

Cheese Meltability as Assessed by the Tube Test and Schreiber Test Depending on Fat Contents and Storage Time, Based on Curd-Ripened Fried Cheese

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Abstract

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The study assessed cheese meltability at elevated temperatures, based on the results of the Tube Test and Schreiber Test. The tests were conducted on curd-ripened fried cheese with varying fat contents ($\Delta\text{fat} = 17\%$) and at different storage times ($\Delta t = 6$ weeks). The protein:fat ratio in full fat cheese was $C:F \approx 1$, while in low-fat cheese it was $C:F \approx 58$. The data on cheese meltability recorded in the Tube Test and Schreiber Test, irrespective of experimental variables, indicated a high degree of correlation ($r = 0.95$). However, the lowest convergence ($r = 0.6$) of both methods was found when analysing low fat cheese. A higher fat content in the tested cheeses resulted in a statistically significantly higher meltability both in the Tube Test (by 12%) and in Schreiber Test (by 18%). The analysis of the regression model and response surfaces of variables confirms the trend showing that the lower the fat content and the longer the sample storage time, the lower the meltability. After 6 weeks the assessed meltability of cheeses was lower by 20.7% in the Tube Test, and by 19.1% in the Schreiber Test in comparison to the meltability of cheeses assessed immediately after their production.

Keywords: fat reduced cheese; meltability; storage

Cheese meltability is a functional attribute reflecting closely the functional quality of cheese and is defined by the consumers' requirements. The modern lifestyle of consumers enforces new models of cheese consumption, e.g. in fondue, pizza, French bread pizzas or sauces. Thus, apart from the flavour value, much more attention has been also focused recently on the cheese texture and its functional attributes, such as meltability under the influence of elevated temperature. This is of special importance, especially in view of consumers' increasing interest in food with reduced calorie content resulting from reduced fat content. A significant role of fat in the modification

of aroma, texture, and consistency of cheese has been indicated in numerous studies (SİPAHIOĞLU *et al.* 1999; MOLINA *et al.* 2000; KOCA & METİN 2004). The reduction of the fat content in milk processing leads to significant changes in rheological properties of cheeses ready for consumption (ROMEIH *et al.* 2002; ZALAZAR *et al.* 2002; VAN HEKKEN *et al.* 2007).

Multifaceted utilisation of different cheeses enforces the necessity of conducting studies and analysing cheese meltability as a function of the action of temperature and time. The diversity of tests measuring meltability, e.g. the Schreiber Test, Tube Test (KOSIKOWSKI 1982; USTUNOL *et*

al. 1994; MUTHUKUMARAPPAN *et al.* 1999), instrumental methods (SMITH *et al.* 1980) or empirical models (ARNOTT *et al.* 1957), results in considerable discrepancies when determining correlations between methods inside a given group, and thus when interpreting the results obtained (KO & GUNASEKARAN 2008). A more in-depth analysis of cheese meltability needs to be based on differences in the basic compositions of cheeses and various technological operations applied in their production (WANG & SUN 2002), as well as their storage times (METZGER *et al.* 2001)

The curd-ripened fried cheese (Polish-Smażony Ser; German-Kochkäse), is produced on the basis of acid tvarog. This tvarog is produced by the separation of whey from the curd, which was previously subjected to the action of a lactic streptococci starter, causing partial milk coagulation (DMYTRÓW *et al.* 2007). Tvarog thus obtained, after being fragmented, is subjected to curd ripening, i.e. casein peptonisation. The curd ripening process is triggered by the action of moulds *Oospora lactis* (*Geotrichum candidum*, *Oidium lactis*) and film yeasts *Mycoderma*, followed by the action of proteolytic and lipolytic bacteria. The secreted hydrolytic enzymes cause the proteolysis of casein proteins and production of proteolysis products, i.e. peptones, peptides, amino acids, and ammonia, which give this cheese its specific taste and aroma. During tvarog ripening, its active acidity is significantly lowered from pH 4.4 to above 5.0, among other things as a result of the decomposition of lactic acid to carbon dioxide and water. After the ripening process is completed, the cheese mass obtained is fried. Cheese frying is performed with the addition of butter generally at a 4:1 ratio and salt is also added to taste, which results in the final product with the fat content of approx. 20%.

The aim of the study was to assess the meltability of curd-ripened fried cheese at elevated temperatures, based on the results of the Tube Test and Schreiber Test. The experimental material was curd-ripened fried cheese with varying fat contents and storage times.

MATERIAL AND METHODS

Cheese making. The production of curd-ripened fried cheese made from acid tvarog was run on a commercial scale using commercial facilities.

The input raw material in the production of acid tvarog was raw skimmed milk of a high hygienic and cytological quality. Milk was pasteurised at 75°C for 15 s in a H17 APV plate pasteuriser (API Schmidt-Bretten GmbH & Co-KG, Bretten, Germany) with a capacity of 2000 l/h. Next, it was cooled to 23°C and pumped to a Tewes-Bis coagulation tank (Barczewo, Poland) with a capacity of 10 000 l, thermally insulated and equipped with a mantle. The tank had two gate mixers equipped with cutting blades. The direct heating medium was hot water heated on a plate heat exchanger with a circulation pump. Mesophilic lactic fermentation streptococci: *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris*, *Leuconostoc mesenteroides* subsp. *cremoris* and *Lactococcus lactis* subsp. *lactis* biovar *diacetylactis* were added to the milk in the tank in the form of F-DVS CHN-22 lyophilised culture (Chr. Hansen) at 50 U/500 l milk in order to inoculate the milk directly. Milk coagulation lasted for 14 h at 23°C. An indicator of the curd ripeness was active acidity, reaching the value of pH 4.6 ± 0.1 . The curd titration acidity was 33 ± 1 SH. The curd with gel consistency, with no cracks or fissures, was heated in the tank to 33°C and cut. Whey was drained from the curd at a temperature of 20°C. Tvarog was made by self-pressing in block moulds. Cheese curd in moulds was pressed for 15 h, gradually increasing the applied pressure. Plastic multimoulds of 101 × 75 mm and cheese weight of 300 g were used. The guaranteed tvarog yield was 714 kg from 10 000 l of processed milk. Tvarog was stored for 24 h at $2 \pm 1^\circ\text{C}$.

Next, tvarog was comminuted using an FW-N32S Bizerba mechanic mincer (Balingen, Germany) with a mincer plate hole diameter \varnothing 4.5 mm. A layer ($h = 6$ cm) of the comminuted tvarog was spread on perforated trays of 700 × 700 × 100 mm. The trays with tvarog were stacked on a rack with 6 trays on each ($h = 1.6$ m) at regular intervals and placed in the ripening chamber for cheese ripening. This process lasted for approx. 3 days at $25 \pm 1^\circ\text{C}$ and relative humidity > 75 RH. During that time, tvarog was turned over on trays twice a day. The content of unripe tvarog, still white and not vitreous, could not visually exceed 25% of total cheese mass. Water loss from cheese during ripening was 5%. Next, cheese was mixed with butter and salt. In the case of the production of cheese with a reduced fat content, the addition of butter was replaced with the same amount of

ripe cheese. Raw materials weighed according to the formulation were stored in acid-resistant stainless steel containers of 680 mm × 670 mm, height 510 mm and capacity of 200 l. Then they were transferred to a UM130 closed thermiser with a water jacket and mixer by Stephan Machinery GmbH (Hameln, Germany), in which the mixture bulk was heated at 87°C for 15 minutes. The time required for cheese to reach 87°C was 7 minutes. After cooling to 70°C, cheese was poured into polyethylene/polyamide (PA/PE) unit containers of 150 cm³. A PAK-TREND 2000 (Radzymin, Poland) packaging machine with a power and hydraulic drive, and a capacity of 2000 units/h was used to package the product. The production cycle of curd-ripened fried cheese from the moment of the milk collection lasted for 7 days.

Curd-ripened fried cheese was stored at $4 \pm 1^\circ\text{C}$ for 6 weeks. The cheese was stored at a warehouse of 132 m², equipped with a cooling system using a DL SGE-401-EWL DWM semi-hermetic single-row compressor by Copeland (Aachen, Germany). Samples for analyses were collected from different production batches ($n = 6$). Cheese composition and pH were determined immediately after the cheese production during the first 24 hours. The other analyses were also conducted after the production and after 2, 4, and 6 weeks of storage. Each measurement and each analysis were performed in three replications.

Composition. The contents of water and fat in cheese were determined using standard methods (AOAC 1995). Total nitrogen content was determined according to Kjeldahl with the use of a Kjetec System 1026 apparatus of the Distilling Unit Tecator Company (Örebro, Sweden). Protein content was expressed in % of total nitrogen ($N \times 6.38$).

Meltability. The meltability of the cheese samples was determined by two methods: the Schreiber Test and a method applying a Test Tube.

For the Schreiber test, a circular cookie cutter with a diameter of 39.5 mm was used to cut out discs of cheese having a height of 5 mm. The discs were placed in a covered 15 mm × 100 mm thin wall Pyrex Petri dish and heated in a forced draft oven preheated to 232°C. Heating was run in a FED Binder hot chamber with forced air circulation (Tuttlingen, Germany). The samples were removed after 5 min and cooled for 30 min at room temperature. Specimen expansion was measured using a scale having six lines marked on a concentric set of circles. Schreiber Test meltability was given as

the mean of six readings on the arbitrary scale of 0–10 units (PARK *et al.* 1984).

In the second method, 10 g of grated cheese were placed in a tube (32 mm × 250 mm) and packed to form a plug at the bottom. The height of cheese was marked. The test tube was covered with aluminium foil and holes were made to let the hot gas escape during heating. The test tube was kept vertically in a refrigerator at 4°C for 30 min and then horizontally in an oven heated at 104°C for 60 min (PODUVAL & MISTRY 1999; KOCA & METIN 2004). Meltability was measured as the flow distance in mm of melted cheese.

Statistical analysis. Statistical calculations were performed using a STATISTICA (Version 7.1) data analysis software system by StatSoft, Inc. Pearson's linear correlation coefficients were calculated in order to determine the degree of proportional correlations between the values of the Tube Test and Schreiber Test. On this basis, regression lines were plotted and the coefficient of determination was calculated, constituting the basis for the size of correlation.

RESULTS AND DISCUSSION

The amount of fat determined in curd-ripened fried cheese with added butter (full fat cheese) was 17.5%, while the cheese produced with no butter added (low fat cheese) contained less than 0.5% fat. An approximate ratio of casein to fat in full fat cheese was C:F≈1, while in low-fat cheese it was C:F≈58. Low fat cheese contained 68% water which was 10% more than in full fat cheese.

When analysing the results of meltability in the Tube Test and the Schreiber Test, a high degree ($r = 0.95$) of their mutual correlation was found. The confirmation of the significant correlation between the results of meltability from the Tube Test and the Schreiber Test, irrespective of the type of cheese and the time of analysis, is the high value of linkage for the analysed variables $R^2 = 0.87$. The reliability of correlations was also high and close to 1 ($\beta = 0.947$). However, the analysis conducted separately with cheeses of different fat contents showed that a higher ($r = 0.77$) degree of convergence of both meltability tests was recorded in the analysis of full fat cheese than in that of low fat cheese (Figure 1). Over 50% meltability results for full fat cheese were found outside the established confidence interval (95%), but within

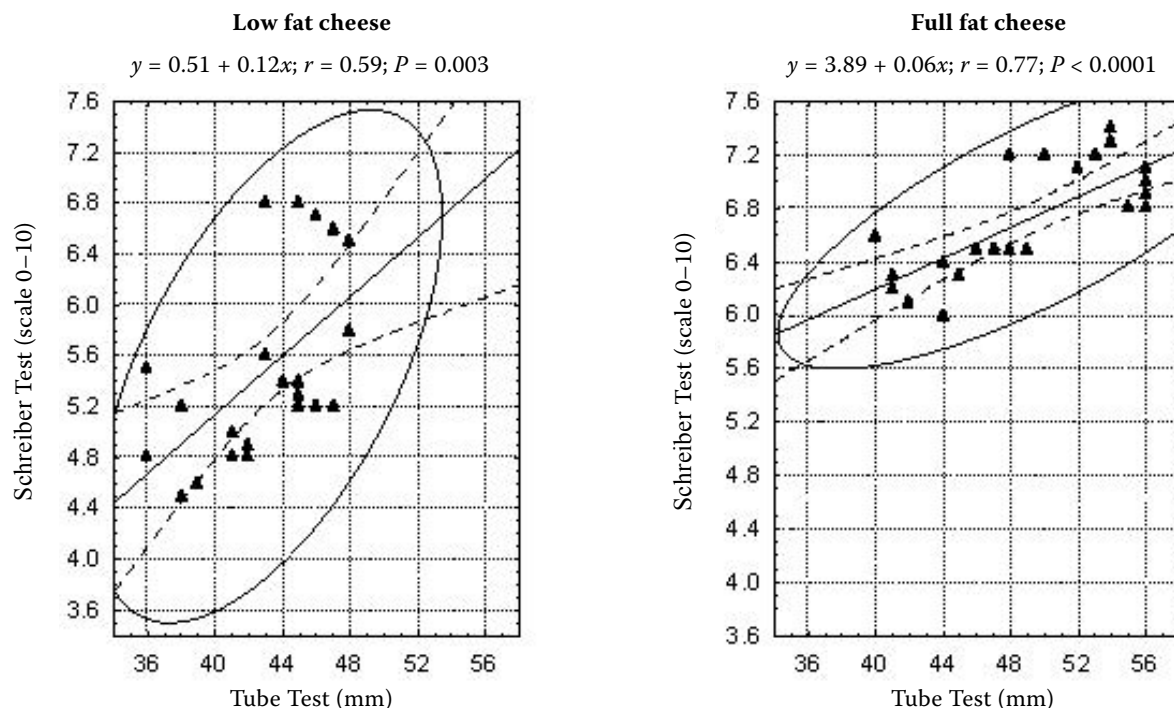


Figure 1. The dependence between meltability as assessed by the Tube Test and meltability as assessed by the Test in curd-ripened fried cheese, irrespective of the fat content and storage time, $\alpha = 0.05$, $df = 46$

the range defined by the covariance ellipse. Irrespective of the fat content in cheese, no deviations were observed from the linear distributions of the analysed variables. The established regression line was described by the initial ordinate ranging from 0.51 for low fat cheese to 3.89 for full fat cheese. In turn, the slopes of these lines were 0.06 and 0.12, respectively.

The meltability of cheese with added butter recorded in the Tube Test, irrespective of storage time, was 49.1 ± 5.5 mm which was 12% higher than that of low fat cheese determined using the same method ($P < 0.0001$). The meltability assessed using the Schreiber Test was 6.7 ± 0.4 and it was statistically significantly 18% higher than that of low fat cheese ($P = 0$). Based on the t -test value for the Bonferroni Test, defining the effect of the fat content, its greater significance ($F = 3.17$) was shown for the range of meltability of curd-ripened fried cheese as determined in the Schreiber Test than in the Tube Test ($F = 2.21$).

The information obtained from the analysis of the regression model on cheese meltability is given in the graphs of response surfaces for the two variables used in the experiment (Figure 2). Their slopes in the 3D system show the size of the effect of the fat content and storage time on

the results of the Tube Test and Schreiber Test. The longer the storage time and the lower the fat content in cheese, the lower its meltability. However, the variables defining the fat content and storage time had a greater effect on the Tube Test values ($y = 51.6 - 1.8x + 2.9y$) than on those of the Schreiber Test. Moreover, the percentage of the results above the mean value of the data reflecting fried cheese meltability as determined in the Tube Test was found to be 56.3% (> 49.13 for full fat cheese and > 43.25 for low fat cheese). The proportion of the meltability results as determined in the Schreiber Test exceeding the means of their values (6.73 for full fat cheese and 5.52 for low fat cheese) was 45.8%.

Complementarity is supplied by the analysis of sections through the response surfaces (Figure 3). In order to provide uniformity of the factor values, the following denotations were introduced: -1 for the smallest value of the analysed factor, and $+1$ for its highest value. It clearly results from the location of variables illustrating the effect of the fat content and storage time on the plane surface that they had an equally significant effect on the results of the Tube Test and Schreiber Test.

Irrespective of the cheese type, significant changes in meltability in the Tube Test, on average amount-

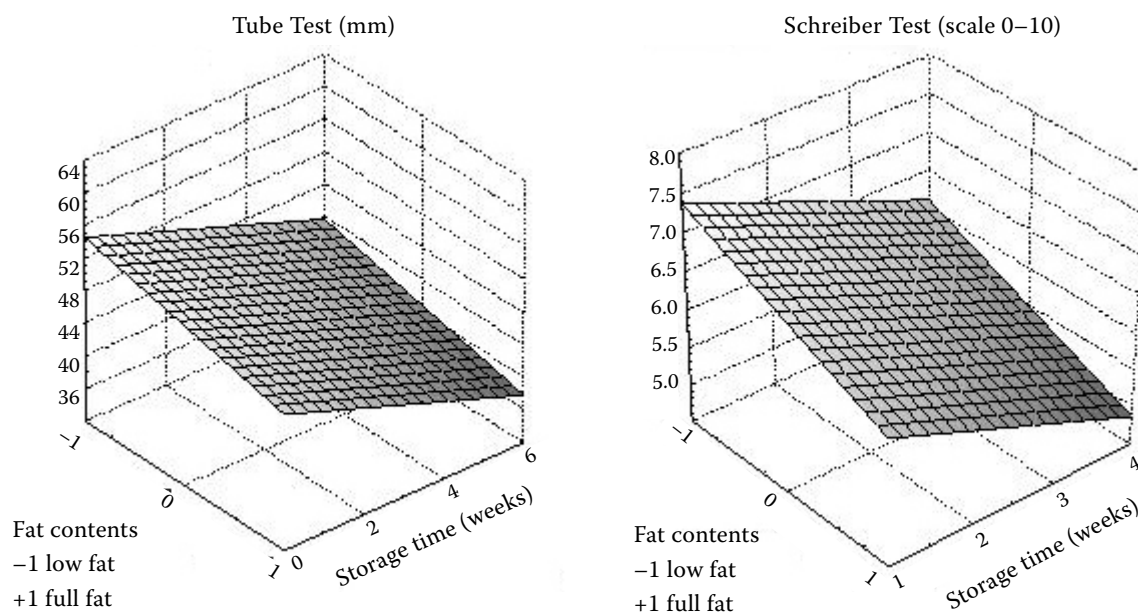


Figure 2. Response surface for changes in meltability of curd-ripened fried cheese depending on the fat content and storage time, $df = 46$

ing to 21%, were found throughout the entire storage time (Table 1). It should be indicated that meltability in the Tube Test for cheese with added fat after 6 weeks was 23.7% lower than that after the production of the samples. At the same time, the changes in meltability as determined by the Tube Test in samples of cheese with added fat were much slower. No statistically significant differences were found between the samples of

cheese without fat examined after 2-week storage and the samples of cheese immediately after its production. In turn, significant differences in the meltability of non-fat cheese were recorded between the samples analysed in successive weeks. As a consequence, the difference in meltability in the Tube Test for cheese without fat addition, measured at the beginning and at the end of storage, was 17.7%. When assessing the effect of storage

Table 1. Analysis of variance of the changes in meltability of curd-ripened fried cheese with different fat contents during storage, $\alpha = 0.05$, $df = 10$

Cheese	Statistics	Storage time (weeks)			
		0	2	4	6
Tube Test (mm)					
Full fat	mean \pm S.D.	55.5 \pm 0.8	52.2 \pm 2.9	46.5 \pm 1.9	42.3 \pm 2.3
	<i>P</i>		0.01	0	0
Low fat	mean \pm S.D.	46.2 \pm 1.9	45.7 \pm 1.8	43.2 \pm 1.7	38.0 \pm 1.9
	<i>P</i>		0.07	0	0
Schreiber Test (scale 0–10)					
Full fat	mean \pm S.D.	7.1 \pm 0.2	7.1 \pm 0.2	6.5 \pm 0.1	6.3 \pm 0.2
	<i>P</i>		0.43	0	0.19
Low fat	mean \pm S.D.	6.7 \pm 0.1	5.4 \pm 0.2	5.1 \pm 0.2	4.9 \pm 0.4
	<i>P</i>		0	0.07	0.45

df – degrees of freedom; S.D. – standard deviation; *P* – value statistically significant

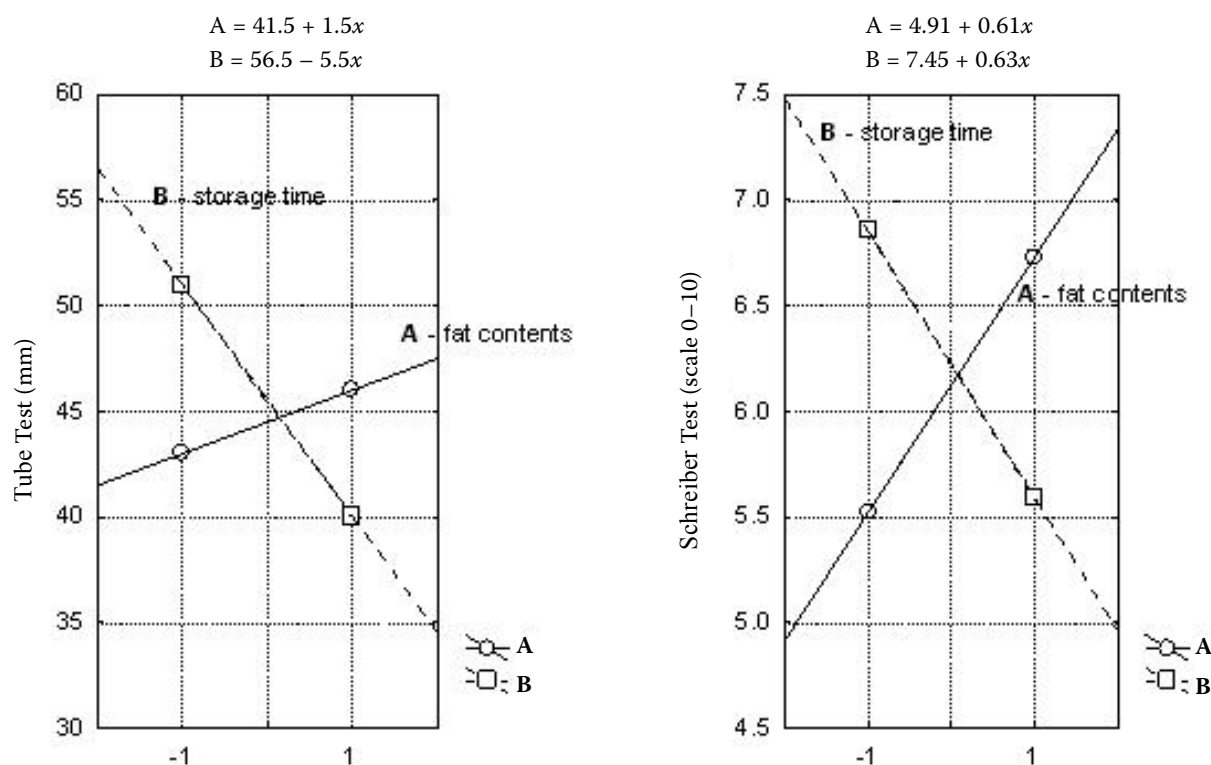


Figure 3. Analysis of the effect of the fat content and storage time of curd-ripened fried cheese on the range of changes in meltability determined using different methods (–1 – minimum value of factor, +1 – maximum value of factor), $df = 46$

time on the Schreiber Test results, no statistically significant differences were found in reference cheese between the samples assessed immediately after the completion of production and after 2-week storage ($P = 0.43$), or between the samples analysed after 4 and 6 weeks of storage ($P = 0.19$) (Table 1). The conducted analysis of variance for the Schreiber Test results in the case of cheese without fat showed significant differences only between the results recorded immediately after the production and those obtained after 2-week storage of cheese. The results of the other measurements for this type of cheese did not differ significantly ($P < 0.07$).

VAN HEKKEN *et al.* (2007) showed a 2 times higher meltability of cheese at a 3 times higher fat content. MERRILL *et al.* (1996) stated that the less fat in cheese, the lower its meltability. A study by KOCA and METIN (2004) showed that the meltability of cheeses decreased significantly with a decrease in their fat contents. The same authors found that meltability in those samples changed in the course of further 90 days of storage. HENNELLY *et al.* (2005), when investigating imitation cheese, showed meltability higher by 77.5% for

the cheeses whose water content increased from 46.4% to 54.2%, at the same time reducing the protein content by 14.7% and the fat content by 9.4%. The studies conducted by HENNELLY *et al.* (2006) confirmed that an increase in water and protein contents by approx. 22% and a reduction of the fat content in inulin-containing imitation cheese by more than 6% result in an increase of meltability by almost 58%. As a result of the fat content reduction from 54.45 to 13.57 w/w fat in dry Gaziantep cheese, meltability was approx. 3 times lower (KAHYAOGLU & KAYA 2003). We wish to mention here also the significant effect of the technological operations on the meltability of cheeses with identical compositions, as confirmed in a study by MADADLOU *et al.* (2007) on the meltability of Iranian White cheese made with unhomogenised and homogenised cream. The higher the pressure applied in the cream homogenisation, the higher the cheese meltability (55–101 mm) as determined in the Tube Test. The meltability of imitation cheese recorded using a single blade Stephan or twin-screw Blentech cookers ranged from 65.78 mm to 111.67 mm, despite a comparable basic composition (NORONHA *et al.* 2008).

CONCLUSION

The meltability of the tested cheese as assessed in the Tube Test and Schreiber Test depends on its fat content. Both tests clearly indicate a reduced meltability with the passage of storage time for the samples of curd-ripened fried cheese. The levels of cheese meltability, recorded in this experiment using the Tube Test and Schreiber Test, are highly convergent and may be approximated using the regression line.

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