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Influence of thermal processing on fat crystallization in Ricotta cheese

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Whey is a liquid by-product of cheese, quark and casein production. There are different whey products, such as whey butter, lactose, beverages, Ricotta, etc. The aim of this research was to investigate the influence of heating and cooling parameters on the fat crystallization and microstructure of thermally processed Ricotta. For this study, a laboratory cooker for processed cheese, thermostats and a binocular microscope with image processing capability were used. The results have proven that the faster the product is cooled, the smaller will be the size of fat crystals. The processing temperature and cooling speed influence the length and specific surface area (SSA) of fat crystal clusters ($p < 0.05$), and these parameters can be used for statistical analysis when describing the effect of processing variables on the product. The results could be used as a tool for predicting and avoiding granularity caused by fat crystallization in products.

Key words: fat crystals and aggregates, Ricotta, cooling speed, processing temperature

Introduction

During the traditional Ricotta manufacture, salt is added to whey (or whey and milk mixture) warmed up to 40–45 °C, and it is heated in an open cooker up to 80–85 °C. Then the pH is changed to 6.0–6.1 by adding lactic, vinegar or citric acid, which results in protein coagulation. Coagulated grains floating on the surface of the hot liquid are scooped out and placed into a perforated mould where they are drained and cooled. When producing dry Ricotta, pressing is also applied [1].

Ricotta produced from a mixture of 80 % of fresh whey and 20 % of milk contains 33.5 % of solids, 16.3 % of proteins and 11.6 % of milk fats, and its pH is 5.6–5.8. The pH of Ricotta produced by whey ultrafiltration is within 5.7–5.9, and the cheese contains 19.8 % of solids, 15.9 % of proteins and 2.4 % of fats [1]. In order to regulate the texture properties such as spreading, hardness, softness, stability, etc., in the traditional processing technology milk or cream are added. Using the extra thermal processing in a melting cooker and choosing various cooling modes, it is possible to regulate texture properties also by fat crystallization or crystallised aggregates. Such a possibility has been studied in whipped and frozen mixtures [2]; however, no similar studies concerning Ricotta are available.

The aim of the current research was to ascertain the impact of the thermal processing of Ricotta on the size and structure of fat crystals and fat clusters formed as a result of cooling.

Materials and methods

In processing tests, a mixture containing 650 g of Ricotta (8 % of fat, 11 % of proteins, prepared at OÜ Põltsamaa Meierei Juustutööstus in Estonia), 6 g of potato starch (prepared at Roquette, France), 5 g of carrageenan (fit for dairy products, prepared at BK Giulini, Germany) and 300 g of water were used. The mixture was poured into a pre-heated (55–75 °C) cooker (Stephan UMC5) and processed for 15 minutes with a simultaneous mixing with two knives of the cooker at the rate of 2400 rpm (251.33 rad/s). In total, nine varieties of processed Ricotta were produced; three of them had the processing temperature of 57.7–58.8 °C, three 73.9–75 °C, and three 85.2–91.4 °C. All products were cooled at four different temperatures to ensure various rates of cooling (Table 1). In addition, the microstructures of fat (particles and aggregates) of these varieties stored in a refrigerator at 2 °C for a longer period (more than 2 days) were analyzed. All nine processed Ricottas contained 5.4 % of fat and 7.4 % of proteins.

Table 1. Samples of cooling modes, temperatures and average rates

Cooling mode	Cooling temperature, °C	Average cooling rate, °C/min
Deep freezer	-21	1.92
Refrigerator	2	0.68
Thermostat	12	0.65
Room	21–22	0.35

The microstructure was analyzed at 400× and 1000× amplification with a binocular optical microscope Nikon SMC 1000 and special software (Fig. 1). Fat crystals and fat cluster length (the longest linear dimension) and the specific surface area (SSA – area of projection on the focal plane) were defined.

The statistical analysis (t-test, correlation, average, minimum, maximum) of the result was made using the MS EXCEL programme package. To ascertain the results of the analysis, the obtained correlations were divided into three groups: strong (r > 0.66), medium (r = 0.33–0.66), and week (r < 0.33).

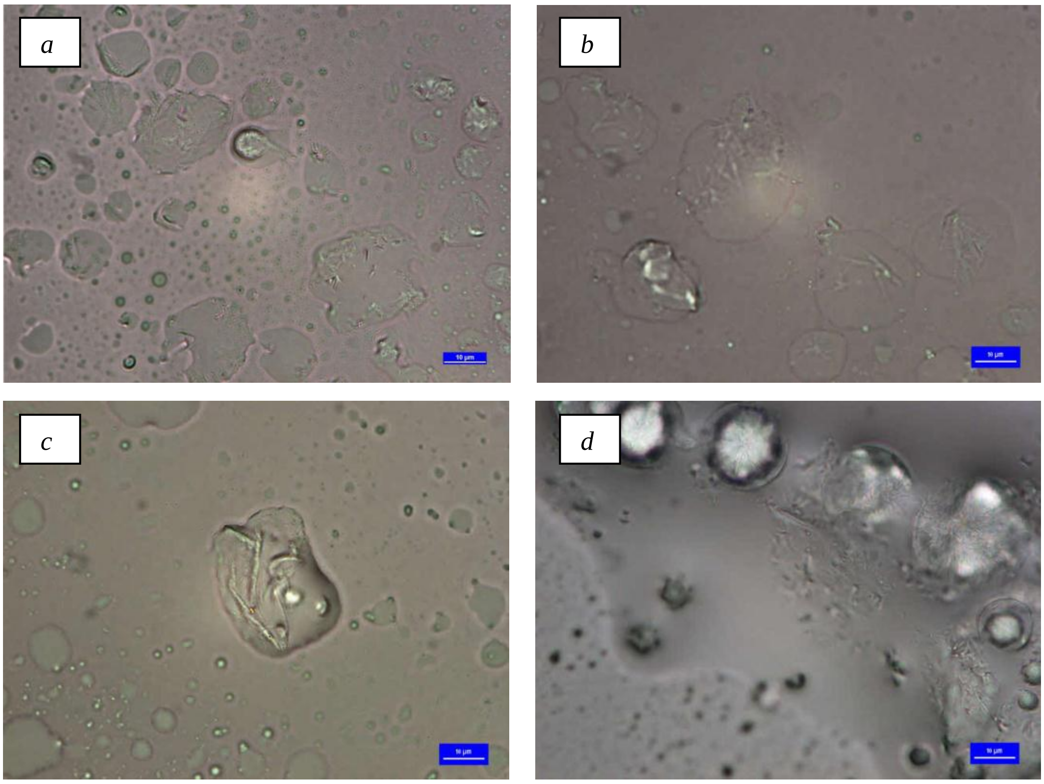

Fig. 1. Photos of processed Ricotta microstructure at various cooling temperatures:
a – 1.92 °C/min, *b* – 0.68 °C/min, *c* – 0.65 °C/min, *d* – 0.35 °C/min (amplification 1000×, author Sirje Pajumägi)

Results and discussion

Hertje and Leunis [3] found that when samples had been cooled from 85 °C to 35 °C, the bigger crystals formed in contrast with samples cooled to 5 °C within the same period of time. Numerous researches have confirmed the impact of cooling rates on the fat crystal size [4, 5]. However, no data on the fat actual cooling rate have been reported, though this is a more generalized index than just the cooling temperature alone. That is why our tests proceeded from the cooling rate – changes of temperature in time (°C/min). At cooling rates of 1.92 °C/min, 0.68 °C/min and 0.35 °C/min, the most common length of fat crystal (mode) was 6 µm. In the product cooled at a rate of 0.65 °C/min, the mode of the crystal sizes was 12 µm. The mode of the fat crystal aggregate length and SSA was less dependent on the cooling rate, remaining between 28–30 µm and 311–550 µm^2, respectively. The main statistical indices of fat crystal and aggregate lengths corresponding to various cooling rates are presented in Table 2.

Table 2. Measures of fat crystals and their clusters corresponding to different cooling rates

Statistical index	Cooling rate, °C/min	Length of crystals, µm	Length of crystal aggregates, µm	SSA of crystal cluster, µm^2
Average	1.92	7.28	35.11	537.58
Minimum	1.54	1	12	11
Maximum	2.33	24	80	4958
Average	0.68	7.67	32.87	479.26
Minimum	0.55	2	13	92
Maximum	1.13	20	62	1872
Average	0.65	9.81	33.56	524.06
Minimum	0.28	5	15	29
Maximum	0.77	18	104	5313
Average	0.35	8.32	34.71	518.29
Minimum	0.29	3	17	49
Maximum	0.37	17	69	1405

Although when cooling the rate increased, fat crystal length and the range of variations generally decreased; however, it is impossible to assert with the same certainty the crystal aggregate length or SSA. The medians of crystal lengths, crystal aggregate length and crystal aggregate SSA more or less coincided with their average values, showing that the corresponding distribution is close to the normal distribution. Two-tail t-test has shown that the cooling rate and the processing temperature influence the length of crystals, the length and SSA of crystal aggregates (in all t-tests $p < 0.05$). Thus, e. g. the correlation between fat crystal length and processing temperature of the product (cooled in a room) is $r = 0.634$. At the same time, the correlation between the cooling rate and the length of crystals was negative (in a deep by freezer-cooled sample $r = -0.678$). The scatter diagram and regression equation of crystal length are given in Fig. 2. For other cooling modes, only a slight correlation between length and SSA was found.

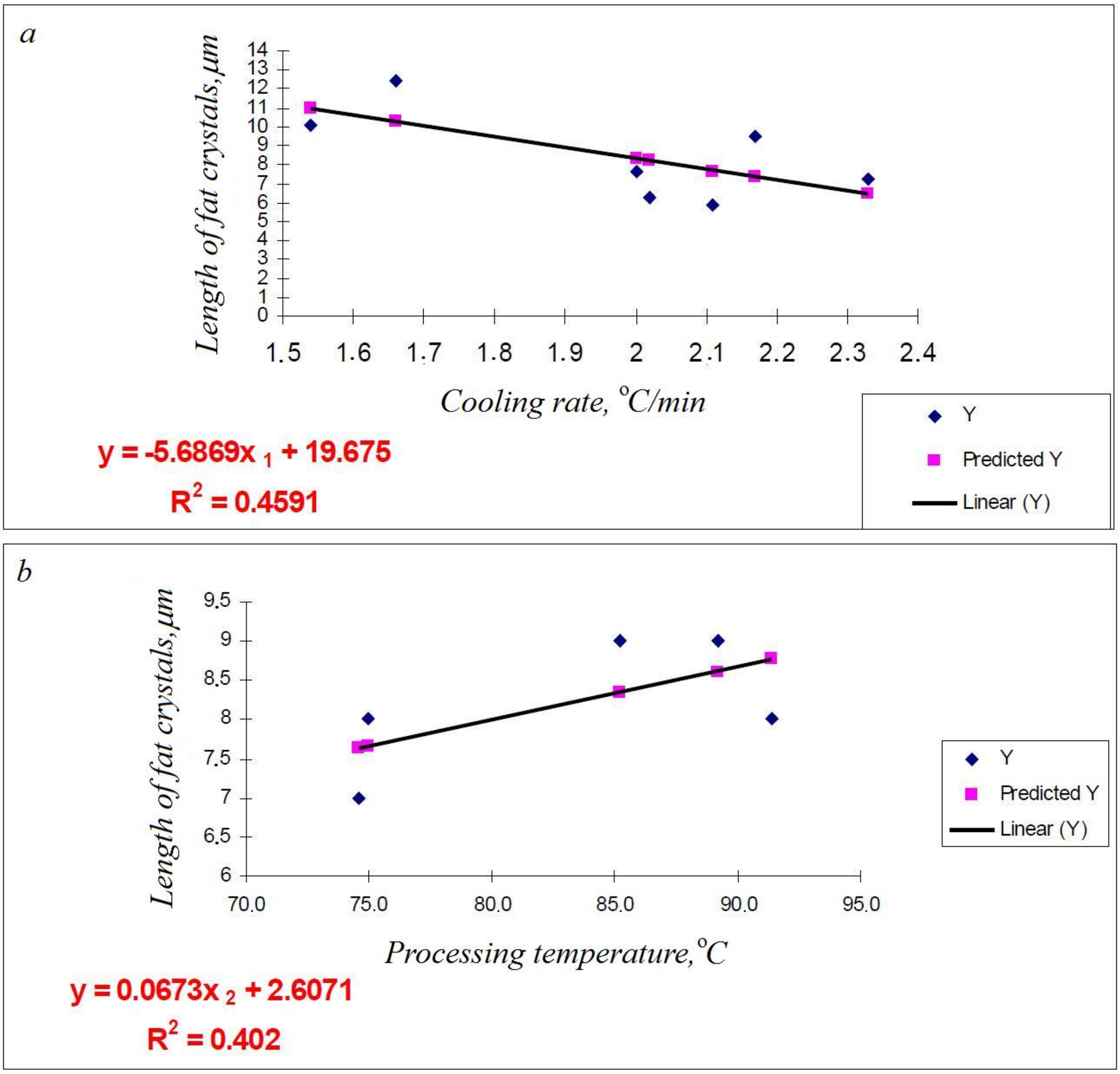

Fig. 2. Scatter diagram of fat crystal length (µm) in connection to:
a – cooling speed, *b* – processing temperature (°C) at cooling speed 0.35 °C/min

The correlation between the length and SSA of crystal aggregates appeared to be significant ($p < 0.05$). At strong positive correlation between the length and SSA of aggregates (1.92 ºC/min $r = 0.954$, 0.68 ºC/min $r = 0.921$, 0.65 ºC/min $r = 0.847$, 0.35 ºC/min $r = 0.891$ stored in a refrigerator at 2 °C for a longer period $r = 0.887$) shows that for the quantitative characterization of the crystallization it is enough to use only one (length or SSA) of the proposed indices (Fig. 3).

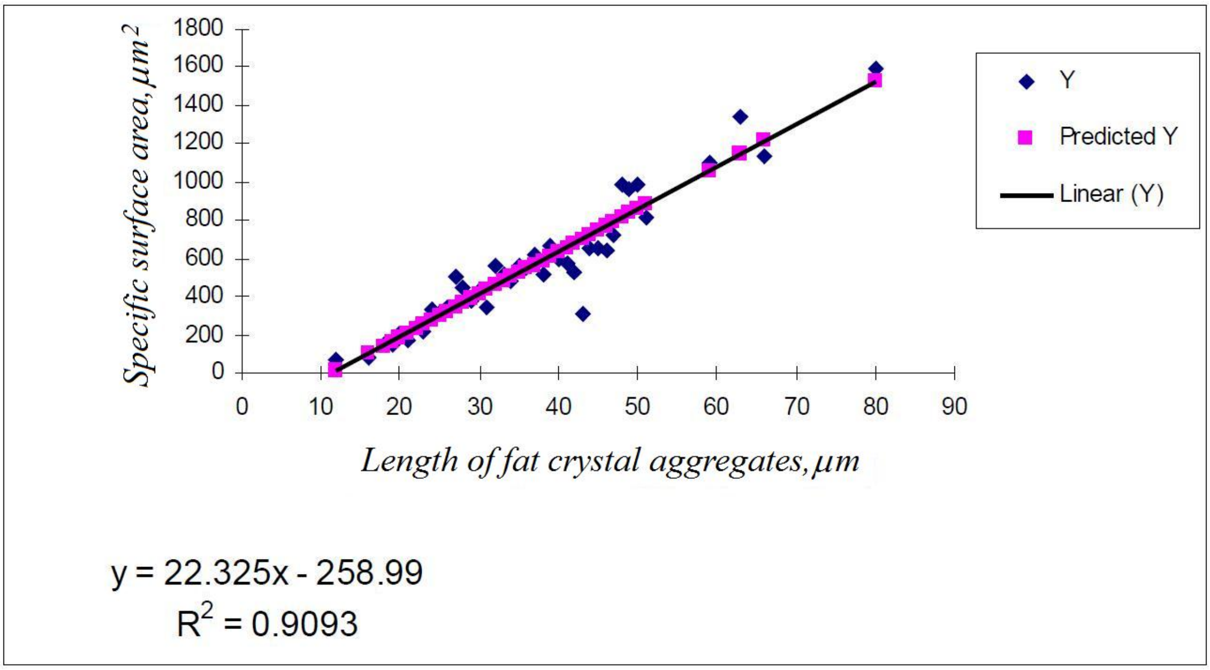

Fig. 3. Scatter diagram of fat crystal aggregate length (μm) and SSA (μm^2) at a cooling rate of 1.92 ºC/min

Conclusions

The results of the current study show that the size of fat crystals and their aggregates in processed Ricotta can be successfully influenced by the cooling rate. As a parameter for the quantitative description of fat crystallization, the length or SSA can be used. The principal models of linear regression allow predicting the size of fat crystals and their aggregates depending on the processing temperature and cooling rate of Ricotta cheese.

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ŠILUMINIO APDOROJIMO ĮTAKA RIKOTOS SŪRIO RIEBALŲ KRISTALIZACIJAI

S a n t r a u k a

Tirta kaitinimo ir vėsinimo parametrų įtaka termiškai apdoroto rikotos sūrio riebalų kristalizacijai ir mikrostruktūrai. Nustatyta, kad produktą vėsinant greičiau susidaro mažesni kristalai. Temperatūra ir vėsinimo greitis taip pat turi įtakos riebalų kristalų sankaupų ilgiui ir savitajam paviršiaus plotui. Tyrimo rezultatus galima panaudoti produktų granuliometrijai, susidarančiai dėl riebalų kristalizacijos, prognozuoti ir išvengti.