shows the modified ANOVA table. The consequences of modifying the analysis depend upon the sum of squares for SP.MF.CP and LAB.SP.MF.CP. SP.MF.CP changes from an error term to a treatment term, while LAB.SP.MF.CP remains an

Table 6 Moisture content in the cheeses after 120 d (g/kg)

Parameters			Laboratories A	B	C	D	E	F	All
Single values									
Skimmed milk		Cream							
Raw	Unfilt.	Raw	444	445	447	454	446	415	442
Raw	Unfilt.	Past.	472	441	440	459	444	409	444
Raw	Microf.	Raw	479	458	439	461	443	393	445
Raw	Microf.	Past.	449	454	438	467	433	402	441
Past.	Unfilt.	Raw	472	464	445	471	442	402	449
Past.	Unfilt.	Past.	479	444	447	436	429	418	442
Past.	Microf.	Raw	492	453	475	477	442	427	461
Past.	Microf.	Past.	475	448	447	467	438	404	446
Means and effects									
All cheeses			470	451	447	462	440	408	446
Effects			24	5	1	16	−6	−38	***
Skimmed milk (SP)									
Raw			461	450	441	461	442	404	444
pasteurized			480	452	454	463	438	413	450
Effects			19^{ns}	3^{ns}	13^{ns}	2^{ns}	-4^{ns}	8^{ns}	6*
Microfiltration (MF)									
Without			467	449	445	455	440	411	444
With			474	453	450	466	439	406	449
Effects			7^{ns}	5^{ns}	5^{ns}	11^{ns}	-1^{ns}	-5^{ns}	5^{ns}
Cream (CP)									
Raw			472	455	452	466	443	409	449
Pasteurized			469	447	443	457	436	408	443
Effects			-3^{ns}	-8^{ns}	-9^{ns}	-9^{ns}	-7^{ns}	-1^{ns}	−6*
2 way interactions									
SP × MF			ns	ns	ns	ns	ns	ns	ns

ns = not significant: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

error term. Numerically, the means for SP.MF.CP are defined as the arithmetic means (within each laboratory) of the LAB.SP.MF.CP means. Since SP.MF.CP is defined from error terms only it follows that the term SP.MF.CP is insignificant. Removing the DAY stratum from the analysis of the study moves the sum of squares for the laboratory residual mean square into the sum of squares for the treatment residual mean square. In effect, the two residual mean squares are averaged. The residual mean square for the Laboratory term is reduced thus increasing the variance ratio for the Laboratory term and the probability of false positive result. Conversely the residual mean square for the treatment terms will be increased thus reducing the treatment variance ratio and importantly, reducing the power of the analysis to detect a significant treatment effect.

Results and Discussion

The discussion focuses on the evaluation of the consistency of the three treatment effects on model cheeses produced in the six laboratories. The gross composition data for the model cheeses is shown in **Table 5**. Strong laboratory-effects were observed for all of the parameters examined. Standardizing the manufacturing protocol did not prevent the cheeses of the six pilot plants from being significantly different. The higher moisture in nonfat solids (MNFS) contents from the laboratories A and E could potentially have led to an increased rate of ripening. The texture of the cheeses from the laboratories E and F would be influenced by the higher fat content.

The mean moisture content for the treatments over all of the laboratories was significantly influenced by the pasteurization of the skimmed milk and cream (**Table 6**). No significant effect could be found within any of the six laboratories, although effects due to the pasteurization of the skimmed milk (five of six cheeses) and of the cream (six of six cheeses) followed the same direction as the overall effect. The increased moisture content of pasteurisation cheese could be associated with the binding of whey protein to the casein micelle. The pasteurization of the cream reduced the moisture content of the cheese.

Reduction of the raw milk flora in the skimmed milk by pasteurization lowered the content of D-lactate and, in consequence, the L-lactate content increased (**Table 7**). This effect was observed in all but one of the participating laboratories. A similar efect was observed on microfiltration with the effect being consistent in all laboratories. The effects were statistically significant in approximately 50% of the laboratories for each treatment. In addition, there was a significant interaction between the two factors. The effect of microfiltration was lower when the microflora of the skimmed milk

Table 7 Relative content of D-lactate in the cheeses after 120 d (% of total lactate)

Parameters			Laboratories						
			A	B	C	D	E	F	All
Single values									
Skimmed milk		Cream							
Raw	Unfilt.	Raw	42	35	47	37	47	45	42
Raw	Unfilt.	Past.	43	36	44	39	46	45	42
Raw	Microf.	Raw	35	9	20	17	40	36	26
Raw	Microf.	Past.	28	15	19	11	33	35	24
Past.	Unfilt.	Raw	45	14	21	34	42	30	30
Past.	Unfilt.	Past.	41	18	16	38	43	14	29
Past.	Microf.	Raw	39	14	35	24	42	36	32
Past.	Microf.	Past.	15	24	25	8	31	12	19
Means and effects									
All cheeses			36	21	28	23	41	31	30
Effects			6	−9	−2	−7	11	1	***
Skimmed milk (SP)									
Raw			37	24	33	26	42	41	34
Pasteurized			35	18	24	26	39	23	28
Effects			-2^{ns}	−6*	−9*	0^{ns}	-3^{ns}	−18*	−6***
Microfiltration (MF)									
Without			43	26	32	37	45	34	36
With			29	16	25	15	36	30	25
Effects			-14^{ns}	−10*	−7*	−22*	-9^{ns}	-4^{ns}	−11***
Cream (CP)									
raw			41	18	31	28	43	37	33
pasteurized			32	24	26	24	38	27	28
effects			-9^{ns}	+6*	-5^{ns}	-4^{ns}	-5^{ns}	-10^{ns}	−5*
2 way interactions									
SP × MF			ns	**	**	ns	ns	ns	**

ns = not significant; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

had already been reduced by pasteurization. This indicates that the experimental design was not fully balanced because skimmed milk had two different treatment factors (pasteurization and microfiltration) but cream only had one (pasteurization). As a result, in skimmed milk the effect of pasteurization was lowered by microfiltration and the effect of microfiltration was lowered by pasteurization. The pasteurization of the cream and skimmed milk had similar effects, although these were not generally significant. Only in Laboratory B did the pasteurization of cream lead to (significant) inverse effects.

The aroma intensity for the treatments over all laboratories was significantly affected by all three treatment factors (**Table 8**). In four of the six laboratories microfiltration reduced aroma intensity, but only in laboratory C was the effect statistically significant. A lower aroma intensity was also noted in all six laboratories in cheeses produced with pasteurized milk or pasteurized cream. The metabolic activity of the raw milk flora probably contributed to a higher aroma intensity during the ripening of the cheese in either the skimmed milk or the untreated cream. The typical descriptor of the aroma was 'animal' (**Table 9**). A reduction in this aroma note was consistent in the majority of treated samples and although the results were not significant in individual laboratories, they were statistically significant overall.

Other results from the sensory evaluation are summarized in **Tables 10–12**. Highly significant differences for taste were identified between the laboratories. The values of aroma and odour were comparable except the descriptor 'animal', which was highly significant in aroma but not in odour.

Conclusions

It proved possible to modify the analysis of the experiment shown in **Table 4** to overcome the major technical difficulties that were outlined. The chosen design was not fully balanced because skimmed milk was treated by two different factors (pasteurization and microfiltration) but cream by only one (pasteurization). To compare several treatment factors in different products such as skimmed milk or cream it is necessary to apply all of the treatments to the different products, otherwise the effects will be reduced in the product with the higher number of treatment factors.

The three objectives identified can be answered, (i) The gross composition and the sensorial properties of the cheeses were very different from laboratory to laboratory.; (ii) Cheeses with reduced raw milk flora had lower contents of D-lactate and lower intensities of aroma and odour, (iii) With few exceptions the individual laboratories noted similar effects although they

Table 8 Aroma intensity in the cheeses after 120 d (scale 0–7)

Parameters			Laboratories						
			A	B	C	D	E	F	All
Single values									
Skimmed milk		Cream							
Raw	Unfilt.	Raw	4.8	4.6	4.4	4.6	4.6	4.6	4.6
Raw	Unfilt.	Past.	4.1	4.0	4.3	4.4	4.1	4.0	4.2
Raw	Microf.	Raw	5.3	4.4	3.8	4.3	3.8	3.6	4.2
Raw	Microf.	Past.	4.4	4.1	3.4	4.1	3.3	3.9	3.9
Past.	Unfilt.	Raw	4.6	3.9	3.9	4.2	3.5	3.9	4.0
Past.	Unfilt.	Past.	4.5	3.9	3.8	3.9	3.3	4.0	3.9
Past.	Microf.	Raw	5.0	4.1	3.5	4.1	3.5	4.1	4.1
Past.	Microf.	Past.	4.0	4.1	3.4	4.1	3.9	3.3	3.8
Means and effects									
All cheeses			4.6	4.2	3.8	4.2	3.7	3.9	4.1
Effects			0.5	0.1	−0.3	0.1	−0.4	−0.2	***
Skimmed milk (SP)									
Raw			4.6	4.3	4.0	4.3	3.9	4.0	4.2
Pasteurized			4.5	4.0	3.6	4.1	3.5	3.8	3.9
Effects			-0.1^{ns}	-0.3^{ns}	−0.4**	-0.2^{ns}	-0.4^{ns}	-0.2^{ns}	−0.3**
Microfiltration (MF)									
Without			4.5	4.1	4.0	4.1	3.9	4.1	4.2
With			4.7	4.2	3.5	3.5	3.6	3.7	4.0
Effects			0.2^{ns}	0.1^{ns}	−0.5**	-0.6^{ns}	-0.3^{ns}	-0.4^{ns}	−0.2*
Cream (CP)									
Raw			4.9	4.3	3.9	3.9	3.8	4.0	4.2
pasteurized			4.3	4.0	3.7	3.7	3.6	3.8	3.9
Effects			−0.6*	-0.3^{ns}	−0.2*	-0.2^{ns}	-0.2^{ns}	-0.2^{ns}	−0.3**
2 way interactions									
SP × MF			ns	ns	*	ns	ns	ns	*

ns = not significant; $*P < 0.05$; $**P < 0.01$; $***P < 0.001$.

Table 9 Aroma animal in the cheeses after 120 d (scale 0–7)

Parameters			Laboratories						
			A	B	C	D	E	F	All
Single values									
Skimmed milk		Cream							
Raw	Unfilt.	Raw	2.9	2.4	2.4	2.5	2.6	1.6	2.4
Raw	Unfilt.	Past.	1.8	2.1	2.9	2.5	1.5	2.7	2.2
Raw	Microf.	Raw	2.8	2.1	1.5	2.3	0.8	2.1	1.9
Raw	Microf.	Past.	2.3	1.8	1.3	2.4	0.9	0.4	1.5
Past.	Unfilt.	Raw	2.8	1.5	2.0	2.6	1.3	0.7	1.8
Past.	Unfilt.	Past.	2.5	2.1	1.1	2.4	1.3	1.0	1.7
Past.	Microf.	Raw	2.1	2.3	1.6	2.4	1.3	1.1	1.8
Past.	Microf.	Past.	2.6	1.6	1.4	1.5	1.0	0.7	1.5
Means & effects									
All cheeses			2.5	2.0	1.8	2.2	1.3	1.3	1.9
Effects			0.6	0.1	−0.1	0.3	−0.6	−0.6	***
Skimmed milk (SP)									
Raw			2.4	2.1	2.0	2.4	1.4	1.7	2.0
Pasteurized			2.5	1.9	1.5	2.2	1.2	0.9	1.7
Effects			0.1^{ns}	-0.2^{ns}	-0.5^{ns}	-0.2^{ns}	-0.2^{ns}	-0.8^{ns}	−0.2*
Microfiltration (MF)									
Without			2.5	2.0	2.1	2.5	1.7	1.5	2.0
With			2.4	1.9	1.4	2.1	1.0	1.1	1.7
Effects			-0.1^{ns}	-0.1^{ns}	-0.7^{ns}	-0.4^{ns}	-0.7^{ns}	-0.4^{ns}	−0.3**
Cream (CP)									
Raw			2.6	2.1	1.9	2.4	1.5	1.4	2.0
Pasteurized			2.3	1.9	1.7	2.2	1.2	1.2	1.7
Effects			-0.3^{ns}	-0.2^{ns}	-0.2^{ns}	-0.2^{ns}	-0.3^{ns}	-0.2^{ns}	-0.3^{ns}
2 way interactions									
SP × MF			ns	ns	ns	ns	ns	ns	ns

ns = not significant; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 10 Sensory evaluation of taste and trigeminal stimulation (mean values and analysis of variance)

Factors/Levels	Sensory evaluation of taste and trigeminal stimul. (scale 0–7)				
	Sweet	Salty	Sour	Bitter	Trigeminal stimulation
All cheeses	1.7	3.6	3.7	2.5	2.5
Laboratory					
A	1.2	4.1	3.8	3.3	3.7
B	2.1	3.8	4.1	2.3	2.9
C	2.1	3.2	3.9	2.5	1.6
D	1.3	3.7	3.5	1.9	2.8
E	1.8	3.0	2.9	2.6	2.0
F	1.8	3.4	4.1	2.4	1.8
Skimmed milk (SP)					
Raw	1.7	3.6	3.7	2.5	2.5
Past.	1.7	3.5	3.7	2.5	2.5
Microfiltration (MF)					
Without	1.7	3.6	3.8	2.5	2.6
With	1.7	3.5	3.6	2.5	2.5
Cream (CP)					
Raw	1.7	3.6	3.8	2.6	2.6
Past.	1.8	3.5	3.7	2.4	2.5
ANOVA					
Laboratory	***	***	***	***	***
Skimmed milk (SP)	(−)	(−)	(−)	(−)	(−)
Microfiltration (MF)	(−)	(−)	(−)	(−)	(−)
Cream (CP)	(−)	(−)	(−)	(+)	(−)
SP × MF	(−)	(−)	(−)	(−)	(+)

(+) = $P < 0.1$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; (−) = $P \geq 0.1$.

Table 11 Sensory evaluation of aroma (mean values and analysis of variance)

Factors/levels	Sensory evaluation of aroma (scale 0–7)								
	Intensity	Acidif. Lactic	Butter	Vegetable	Fruity	Animal	Roasted	Spiced	Others
All cheeses	4.1	2.8	1.3	0.9	0.9	1.9	0.7	1.1	1.1
Laboratory									
A	4.6	2.8	0.9	1.6	0.8	2.5	1.1	0.9	1.6
B	4.2	3.7	0.8	1.4	1.1	2.0	1.0	1.4	1.6
C	3.8	2.9	1.8	0.6	1.0	1.8	0.7	1.1	0.3
D	4.2	2.7	1.8	1.4	1.6	2.2	0.9	1.7	1.7
E	3.7	1.8	1.6	0.2	1.0	1.3	0.4	0.6	1.1
F	3.9	2.8	0.9	0.1	0.1	1.3	0.3	0.6	0.3
Skimmed milk (SP)									
Raw	4.2	2.9	1.3	1.0	0.9	2.0	0.8	1.1	1.2
Past.	3.9	2.7	1.3	0.9	0.9	1.7	0.7	1.0	1.0
Microfiltration (MF)									
Without	4.2	2.9	1.2	1.0	0.9	2.0	0.8	1.2	1.2
With	4.0	2.7	1.3	0.8	0.9	1.7	0.8	1.0	1.1
Cream (CP)									
Raw	4.2	2.8	1.3	0.8	0.9	2.0	0.8	1.0	1.1
Past.	3.9	2.8	1.3	1.0	0.9	1.7	0.7	1.1	1.1
ANOVA									
Laboratory	***	***	***	***	***	***	***	***	***
Skimmed milk (SP)	**	(+)	(–)	(–)	(–)	*	(–)	(–)	(+)
Microfiltration (MF)	*	(–)	(–)	(–)	(–)	**	(–)	*	(–)
Cream (CP)	**	(–)	(–)	(–)	(–)	(+)	(–)	(–)	(–)
SP × MF	*	(–)	(–)	(–)	(–)	(+)	(–)	(–)	(–)

(+) = $P < 0.1$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; (–) = $P \geq 0.1$.

were less significant compared with the overall effect. The study has shown that results obtained from cheese manufacturing experiments in different laboratories may only be compared if detailed data on experimental design, manufacturing, sampling and analyses are available. Absolute values obtained from individual laboratories are only comparable if standardized protocols are rigidly adhered to. In contrast, treatment effects can be remarkably consistent among different laboratories.

Table 12 Sensory evaluation of odour (mean values and analysis of variance)

Factors/levels	Sensory evaluation of aroma (scale 0–7)								
	Intensity	Acidif. Lactic	Butter	Vegetable	Fruity	Animal	Roasted	Spiced	Others
All cheeses	3.2	2.1	1.5	0.8	0.9	0.7	0.5	0.7	0.6
Laboratory									
A	3.5	2.1	1.1	1.1	0.8	0.4	0.6	0.4	0.9
B	3.5	2.7	1.2	1.1	0.9	1.1	0.9	1.1	1.2
C	3.0	2.1	2.1	0.5	0.9	0.9	0.5	0.9	0.2
D	3.1	1.7	2.1	1.3	1.5	1.0	0.9	1.0	0.4
E	2.9	1.6	1.4	0.4	0.9	0.4	0.3	0.4	0.2
F	3.1	2.2	0.9	< 0.1	0.1	0.4	< 0.1	0.4	1.0
Skimmed milk (SP)									
Raw	3.3	2.3	1.4	0.8	0.9	0.7	0.5	0.7	0.7
Past.	3.1	1.9	1.6	0.8	0.9	0.7	0.5	0.7	0.5
Microfiltration (MF)									
Without	3.3	2.2	1.4	0.7	0.9	0.8	0.5	0.8	0.6
With	3.1	2.0	1.6	0.8	0.9	0.7	0.6	0.7	0.6
Cream (CP)									
Raw	3.3	2.2	1.4	0.8	0.9	0.7	0.5	0.7	0.6
Past.	3.1	2.0	1.5	0.7	0.8	0.7	0.6	0.7	0.6
ANOVA									
Laboratory	***	***	***	***	***	(–)	***	***	***
Skimmed milk (SP)	**	**	(–)	(–)	(–)	(–)	(–)	(–)	*
Microfiltration (MF)	*	(–)	(–)	(–)	(–)	(–)	*	(+)	(–)
Cream (CP)	**	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
SP × MF	**	(–)	(–)	(–)	(–)	(+)	(–)	(–)	(+)

(+) = $P < 0.1$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; (–) = $P \geq 0.1$.

The findings on other chemical, biochemical, rheological and microbiological data obtained for the samples produced in these trials will be published elsewhere.

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