ELSEVIER

Food Chemistry 71 (2000) 363–378

Food Chemistry

www.elsevier.com/locate/foodchem

Dynamic analyses of sensory and microstructural properties of cream cheese

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Received 4 January 2000; received in revised form 1 May 2000; accepted 14 June 2000

Abstract

Flavour and texture in cream cheese depend on the microstructure. The objective of this work was to study the influence of fat content, salt content and homogenisation pressure on the microstructure and sensory properties of cream cheese. Twelve types of cream cheese were produced according to a full-factorial design, whereby the fat content was set at three levels, the salt content at two levels and the homogenisation pressure at two levels. The cheeses were analysed by a sensory panel, using both quantitative descriptive profiling and time intensity (TI) evaluation, and by using a confocal laser scanning microscope, CLSM, whereby the microstructure of the cheeses was analysed. All the design parameters had a significant influence on the flavour and texture, although fat had the largest effect. Interaction effects between the design parameters were also found to influence the character of cream cheese. The results showed that it is possible to create a cream cheese with lower fat content and with sensory attributes similar to the attributes in cream cheese with high fat content, by modification of production parameters.

1. Introduction

A main problem in many European and American cultures is a too high consumption of fat (Bruhn, Cotter & Diaz-Knauf, 1992). It was recently shown, in the UK, that most consumers were not prepared to sacrifice taste or any other quality of foods for any perceived health benefits (McIlveen & Armstrong, 1995). This implies that the food industry is facing a challenge to produce fat-reduced foods, which have similar properties as high-fat products. A serious problem in low-fat food products, such as cream cheese, is that both partial and total fat reduction have profound effects on the final flavour and texture (de Vor, 1991; Yackel & Cox, 1992).

One problem in low-fat foods is that both taste and flavour are more intense than in high-fat products but disappear quicker, and that the fullness of texture is thus lost (de Roos, 1997). Earlier studies have shown that basic gustatory sensations change according to the level of fat. Reducing the fat content in Edam cheese caused an increase in the intensities of all gustatory sensations except for saltiness, which decreased in intensity (Shamil, Wyeth & Kilcast, 1992). The same authors also showed that flavours in, for example cheese, and dressing became more harsh when the fat content was reduced (Shamil et al., 1992). However, in cheese spreads with different fat contents it was mainly texture parameters that were depending on the fat content (Muir, Williams, Tamine & Shenana, 1997). Successful attempts to increase the fullness in cream and cheese have been made by homogenisation, so that the number of fat-droplets increased and their sizes decreased (Drake & Swanson, 1995; Tepper & Kuang, 1996).

Cream cheese contains a large amount of proteins, which are able to keep a large amount of water in the product. Thus, the interaction between salt and proteins is important when decreasing the fat content. Salt has for example an effect on the aggregation of milk proteins (Cheftel & Cuq, 1985). In reduced-fat cheddar cheeses, hardness and fracturability increased as the salt content increased. Cheeses with the highest salt content had the least desirable texture, but there was no impact on the flavour (Mistry & Kasperson, 1998).

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0308-8146/00/$ - see front matter
PII: S0308-8146(00)00200-4

In a study of cheese analogues, however, it was observed both with profiling and time intensity (TI) methodology that the salt content (varied from 0.5 to 2.0%) had an influence on both saltiness and sourness (Stampanoni & Noble, 1991a, b).

The influence of various design parameters on the sensory attributes has been investigated. Relationships between fat content, processing conditions and sensory and structural properties have been established in different model systems (Langton, Åström & Hermansson, 1997, 1999; Langton, Åström, Stading & Hermansson, 1997; Wendin, Aaby et al., 1997; Wendin, Solheim, Allmere & Johansson, 1997; Wendin, Ellekjaer & Solheim, 1999).

One of the reasons why low-fat and high-fat products are perceived to be different is that they behave differently in the mouth, both with respect to flavour release and structure breakdown (Taylor & Linforth, 1996). This type of dynamics can be studied by the time intensity method (Kilcast, 1992; Shamil et al., 1992).

The objective of this investigation was to characterise the influences of fat content, salt content and homogenisation pressure on flavour, texture and microstructure in cream cheeses. Another aim was to explain the perception of cream cheese based on the microstructure. The sensory methods were descriptive profiling and time intensity (TI), and the microscopy used was a confocal laser scanning microscope (CLSM), by which both the fat phase and the protein phase were analysed. In addition, the fat phase was also examined as a function of temperature.

2. Materials and methods

2.1. Cream cheese

The cream cheeses in this investigation were produced in a random order according to a full factorial design (Table 1a), where the fat content was kept at three levels, 22, 28 and 34% fat. The salt content was kept at two levels, 0.4 and 0.7% salt (NaCl) and the homogenisation was kept at two levels, 8×10^3 and 2.5×10^4 kPa. A total of 12 cheeses were produced. Table 1 shows recipes and process parameters according to the experimental design, and the codes for the samples further used in the analyses. The protein content was 7.5% in all cheeses. The cheeses were made from cow's milk by using addition of rennet and a microbiological acidification culture. The cream cheeses were produced in a pilot plant (Alfa Laval, Sweden) at Arla, Götene, Sweden.

The cheeses were stored in 0.25-l plastic containers with a weld lid of aluminium, used for commercial cream cheese, and kept at +8°C until analysis. Chemical analysis was performed on the produced samples, and the results are shown in Table 1b.

Table 1

a. Cream cheeses, codes and recipe/process parameters

Code	Fat content (%)	Salt content (%)	Homogenisation pressure (kPa)
p1	22	0.4	8×10^3
p2	22	0.4	2.5×10^4
p3	22	0.7	8×10^3
p4	22	0.7	2.5×10^4
p5	28	0.4	8×10^3
p6	28	0.4	2.5×10^4
p7	28	0.7	8×10^3
p8	28	0.7	2.5×10^4
p9	34	0.4	8×10^3
p10	34	0.4	2.5×10^4
p11	34	0.7	8×10^3
p12	34	0.7	2.5×10^4

b. Chemical analysis

Code	Water content (%)	Fat content (%)	Fat content in dry matter	Protein content (%)	Salt content (%)	pH
p1–2	65.4	23.8	68.6	7.6	0.5	4.6
p3–4	64.4	24.5	68.1	7.7	0.8	4.7
p5–6	56.9	29.8	72.4	7.6	0.5	4.7
p7–8	59.4	30.4	74.9	7.5	0.8	4.7
p9–10	53.7	36.4	78.7	7.7	0.5	4.7
p11–12	48.7	41.8	81.5	6.7	0.7	4.7

2.2. Sensory analyses

The analyses were performed by an external trained panel (SIK, Sweden). The panel was selected and trained according to ISO 8586-1993. Carbonated water and neutral wafers were used for cleaning the palate between the samples.

The intensity ratings were recorded and converted into numbers by a computerised system (PSA, system/3, version 2.08a, Oliemans Punter and Partners, The Netherlands).

2.2.1. Descriptive profiling

The panel consisted of eight assessors. During three training sessions the assessors developed the sensory attributes by comparing cheeses which had large differences in sensory qualities. The assessors were trained how to evaluate flavour, taste, texture and appearance attributes of the cheeses, and how to utilise a 100 mm continuous line-scale anchored with low intensity at 10 mm and high intensity at 90 mm. The sensory attributes and their definitions are given in Table 2.

The cream cheese samples were cut as cylinders with a diameter of 60 mm and a height of 25 mm. One-quarter (15 g) of the cylinders from each of the cheeses was served on small plates to the judges. The serving temperature was ambient, approx. 20°C.

The cheese samples were served in triplicate in individual randomised order. All samples were evaluated in 2-h sessions during 3 days.

2.2.2. Time intensity

The panel consisted of five assessors. During four training sessions the assessors were trained how to use a computer to evaluate the intensity of a particular attribute of the cheeses continuously, utilising a 100 mm continuous line-scale anchored with low intensity at 10 mm and high intensity at 90 mm. The evaluation took place during four sequential days. The sensory attributes used for the TI assessments were derived from the profiling attributes which were sourness, saltiness and fat-creamy, marked with * in Table 2. These attributes were evaluated, one attribute at a time, during 40 s per attribute.

The samples (1 g on a teaspoon) had a temperature of 20°C. They were served in randomised order and evaluated in triplicate. The sampling rate of the computer was 1/s. From the TI data the following parameters were calculated: I_{max}, the maximum observed intensity; T_{max}, the time at which maximum intensity occurred; AUC, the area under the curve; Dur, the intensity duration (Meilgaard, Civille & Carr, 1991).

2.3. Microstructural analysis

A confocal laser scanning microscope, CLSM, Leica TCS 4D, (LLT, Heidelberg, Germany), was used to study the microstructure of the cream cheeses. All 12 samples were analysed by the following protocol; small specimens were prepared by punching out tubes of cheese with a metal cylinder. From the tubes 2-mm thick slices were cut. The fat phase was stained with Nile red, and in some experiments the protein was stained with Acridine orange. In the doubled stained samples the fat phase was red and the protein phase was green. The coloured images have been converted to greyscale images in this paper. In order to prevent melting of the fat phase during analysis the samples were kept at a low temperature, +4°C, with a temperature stage (Linkam Scientific Instruments Ltd, UK), during the analysis. Experiments were also performed wherein the temperature had been increased from 10 to 40°C. The temperature was increased by ~20°C/min, in steps of 5°C, and kept at this temperature for 2 min. The temperature control stage made it possible to characterise the melting behaviour in a controlled manner. Images were captured as fast as possible after the holding time.

2.4. Statistical analyses

Standard error of the descriptive profiling measurements (S_{ref}) was calculated (Ellekjaer, Isaksson & Solheim, 1994) in order to get an indication of the uncertainty of the analysis due to judges. S_{ref} is defined for the sensory attribute y_i by:

$$S_{ref} = \sqrt{\frac{MSE}{A \cdot R}} \quad ,$$

Table 2
Sensory attributes and standard error of the measurements

Attribute	Definition	Standard error of measurements (S_{ref})
Appearance		
Yellow colour	Scale yields from white to yellow	0.48
Granularity	Low = a smooth cheese High = a grainy cheese	0.43
Watery	Wet and shiny look	0.49
Compact	Low = porous High = compact	0.53
Flavour/taste		
Sourness[a]	Fresh sourness, reminding of yoghurt	0.42
Butter	Flavour of butter	0.41
Saltiness[a]	Taste of salt	0.34
Texture/Mouthfeel		
Granularity	Low = a smooth cheese High = a grainy cheese	0.61
Fat-creamy[a]	Creamy feeling of fullness in the mouth	0.45
Texture by hand		
Spreadability	Low = hard to spread (2mm layer) on a cracker High = easy to spread (2mm layer) on a cracker	0.48

[a] Attributes analysed by TI technique.

where MSE is the mean square error derived from two-way ANOVA with samples and assessors (A) as fixed effects and with the interaction included. R represents the number of sensory replicates. The calculated values, shown in Table 2, indicate that the performance of the panel was similar to what has been reported in previous studies on food (Ellekjaer et al., 1994; Wendin et al., 1999).

Two-way ANOVAs with samples and assessors as fixed effects were made on both descriptive profiling and TI data. Tukey's multiple comparison test was performed on attributes for which effect significant differences were found in ANOVA (P-value $\leqslant 0.05$) (SYSTAT 8.0, SPSS Inc.).

Three-way ANOVAs with design parameters (salt content, fat content and homogenisation pressure) as fixed effects were performed on both descriptive profiling and TI data. Tukey's multiple comparison test was performed on attributes, for which effect significant differences were found in ANOVA (P-value $\leqslant 0.05$) (SYSTAT 8.0, SPSS Inc.).

Principal component analyses (PCA) were performed (Guideline +, CAMO ASA, Norway) on the averages of subjects and replicates to describe the main variation in sensory data.

3. Results and discussion

The samples were characterised sensorially and microstructurally. First the sensory analysis is over-

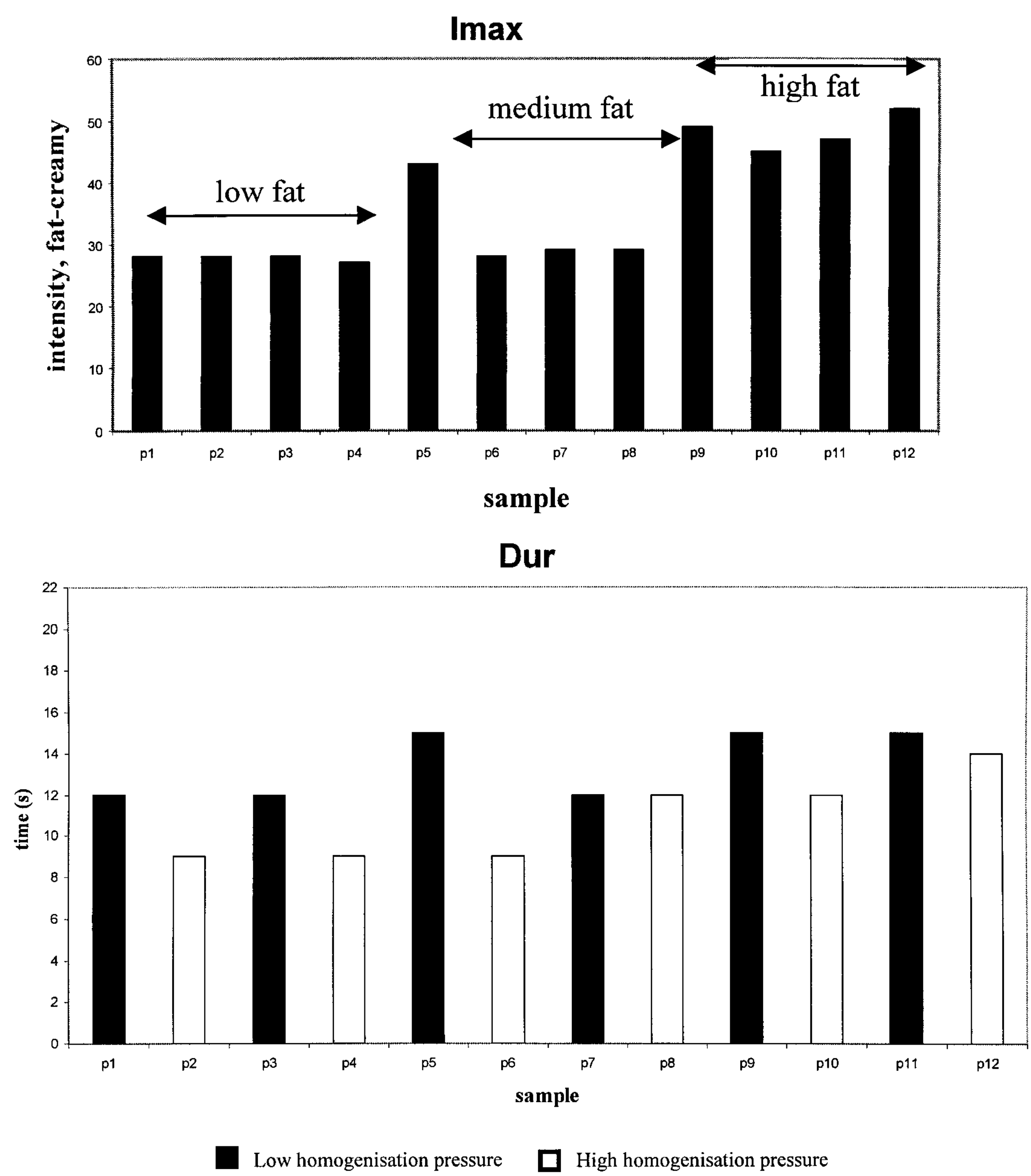

Fig. 1. Fat-creamy measured by TI.

viewed, followed by a description of the microstructure. Finally, the sensory results will be discussed along with the microstructure in parallel with the experimental parameters. The influence of microstructure on perception will be shown.

3.1. Sensory analysis

The sensory results are given as mean values in Fig. 1 and Tables 3 and 5, and as PCA plots in Fig. 2a and b (descriptive profiling) and in Fig. 3a and b (TI). The descriptive profiling results show that there were big differences between the samples in many of the attributes, e.g. yellow colour, fat-creamy and granularity, as shown in Table 3. The first PC, which explained 78% of the variance, was mainly defined by the attributes fat-creamy in one direction and watery in the opposite direction (Fig. 2a and b). The second PC, which only explained 9% of the variance, was defined by spreadability and saltiness. Thus the texture attributes were more important than taste and flavour attributes in describing the differences between the samples.

Out of the three attributes, which were studied by the TI method, fat-creamy showed the biggest differentiation between the samples (Fig. 1 and Table 5). For example, the shortest duration was about 9 s and the longest about 15 s according to Fig. 1. The PCA plot of the TI results in Fig. 3 shows a similar sample separation as the plot based on the descriptive profiling results.

Effects of the experimental design parameters and their interactions on the sensory properties are shown in Fig. 4a–d and Tables 4 and 6. Almost all attributes were affected by the fat content. It was expected that 12% change in fat content would have an impact and was in fact the reason why the fat content was kept at three levels.

3.2. Microstructure

The results from the microstructural analysis are divided into three different types of fig. An overview of the fat phase of all 12 samples is given in Fig. 5. The fat phase is visualised and appears as brighter globules, where the left column shows the low fat samples, the middle column medium fat level, and the right column shows the high fat samples. In order to illustrate the interaction effects, examples are given in Fig. 6, where both the fat phase and the protein phase are visualised. Additional experiments were performed wherein the temperature was increased during the analysis under the microscope (Fig. 7a and d). This was done to simulate the temperature increase of the cream cheeses in the mouth.

The microstructure was affected by fat content, homogenisation pressure and salt content (p1–12, Fig. 5: 1–12). An increase in fat content resulted in an increase in droplet size as well as in the size of the cluster of droplets, when all other conditions were kept constant. Increased homogenisation pressure decreased the size of the fat droplets (compare odd and even sample codes in Fig. 5). The salt content affected the samples differently depending on the fat content. In samples with low fat content, a high salt content decreased the size of the droplets (p1–4), whereas in the samples with medium and high fat content a higher salt content increased the droplet size (p5–12). When studying p5, it can be noted that the droplets were round and well defined, and the sizes were up to 10 μm. The droplets were unevenly distributed and clusters of droplets were also found. The character of sample p5, at medium fat content, reminded to a great extent of the samples with a higher fat content.

Table 3
Plot of mean values from the descriptive profiling

Sensory attribute	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10	p11	p12
Appearance												
Yellow colour	25	22	25	21	26	26	31	27	31	30	45	38
Granularity (app.)	32	34	29	32	26	32	27	25	28	24	31	22
Watery	38	36	32	32	31	31	27	30	23	21	25	18
Compact	29	27	35	32	38	30	37	35	38	43	38	47
Flavour/taste												
Sourness	45	44	49	48	45	42	49	46	45	46	45	46
Butter flavour	27	26	32	29	32	33	32	32	35	34	38	40
Saltiness	30	28	34	33	28	28	33	35	28	28	34	32
Texture/mouthfeel												
Granularity (text)	34	35	27	41	22	39	30	31	21	24	23	16
Fat-creamy	30	30	38	31	41	34	38	34	46	45	47	51
Texture by hand												
Spreadability	53	48	47	46	51	42	45	46	51	47	44	45

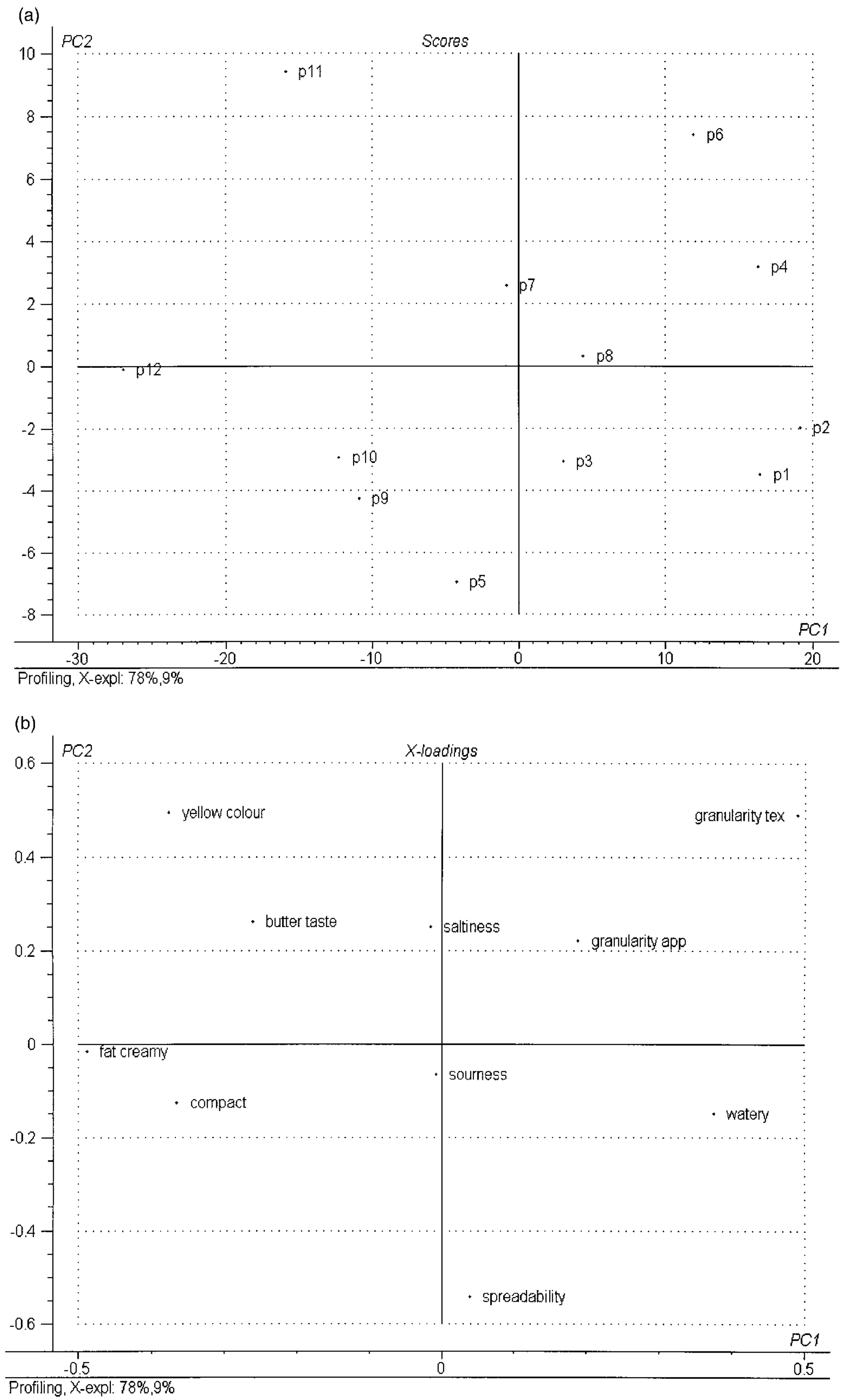

Fig. 2. (a) Scores, PCA plot of the descriptive profiling results; (b) loadings, PCA plot of the descriptive profiling results.

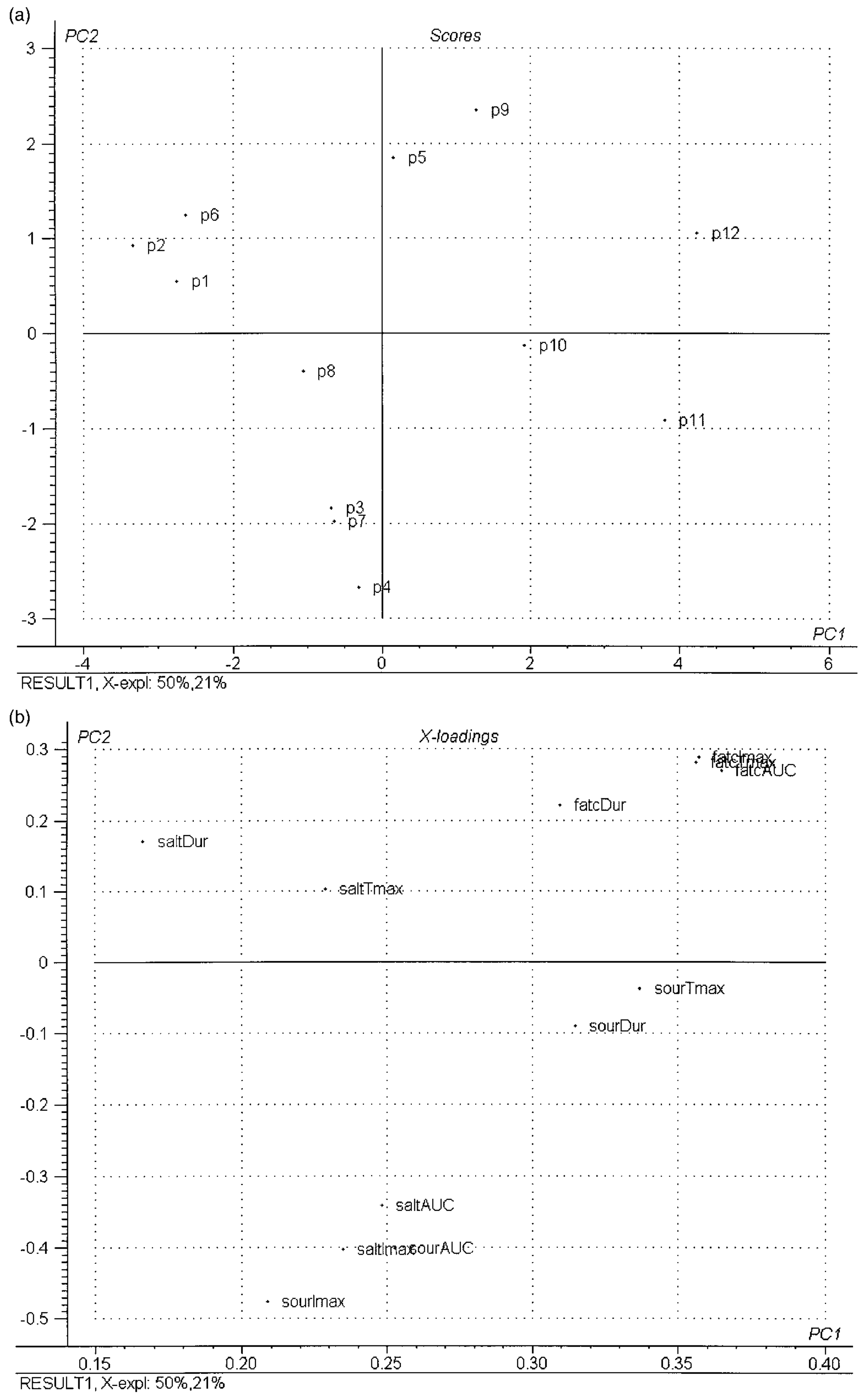

Fig. 3. (a) Scores, PCA plot of the TI results; (b) loadings, PCA plot of the TI results.

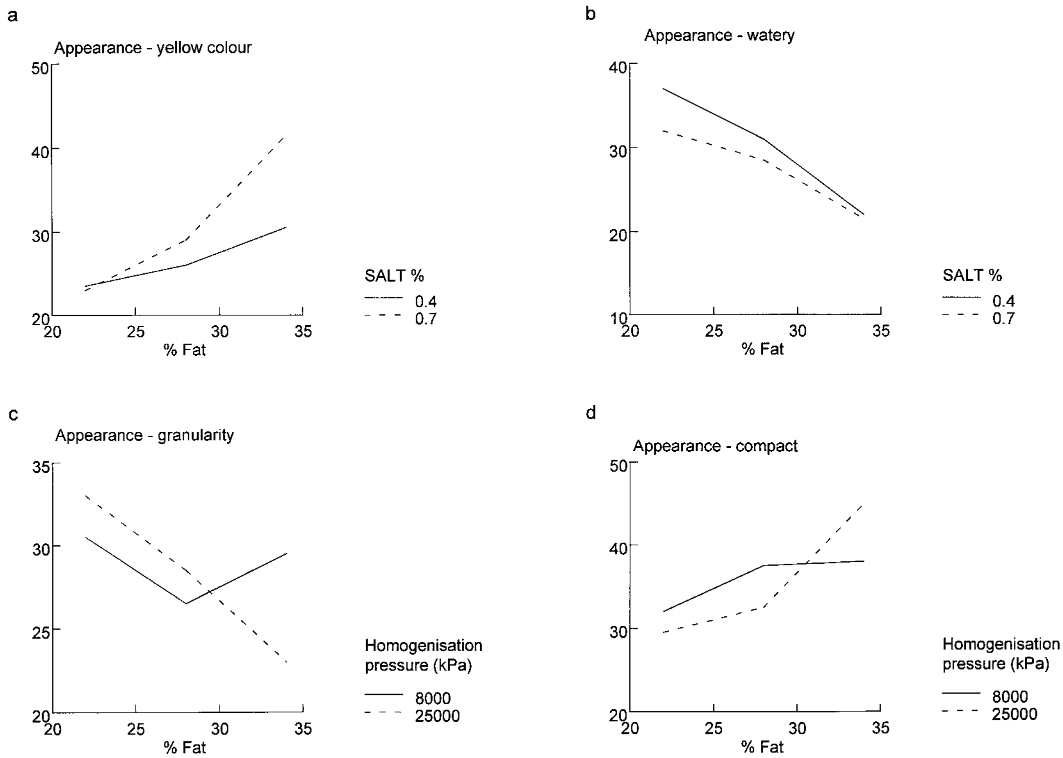

Fig. 4. Interaction effects, descriptive profiling.

Table 4
Influence of design parameters and their interactions, descriptive profiling. Significant β-coefficients are given[a]

Sensory attribute	Fat content	Salt content	Homogenisation	Fat X salt	Fat X hom	Salt X hom
Appearance						
Yellow colour	0.86***	8.93*	-2.06×10^{-2}**	2.16**	ns	ns
Granularity	−0.34*	ns	ns	ns	−2.24*	ns
Watery	−0.85***	ns	ns	2.26*	ns	ns
Compact	0.72**	ns	ns	ns	2.28*	ns
Flavour/taste						
Sourness	ns	9.02*	ns	ns	ns	ns
Butter	0.59***	ns	ns	ns	ns	ns
Saltiness	ns	20.21***	ns	ns	ns	ns
Texture / Mouthfeel						
Granularity	−0.90*	ns	ns	ns	ns	ns
Fat-creamy	1.02***	ns	ns	ns	ns	ns
Texture by hand						
Spreadability	ns	ns	ns	ns	ns	ns

[a] The parameters having a significant influence on a certain attribute are marked by *** (0.001 significance level), ** (0.01 significance level), * (0.05 significance level) or ns (non significant).

3.3. *Effect of fat content*

The main influencing experimental parameter in this study was the fat content, which most of all influenced the texture attributes (Figs. 1 and 5, and Tables 3–6). This was in accordance with results obtained by Muir et al. (1997), who studied cheese spreads.

The intensities of the profiling attributes granularity (both appearance and texture), watery, compact, fat-creamy and butter flavour in the high-fat (34% fat) products plus sample p5 (28% fat) were significantly different from the intensities in the samples with low-fat content (22% fat). The high-fat samples were less granular (appearance and texture), less watery, more compact, more fat-creamy and had a higher intensity of butter flavour (Figs. 1–3). The largest fat droplets were found in samples with the highest fat content (Fig. 5). This could of course be due to the high fat content itself, but

Table 5
Mean values on time intensity measurements

Sample	Saltiness				Sourness				Fat-creamy			
	AUC	I_{max}	T_{max}	Dur	AUC	I_{max}	T_{max}	Dur	AUC	I_{max}	T_{max}	Dur
p1	324	40	9	16	416	45	10	17	148	28	7	12
p2	324	40	9	15	384	41	10	16	148	28	7	9
p3	504	53	10	16	468	51	11	16	156	28	7	12
p4	532	55	10	17	504	52	11	17	140	27	7	9
p5	360	41	10	15	416	44	11	16	304	43	9	15
p6	384	43	11	19	380	42	10	14	156	28	7	9
p7	452	55	10	15	468	52	10	18	164	29	7	12
p8	516	56	11	17	396	43	11	15	168	29	8	12
p9	404	46	10	18	404	44	11	17	356	49	9	15
p10	492	47	10	17	496	52	11	19	336	45	9	12
p11	488	55	11	16	572	54	12	18	364	47	10	15
p12	568	57	12	21	440	47	11	20	408	52	10	14

Table 6
Influence of design parameters and their interactions, TI measurements. Significant β-coefficients are given[a]

Attribute	Fat content	Salt content	Homogenisation	Fat×salt	Fat×hom	Salt×hom
Sourness						
I_{max}	ns	ns	ns	ns	ns	ns
T_{max}	ns	ns	ns	ns	ns	ns
AUC	ns	ns	ns	ns	ns	ns
Dur	ns	ns	ns	ns	ns	ns
Saltiness						
I_{max}	0.44***	40.19***	ns	ns	ns	ns
T_{max}	ns	ns	ns	ns	ns	ns
AUC	0.14**	10.73***	ns	ns	ns	ns
Dur	ns	ns	ns	ns	ns	ns
Fat-creaminess						
I_{max}	1.36**	ns	ns	ns	ns	ns
T_{max}	0.15***	ns	ns	ns	ns	ns
AUC	0.36**	ns	ns	ns	ns	ns
Dur	0.26**	ns	-1.46×10^{-2}**	ns	ns	ns

[a] The parameters having a significant influence on a certain attribute are marked by *** (0.001 significance level), ** (0.01 significance level), * (0.05 significance level) or ns (non significant).

since smaller fat droplets induced by higher homogenisation pressure gave less fat-creamy products, both fat content and droplet size had an impact. The PCA plots (Figs. 2–3) confirm that the samples with high fat content were more fat-creamy, compact, yellow and had a higher intensity of butter flavour than samples with low and medium fat contents, which were more watery and granular. These plots also show that sample p5 (28% fat) was more similar to the high-fat samples.

Sourness was not significantly affected by the fat content, while saltiness was observed to be dependent of the fat content in the TI analysis (Tables 5–6). A reduction of fat was shown to give a loss of 'rounded' flavours (Shamil et al., 1992). In our study, this could be seen for the butter flavour, which was less intense in samples with a lower fat content (Tables 3 and 4). These phenomena were probably due to differences in fat/water proportions in low-fat and full-fat products. The fat/water proportion in a product influences the distribution of flavour compounds in the food and on the taste/flavour receptors. It was noted that the swallow times for low-fat cheeses were usually longer than for full fat cheeses, which also could explain differences in flavour intensities (Shamil et al., 1992).

3.4. Effect of salt content

The salt content had a significant influence on the attributes saltiness, sourness and yellow colour, but had no influence on the texture attributes (Tables 4–6). A comparison between the samples with low and high salt content shows that the samples with low fat content (22%) and a higher salt content gave smaller fat droplets as seen in Fig. 5: p1–4. The small droplet size was the reason why these samples were less yellow. In samples containing 28–34% fat a higher salt content yielded

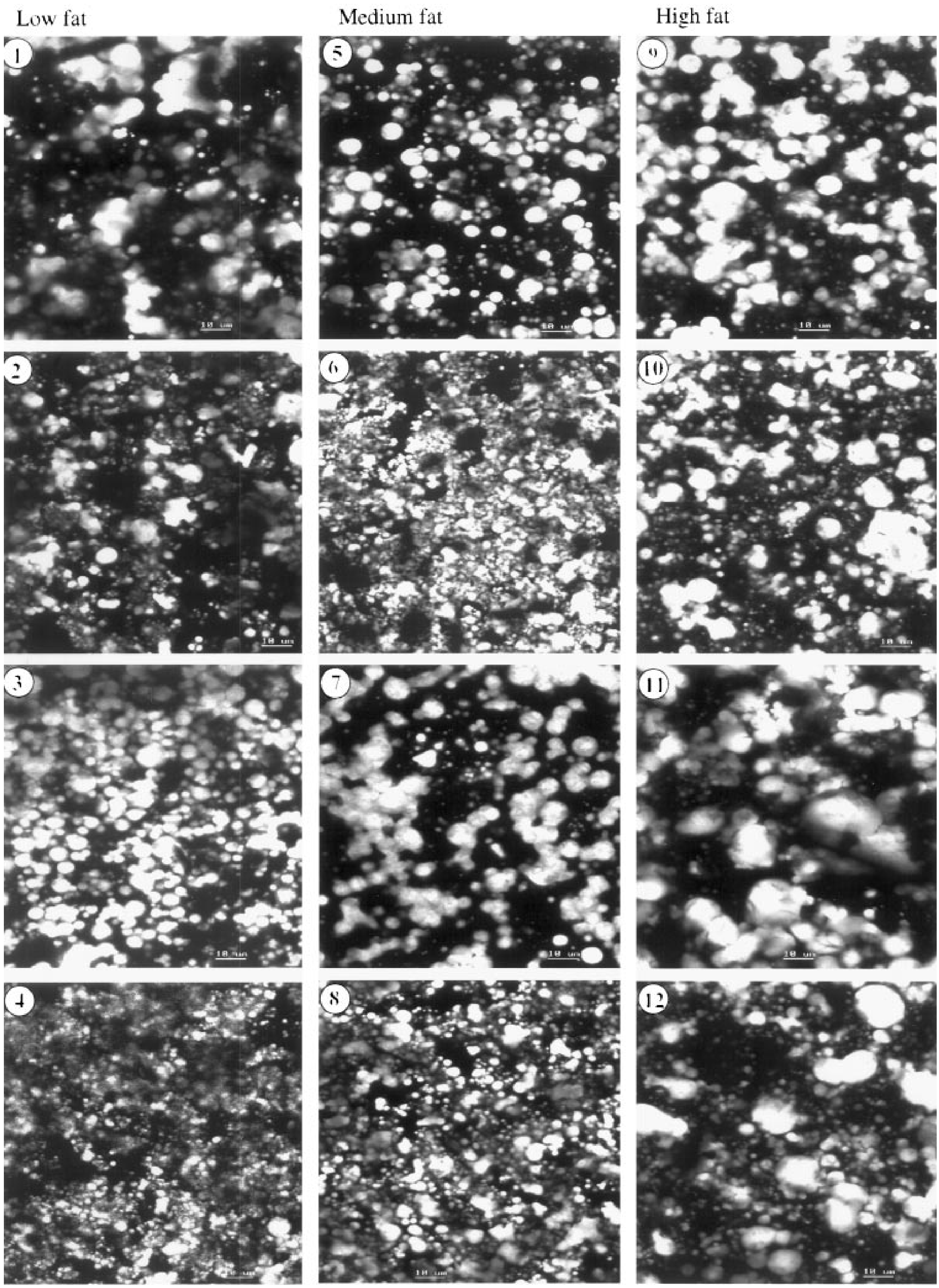

Fig. 5. CLSM-micrographs of the 12 samples 1–12, as depicted in Table 1. The fat droplets are shown as bright globules.

larger droplets (Fig. 5: p5–12) while the samples were more yellow. The variation in droplet sizes was probably due to salt interactions with protein, which in turn led to variation in protein adsorption to the oil droplet surface. It has been shown that protein structures surrounding fat globules are more dense and compact in low-fat cheese and these internal structures are among the most important factors in determining textural properties of cheese (Sohn & Harper, 1995). Figs. 6 and 5: p5–8 visualise the fact that the fat droplets became smaller by increasing the homogenisation pressure and that samples with low salt content had smaller proteins aggregates than samples with high salt content. The larger protein aggregates are depicted by an arrow in Fig. 6. Thus, the salt content affected the distribution of protein in the cream cheese.

The addition of salt increased the cluster formation in whey protein gels (Langton, Åström & Hermansson, 1997). This is in agreement with results found in this study, where an increase in salt content resulted in cluster formation of the protein (Fig. 6). Studies on reduced-fat cheddar cheeses, where the salt content in the cheeses varied from 1.3 to 2.0%, showed that the cheeses with the highest salt content were harder and more fracturable, but no differences in flavour were shown (Mistry & Kasperson, 1998). This is in contrast to the results we have found. In our study the salt content was lower (0.4–0.7%). We found no effect of salt contents on the texture attributes, however, both saltiness and sourness were significantly influenced by the salt content (Tables 4 and 6). Differences in the intensity of saltiness were due to the differences in salt content. Although salt content had a significant influence on the sour taste (Table 4), no significant differences between the samples were observed (Table 3). This is in accordance with other studies, which have shown that salts and acids enhance each other at moderate concentrations (Breslin, 1996). For example, in a study on whey protein gels by Langton, Åström and Hermansson, 1997, the acid taste was found to be more intense in samples containing salt.

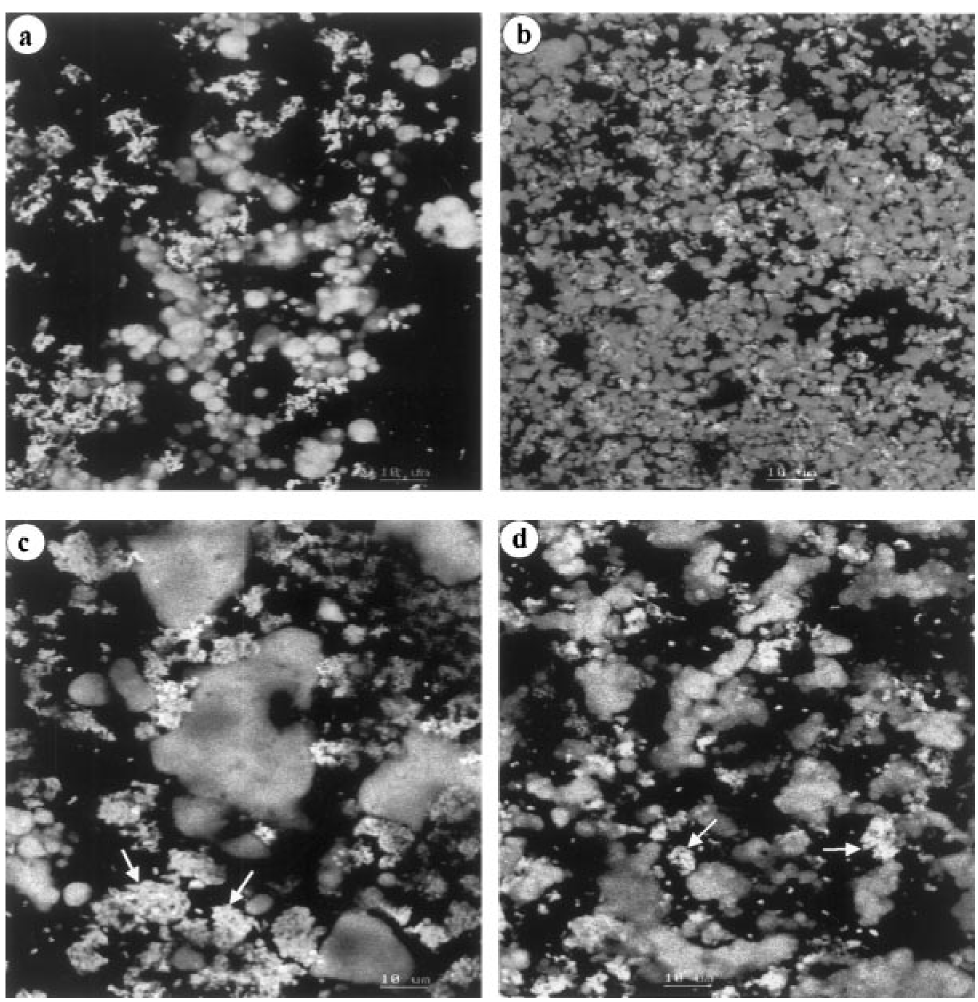

Fig. 6. CLSM image, visualising the larger fat globules and the smaller bright aggregates of milk proteins in sample p5–p8 a–d, respectively.

3.5. Effect of homogenisation pressure

An increase in the homogenisation pressure reduced fat droplet size and made the droplets more evenly distributed in the product (Fig. 5). Samples with odd numbers were homogenised at a low pressure and samples with even numbers at a higher pressure. Large fat compounds were found in samples having the highest amount of fat, 34% (Fig. 5: p9–12). The fat was least dispersed in sample p11 with low homogenisation pressure and high salt content. Smaller fat droplets, e.g. samples with high homogenisation pressure, exhibit shorter duration in the dynamic sensation of 'fat-creamy', as seen in Fig. 1. Small particles spread the light more than bigger particles, which indicates that smaller particles will give a whiter sample. This light phenomenon can be seen in the descriptive profiling analysis, where homogenisation lowered the intensity of yellow colour (Table 4).

Homogenisation breaks up the milk fat globules into small droplets and disperses them throughout the cheese matrix. Contrary to our results small, dispersed fat globules were shown to have a 'fat-extending' effect on for example Edam cheese (Drake & Swanson 1995; Jana & Upudhyay, 1992). It has been reported that homogenisation can increase the retention of moisture in cheese (Drake & Swanson; Jana & Upudhyay), and induce a more bland flavour (Swaisgood, 1985). In our study, homogenisation had a significant decreasing effect on the duration parameter (TI) of the attribute fat-creamy (Table 4). According to McClements and Demetriades (1998) the sensation of 'creaminess' in a food demands that the fat/oil droplets has a critical size, which is product specific. In our study, sample p5 (28% fat) seemed to contain fat droplets of the specific size for 'fat-creamy' in cream cheese, since the analysis showed that it was closer to samples with 34% fat than to samples with a lower fat content (Table 3 and Figs. 1–3). This sample also had the same size of fat droplets as the comparable sample p9, with 6% higher fat content.

3.6. Melting behaviour

Fig. 7 shows the effect of temperature on the fat phase in the cream cheeses. Under the conditions used, the structure appeared to be more or less unaffected up to 20°C. Figs. 7a and b show that the droplets in samples p7 and p8, with medium fat content, start to melt already at 25°C, which resulted in loss of droplet shape, as indicated by arrows in the fig. Further increase of the temperature, to 30°C, gave larger areas of melted fat. At 35°C almost no individual droplets remained in sample p7 and large pools were found in sample p8.

Fig. 7c and d show sample p5 with medium fat content and sample 9 with high fat content, both produced with low pressure and low salt content. During temperature increase the fat phase gradually melted but the shape of the droplets was fairly well preserved even at 35°C. These samples were less affected by heating than the samples p7 and p8. It is interesting to observe that the two samples, p5 and p9, which stayed more unaffected by a temperature increase, were perceived as more fat-creamy than p7 and p8 (Fig. 1).

3.7. Interactions

Previously we have discussed main effects, but the system was more complex than that and the statistical evaluation also showed four significant interaction effects on the sensory perception, visualised as plots in Fig. 4a–d. The β-coefficients were calculated and presented in Table 4. Fig. 4a shows that a larger amount of salt increased the intensity of yellow colour at a higher fat content, whereas the salt content had little or a reverse effect at the lowest fat level. This can be explained by the droplet size; at a low fat content smaller droplets were found when more salt was added, whereas at a medium and high fat content the higher salt content resulted in larger droplets. They were also perceived as more yellow.

The attribute watery, Fig. 4b, was almost negatively correlated to yellow. The intensity of watery could not only be explained by the droplet size. Flocculation and volume fraction of the water phase also had an impact. Thus samples with more water, i.e. with low fat content, were for example evaluated to be more watery. These samples were also more sensitive to the salt level, and the amount of salt could affect the aggregation of proteins.

The effects of interactions between homogenisation pressure and fat content on the attributes' granular appearance and compact were more complex as seen in Fig. 4c and d. Generally, a reduction in granular appearance was found when the fat content was increased as well as at lower homogenisation pressure, except when having high fat content and low homogenisation pressure, as seen in Fig. 4c.

Samples with low and medium fat content and also with low homogenisation pressure were more compact than the other samples. In the samples with high fat content a high homogenisation pressure gave a more compact product. Samples with small fat droplets and to some extent pools of fat (p4, p6 and p8), produced by the high homogenisation pressure were positively related to granularity and negatively related to compact as seen in the PCA-plots in Fig. 2a and b. The pools of fat in the microstructure could probably be connected to over-processing at these conditions. The pools and small droplets interacted and might together be perceived as large clusters, resulting in a more granular and less compact product.

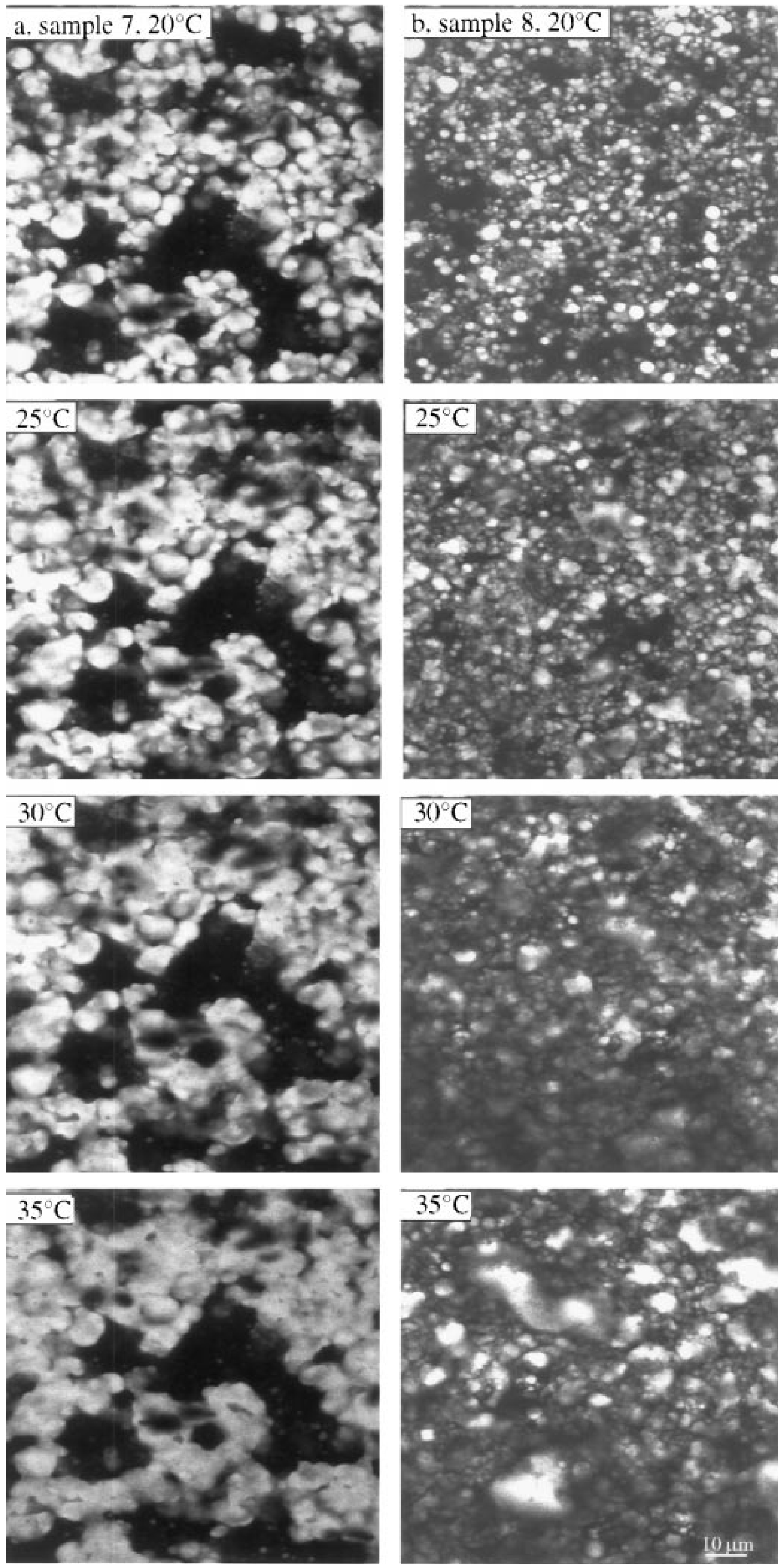

Fig. 7. CLSM micrographs as a function of temperature, 20–35°C, of (a) sample p7, (b) sample p8, (c) sample p5, and (d) sample p9 (*continued on next page*).

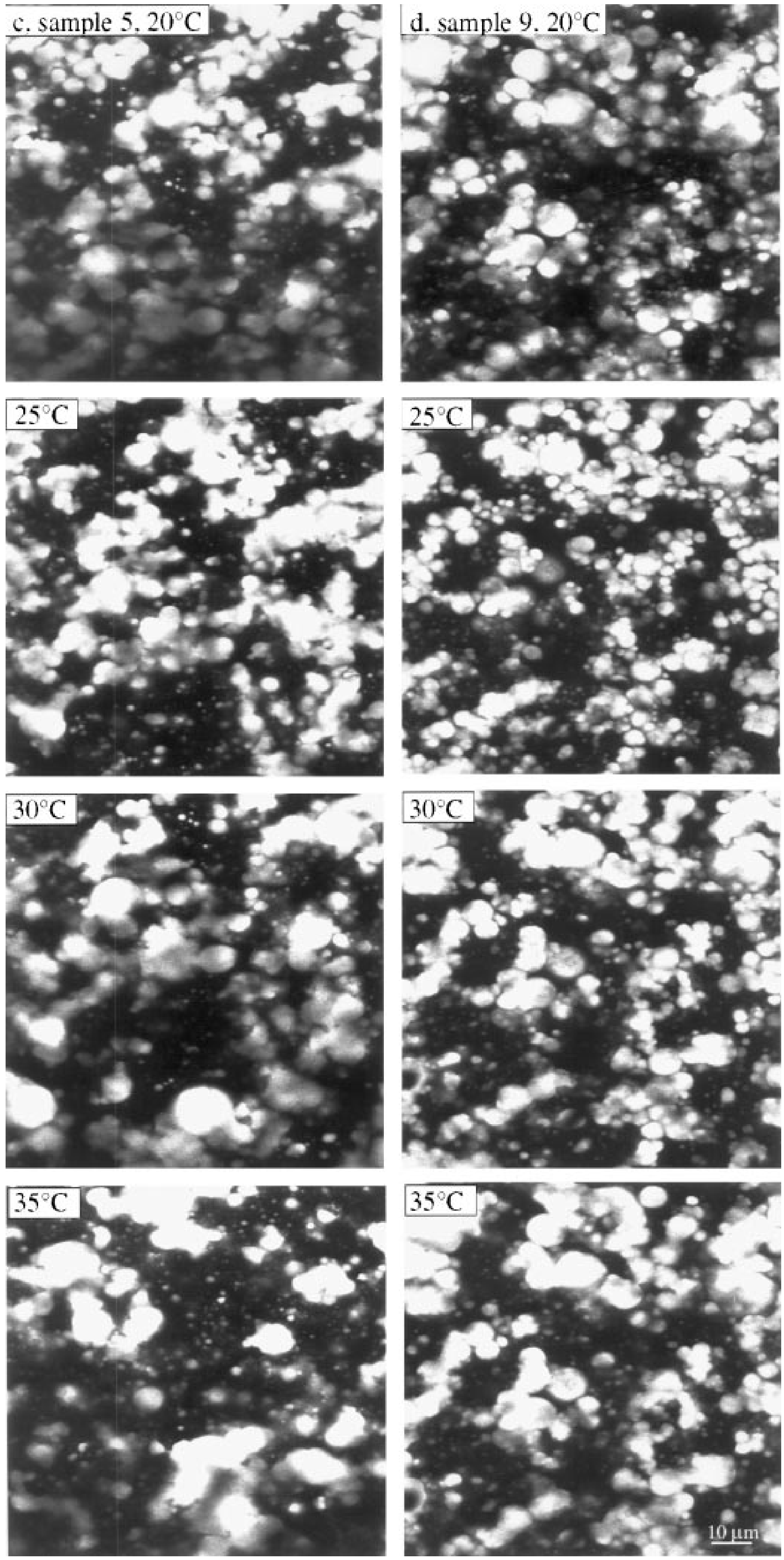

Fig. 7. (*continued*).

The interaction effects were best visualised at the medium fat level, where the combination of low salt content and low homogenisation pressure resulted in a somewhat unique structure with exceptional sensory characteristics. The four samples with medium fat content were spread in the PC-analysis, both descriptive profiling and TI in Figs. 2–3. It is likely that the low salt content during homogenisation made it possible for the protein to absorb on the oil droplet surface, at least when the homogenisation pressure was low as in sample p5, and no pools of fat were detected caused by possible over-processing. The protein film stabilised the droplets during tempering. The higher salt content instead favoured formation of protein aggregates; these samples, p7 and p8, were more unstable during heating as seen in Fig. 7.

Small droplets seemed to give a low contribution to the perception of the attribute fat-creamy. The fat globules needed to be fairly well preserved during a mild temperature increase. According to the attribute 'fat-creamy', there seemed to be an optimum in the fat distribution, close to the structure in sample p5. The results indicated that the system was complex and that there were interaction effects between fat level, salt content and homogenisation pressure. Small droplets having high internal pressure could be assumed to be more solid-like. In our study, sample p5 had medium fat content, but sensory characteristics reminding of products with a higher fat content.

4. Conclusion

The fat and salt content as well as homogenisation pressure affected both microstructure and sensory properties of cream cheese. Fat content was the main influencing parameter on taste, flavour and texture. Butter flavour and saltiness were more intense in samples with high fat content. An increase in fat content resulted in a texture, which was perceived as more compact, fat-creamy and yellow. Salt content not only influenced saltiness but also sourness. The yellow colour, the droplet size, and the aggregation of the milk proteins were also affected by the salt content. An increase in the homogenisation pressure reduced the fat droplet size and made the droplets more evenly distributed in the product. Smaller droplets gave a less yellow sample, and a shorter duration of fat-creamy sensation.

Significant interaction effects between the design parameters were found, but there were probably also interaction effects between other ingredients of the cream cheeses, as the salt content affected the aggregation of protein. In our study, we obtained one sample with unique characteristics as a result of an interaction between all three design variables, namely at medium fat level, low salt content and low homogenisation pressure. This sample had a microstructure and sensory properties similar to products with 6% higher fat content. The results showed that it was possible to create a cream cheese, with lower fat content and with sensory attributes similar to the attributes in cream cheese with high fat content, by modification of production parameters.

Acknowledgements

The authors are grateful to Elvy Jordansson for microstructure analysis and to Maud Berg for assistance during the sensory analysis. Special thanks to Arla AB, Sweden for the production of cream cheese and to the KK-foundation, Sweden.

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