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Possibility of using reconstituted milk in manufacture of cheese with cheddaring and cheese curd stretching

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Abstract. The use of reconstituted milk may significantly increase the possibility of cheese manufacture and limited irregular milk supplies for cheese making plants. Data collecting and analyzing revealed that there are cheese technologies with cheddaring and cheese curd stretching accompanied by partial replacement of natural milk by reconstituted. Therefore, the aim of this research is to develop the technology of cheese with cheddaring and curd stretching made from reconstituted milk as the main raw material. A comparative study of physicochemical characteristics of five dry milk powder samples obtained from different producers and natural milk has been carried out. The choice of reconstituted skimmed milk as the raw material is explained; its quality is assessed and the process parameters of milk reconstitution are chosen. It is recommended to combine holding of reconstituted skimmed milk and milk ripening. Cheddaring is known to be a fairly time-consuming process, the use of starter cultures during reconstituted milk ripening can intensify this process. The process of milk ripening has been carried out at 16 °C for 10 h using the manufacturer's recommended dosages of starter cultures. The best results have been obtained when Lyofast MOT 092EE is used. Milk ripening is found to be a very important operation for the production of cheese with cheddaring and cheese curd stretching made from reconstituted milk.

Keywords: cheese, pasta filata, reconstituted skimmed milk, stretchability, meltability

INTRODUCTION

Pasta Filata type cheeses / Pizza type cheeses (PF cheese) are referred to cheeses with cheddaring and stretched curd and include such cheeses as Italian Mozzarella, Provolone, Kashkaval balkan, Mexican Oaxaca cheese, etc. These cheese varieties have the unique ability to stretch into thin strands when heated above 60 °C. Almost all pizza packagings and commercials focus on a cut pizza slice being lifted up to show the cheese melting and stretching out. Apparently, this cheese ability to stretch broadens consumer appeal for pizza and other food products containing PF cheeses (Gunasekaran & Ak, 2003).

The use of non-fat milk powder (NFMP) produced at low drying temperatures is of great interest for the production of PF cheeses with cheddaring and thermal processing. However, the production of PF cheeses from reconstituted skimmed milk (RSM) is a rather difficult task. During the manufacture of spray-dried milk, there are physical and chemical changes in milk components. These alterations are attributed, in particular, to whey proteins, as they have large amounts of hydrogen and easily cleavable covalent bonds. When unfolding protein globules during the denaturation process, the increase in

reactivity of sulfhydryl groups of cysteine and other sulfur-containing amino acids was observed. The aggregation of the denatured protein molecules occurs, involving hydrophobic interactions and the redox reactions of sulfhydryl groups forming disulfide bonds. Denaturation of β-lactoglobulin during heating is of practical interest. It forms stable complexes with κ-casein, preventing its losses in whey. Denatured β-lactoglobulin affects the properties of κ-casein, reducing the rennet coagulation properties, and the ability to stretch when heated (Wijayanti et al., 2014).

Avakimyan (2010) reported that a positive result was observed when NFMP in the amount of 50%by weight was used in the manufacture of cheeses with cheddaring and stretched curd. According to Gilles et al., (1982), unsatisfactory results were obtained when the low-heat NFMP was used as the raw material to produce Cheddar cheese. In this study RSM was standardized with fresh cream and dehydrated milk fat and then subjected to homogenization. The finished product had mealy texture and spongy body and had a metallic after–taste. In the manufacturing procedure for Cheddar cheese, the replacement of milk with NFMP up to 25% is a normal practice (Westergaard, 2010). NFMP was reconstituted with water to a total solids content range of 9–12%, held for 12 h and standardized with whole natural milk. According to Davide et al., (1993), it is possible to obtain mozzarella cheese with good meltability and stretchability using a combination of RSM (40–60%) and natural whole milk. Higher replacement ratio of RSM and natural milk has led to cheeses with higher moisture content and rigid curd.

In the literature studied there is information about the possibility of partial replacement of fresh milk with NFMP, however, no published information is available concerning the use of NFMP as the main raw material for PF cheese manufacture, therefore this research has been undertaken to fill in the gap.

The objective of this study was to develop the technology for producing cheese with cheddaring and curd stretching with the use of reconstituted NFMP as the raw material and to study the effect of RSM ripening on functional properties of cheese and the duration of cheddaring process.

MATERIALS AND METHODS

The study included one control cheese group and three treatment cheese groups.

Control samples were made from unripened reconstituted skimmed milk. The treatment samples represented cheeses made from ripened reconstituted cheese milk.

Preparation of cheese milk

PF cheeses can be produced only from low-heat NFMP (WPNI > 6 mg g^{-1}), as in this case, the less severe heat treatment is applied to milk while processing it to milk powder (Patel et al., 2007; Westergaard, 2010; Bylund, 2015). This study included 5 treatment samples of NFMP: 'Vamin', Russia; 'EuroSerum S.A.S. ', France; 'Lácteos La Cristina S.A. ', Argentina; 'Slutsk cheesemaking plant', Belarus; 'DMK Deutsches Milchkontor GmbH', Germany. On the basis of the results obtained, it was evident that only one sample of NFMP was matched to WPNI for low-heat milk powder, namely, 'DMK Deutsches Milchkontor GmbH' (36.6 ± 1.2% total protein, 4.0 ± 0.5% total moisture, 1.0 ± 0.3% total fat, 6.3 ± 0.2 mg N g^{-1} WPNI, 0.5 ± 0.1 ml, solubility index).

The NFMP reconstitution was carried out using softened water (0.058°dH) at a temperature of 45 °C. The NFMP was dissolved using shear pump RPA–5 looped by

connecting the reservoir avoiding dry running and stirred for 10 min until completely dissolved. The total solids content of RSM was 10% (w/v). RSM was subjected to vat pasteurization at 63 °C for 30 min. These heat treatment parameters are recommended for milk and milk products (Clark et al., 2008).

To produce treatment samples of cheeses the following lyophilized direct vat set cultures recommended for PF cheese production were used: CHOOZIT ™ ALP LYO, France, 100DCU; AiBi LcLs30.11, Russia; Lyofast MOT 092EE, Italy, 10UC.They contain mesophilic and thermophilic microorganisms. Mesophilic starter cultures are necessary for milk ripening. The procedure of pack opening was as follows: the pack edge and scissors were processed using a swab dipped in 70% alcohol solution. The amount of starter cultures was ¼ of the pack following the recommendations provided by the manufacture (1 pack per 1000–2000 l of milk). The optimum temperature of the milk ripening is in the range of 10–20 °C. It is the lowest temperature limit for growth of mesophilic lactic acid microorganisms (Robinson, 2002). This research suggested RSM ripening at a temperature of 16 °C for 10 h. The technological parameters were indicated by Avakimyan (2010).

Cheddaring process is a rather long-term operation and can take up to 5 hours depending on the types of microorganisms, used as a starter, and cheddaring temperature. Therefore, RSM ripening can intensify this process, i.e. reduce the time needed to reach the required values of pH.

Cheese milk for the production of unripened milk cheese samples was normalized after milk reconstitution and pasteurization. For the treatment cheese samples cheese milk was standardized after the RSM milk ripening.

The fat content of RSM was standardized to 2.8% with pasteurized cream (15% fat). The cream was subjected to heat treatment in 'Prinevskoe' Student farm, Russia, Leningrad region, Vsevolozhsk district. Normalization was carried out using RPA–5 pump looped by connecting the reservoir at a temperature of 45 °C. Standardized mixture formulation is presented in Table 1.

Table 1. Formulation for the standardized mixture

Ingredients	Amount, kg	Total solids, %	Fat, %
NFMP	25.0	96.0	1.0
Water	180.0	-	-
Cream	45.0	22.0	15.0
Total	250.0	13.5	2.8

Cheese making process

The cheese making process (Fig. 1) was performed using medium-scale manufacturing conditions at the 'OOO Sfera', Saint – Petersburg, Russia. The manufacturing process was carried out using cheese equipment 'DR. GUBER', Russia. It produced twelve cheese batches (1 batch per day).

Cheese made from ripened milk

After ripening and standardization, the prepared mixture (250 l) was cooled to 38 °C. Calcium chloride in the amount of 50 g per 100 kg of the mixture as a 40% solution prepared with distilled water was added.

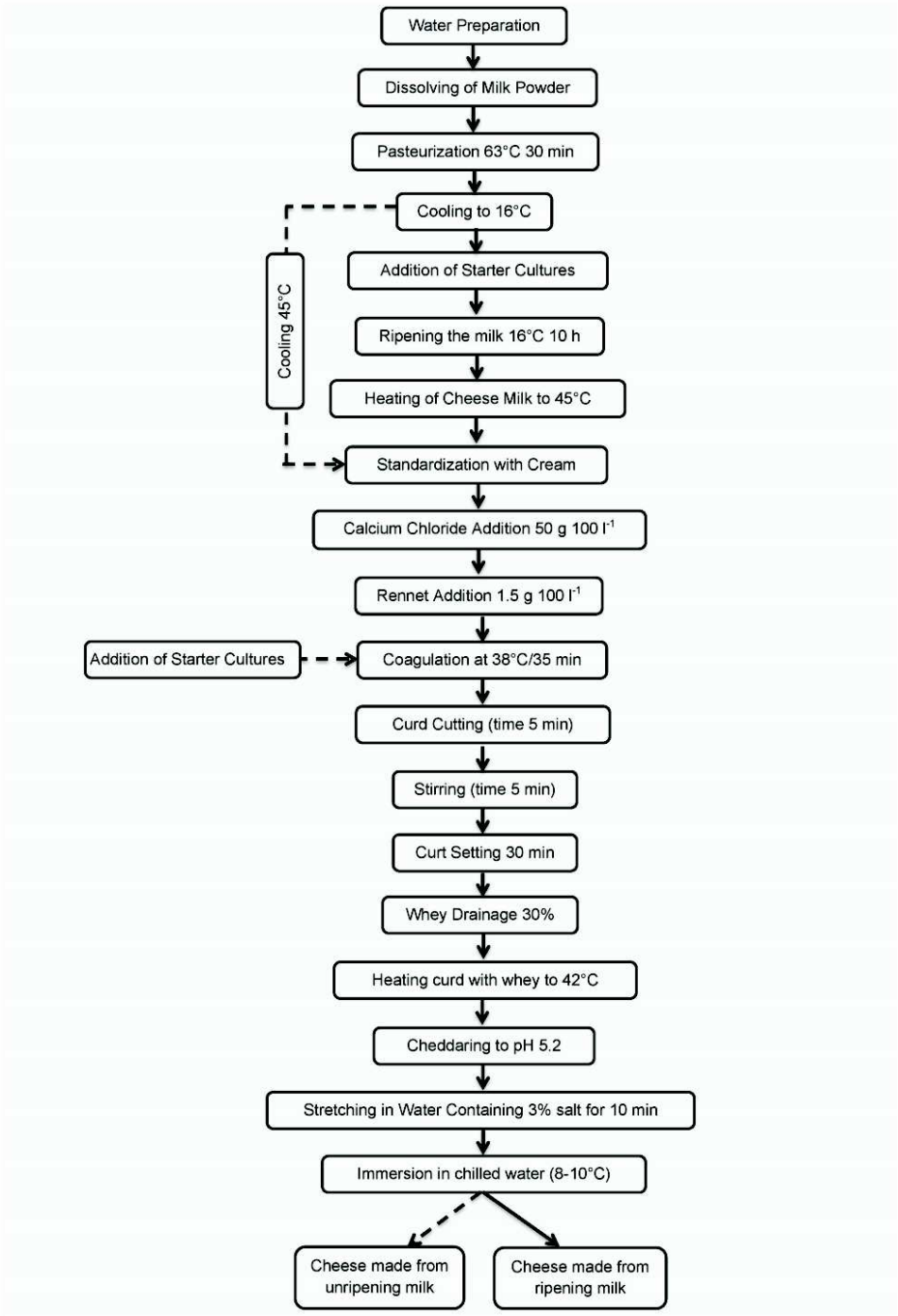

Figure 1. Flow chart for manufacture of pasta filata cheese.

Rennet ('Renmax 2100 Granular', MAYASAN Food Industries A.S., Turkey, 1.5g 100 l^{-1}) was added according to the following technique: 4.5 g of rennet was dissolved in 250 cm^3 of warm distilled water an hour before use. The mixture was coagulated at

38 °C for 35min. The end of coagulation was defined as the point at which the curd was firm enough to be cut during cheese making. It was determined by inserting the spatula into coagulum at 45°, gently lifting the spatula and observing the curd split. A sharp, clean split indicates that the curd is ready for cutting. The resulting curd was cut into 10 mm^3 cubes with vertical and horizontal curd knives and cheese grain formation was carried out to promote whey expulsion. Then, whey was drained partially (30%) and the curd particles were subjected to cheddaring at 42 °C until the pH of the curd reached 5.1–5.2 with subsequent hand formation of balls with the diameters of 5–8 cm in brine solution (3%) at 65 °C. After these operations, the obtained cheeses were cooled by soaking in water for 5 minutes with a temperature ranged from 8 °C to 10 °C.

Cheese made from unripened cheese milk

The samples were produced according to the same process of ripened milk cheese sample manufacture, except that the starter culture was added after the standardization process and cooling to 38 °C.

The samples used in this study for comparing stretchability and meltability were as follows: control sample – Mozzarella (Galbani, Russia), purchased by the researchers at a local food market with a full–service cheese department which allowed for proper cheese storage; sample 1 – cheese made from standardized ripened reconstituted milk; sample 2 – cheese made from standardized unripened reconstituted milk.

Chemical analyses and functional tests

Titratable acidity (TA) was determined according to AOAC method 947.05 (1995). TA was determined by titration of a known amount of milk sample with 0.1 N NaOH using phenolphthalein as indicator. TA was expressed as a percentage of lactic acid. Total moisture content of NFMP was determined according to ISO 5537:2004. pH values were measured using pH-meter (pH-410, Akvilon Company, Russia). WPNI was determined by GEA method (GEA Niro Method No. A 21 a) by Kjeldahl method using the automated analyzer Kjeltec System 1030 (FOSS Analytical AB, Sweden) and spectrophotometer UV-1800 (Shimadzu, Japan). Solubility index was determined according to ISO 8156:2005. Total fat in NFMP was determined according to ISO 1736:2008. The amount of total nitrogen was determined as the amount of soluble nitrogen divided by the total nitrogen amount and expressed as a percentage. Total nitrogen and soluble nitrogen contents of the cheese samples were measured according to ISO 27871:2011. Total protein was expressed as total nitrogen content multiplied by 6.38 (Moatsou et al., 2002). Moisture content of cheese samples was determined according to ISO 5534:2012. Total protein was determined by Kjeldahl method according to ISO 8968-1:2014. Fat in dry matter was determined by gravimetric method according to ISO 1735:2004.

Laboratory balance DL-120, (A&D, Japan) was used for accurate measurements of weight.

The meltability was determined according to the method described by Richouxet et al., (2001), which was derived from the Schreiber test, and was expressed as the percent increase in the cheese disc diameter after heating at 225 °C for 3 min.

Stretchability test was carried out according to USDA (1980) and (Caro et al., 2011), the technique used was as follows: cheese samples (30 g) were placed in the center of the corn tortillas and heated in a microwave oven at 1,650 W for 30 sec before the

evaluation. A stainless steel fork with 4 tines was lowered into the melted cheese to a depth of 3 mm at 45-degree angle, then the fork was pulled slowly and vertically for 5 sec. The distance, which cheese strands were lifted to, until they broke, was defined using metric measuring tape. The results were measured using 9-point structured scale (from 1 = 10 cm to 9 = 90 cm, respectively). To minimize inaccuracy, a panel consisted of 5 members was formed. Each member conducted 5 tests and calculated the mean value of a data set. As a result, the mean value of 5 observations of all members was taken.

Statistical analyzes

All experiments were performed at least in triplicate (unless stated otherwise) and the results were expressed as the mean values ± standard deviation. Statistical processing of data was carried out using computer programs Microsoft Office Excel 2010. The Bonferroni t-test was used to determine significant differences among means, and differences were described as significant only at $p < 0.05$.

RESULTS AND DISCUSSION

According to the data presented in Table 2, TA mean values for RNFMP before and after ripening showed that the application of AiBi LcLs30.11 and Lyofast MOT 092EE starter cultures increased TA mean values by 0.036 ± 0.03 %LA, while the use of CHOOZIT™ ALP TA led to an increase in TA mean values by 0.041 ± 0.06 %LA. The average pH values showed an increase with the use of AiBi LcLs30.11 by 0.23 ± 0.03 and by 0.25 ± 0.03 and 0.27 ± 0.06 for Lyofast MOT 092EE and CHOOZIT™ ALP samples, respectively. Obvious differences in the starter cultures at this stage were not found.

Table 2. Changes in TA of RNFMP samples (± standard deviations)

Starter Culture	Before ripening		After ripening	
	Titratable acidity, %LA	pH	Titratable acidity, %LA	pH
CHOOZIT™ ALP	0.153 ± 0.03	6.71 ± 0.10	0.194 ± 0.06	6.44 ± 0.12
AiBi LcLs30.11	0.153 ± 0.03	6.71 ± 0.10	0.189 ± 0.03	6.48 ± 0.10
Lyofast MOT 092EE	0.153 ± 0.03	6.71 ± 0.10	0.189 ± 0.03	6.46 ± 0.11

When AiBi LcLs30.11 was used, active acidity (pH) decreased very slowly and after 160 minutes it reduced to a value of 5.87 as compared to other samples that reached 5.13 and 5.17 for Lyofast MOT 092EE and CHOOZIT ™ ALP LYO, respectively (Fig. 2). Apparently, these results were obtained due to the low quality of the starter culture used or the attack of bacteriophage and poor resistance of the starter culture strains to the action of bacteriophage. No significant differences were observed in the activity of Lyofast MOT 092EE and CHOOZIT ™ ALP LYO ($p < 0.05$).

The quality of the cheese is directly affected by proteolysis. This is due to the disruption of the casein matrix under the action of proteolytic systems produced by bacterial cells. As a result, this process causes the improvement in cheese melting, but it becomes less stretching and is easily disrupted. Therefore, the stronger the proteolytic cleavage in the cheese curd, the lower its stretchability (McSweeney, 2007; Avakimyan,

2010). In this regard, the degree of cheese curd proteolysis was studied by investigating the process of proteolysis product accumulation in cheese curd at the end of cheddaring stage using Lyofast MOT 092EE and CHOOZIT ™ ALP LYO.

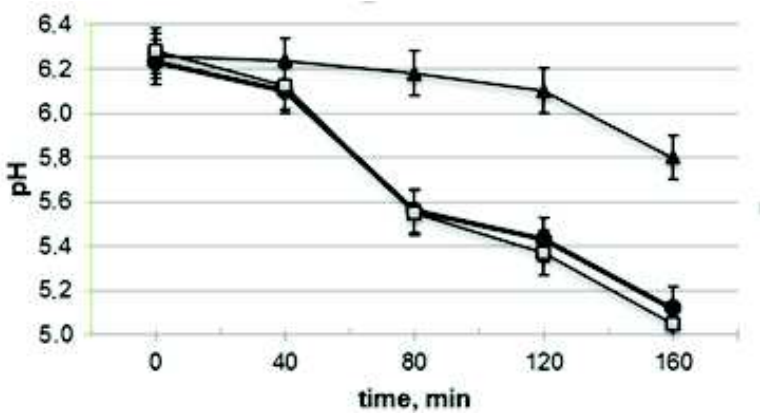

Figure 2. Changes in pH values (± standard deviations) during cheddaring (● – CHOOZIT™ ALP; ▲ –LcLs30.11; □ – Lyofast MOT 092EE).

In terms of the result it was found that the analyzed samples differed in their average total soluble nitrogen (Fig. 3) content which reached 17.5 ± 0.8% and 13.1 ± 0.6% in cheese curd with the use of CHOOZIT ™ ALP LYO and Lyofast MOT 092EE, respectively. The results revealed that the most proteolysis product accumulation was in the cheese curd containing CHOOZIT ™ ALPLYO, which has a higher proteolytic activity compared to Lyofast MOT 092EE. This activity manifested itself in the cleavage of casein with the formation of free amino acids, peptides and nitrogen.

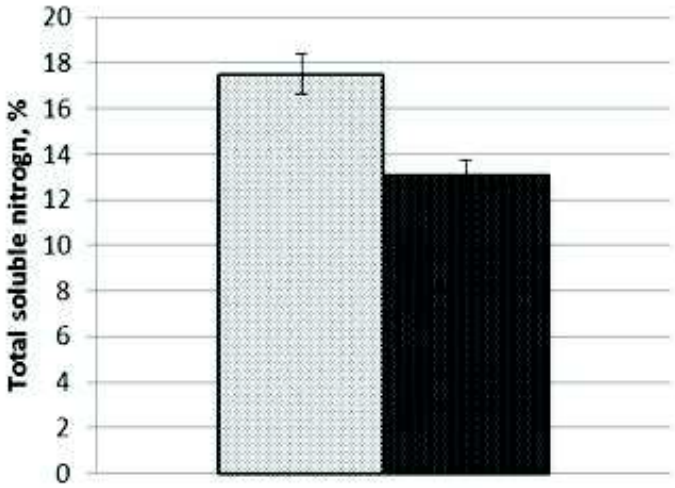

Figure 3. Total soluble nitrogen content, % (± standard deviations) in cheese curd at the end of cheddaring (▒ -CHOOZIT ™ ALP LYO, ▓ - LyofastMOT 092EE).

Thus, the findings of this research allowed to draw a conclusion that the use of Lyofast MOT 092EE for obtaining elastic and more plastic cheese, as well as for cheddaring process intensification, was more efficient.

The next step of the study was to determine the influence of milk ripening on the cheddaring process duration. From Fig. 4 it can be seen that the duration of cheddaring process decreased by about 50 minutes until pH reached a pH of 5.2. This decrease could be due to the development of mesophilic lactic acid bacteria during ripening and preparing favorable conditions for lactic acid microorganism growth (Law et al., 2010).

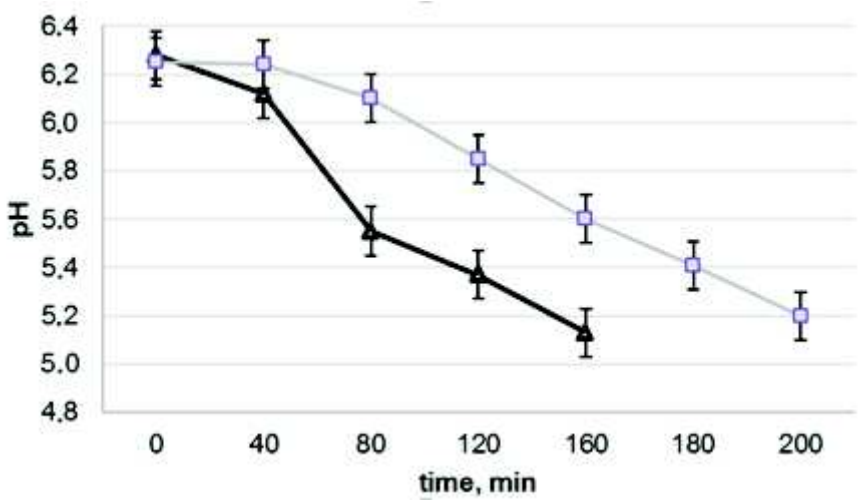

Figure 4. Changes in pH values (± standard deviations) during cheddaring process (▲ – cheese made from ripened milk; □ – cheese made from unripened milk).

It can be seen from Table 3 that physico-chemical parameters of the samples did not differ significantly ($p < 0.05$).

Table 3. Physicochemical parameters of cheese samples (± standard deviations)

Cheese composition	Control	Sample 1	Sample 2
Moisture (g 100 g^{-1})	56.4 ± 2.2	52.2 ± 4.5	55.5 ± 2.6
Fat (g 100g^{-1})	19.6 ± 1.0	22.1 ± 1.2	21.5 ± 1.0
Protein (g 100 g^{-1})	21.5 ± 0.9	22.2 ± 1.5	20.5 ± 1.2
pH	5.15 ± 0.10	5.2 ± 0.12	5.15 ± 0.12

As shown in Figs 5 and 6, the control sample represented the best results for stretchability and meltability (6.5 ± 0.4 points and 48.3 ± 4.1%, respectively). Sample 1 also demonstrated good melting and stretching properties (35.0 ± 3.2% and 5.1 ± 0.2 points) in contrast to sample 2, which showed poor ability to stretch (0.5 ± 0.1 points).

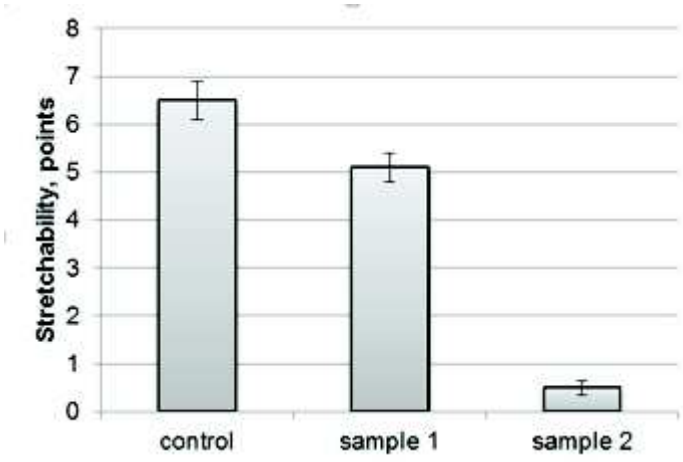

Figure 5. Stretchability mean values (± standard deviations) of different cheese samples.

The inferior melting and stretching can be caused by both changes in the protein molecule of casein and salt balance occurring during the drying process. Apparently, holding of RSM with the use of starter cultures for at least 10 hours contributes to casein unfolding and maximum recovery of its native properties.

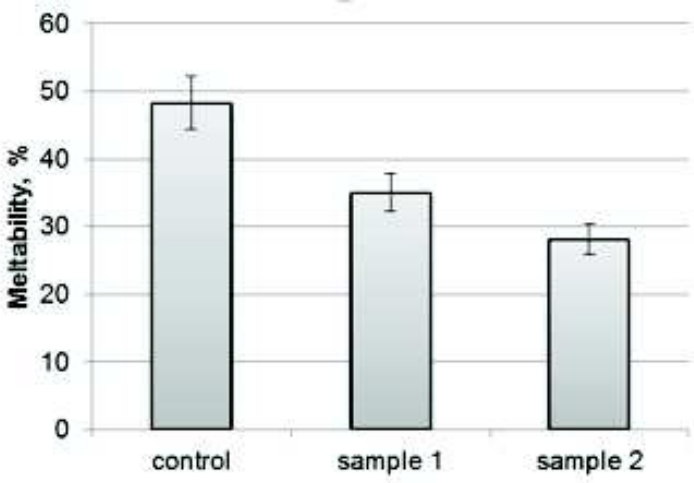

Figure 6. Meltability mean values (± standard deviations) of cheese samples.

In addition, the following physicochemical and colloidal properties are changed: the oxidation-reduction potential is reduced, the content of polypeptides is increased, and some of the calcium salts become soluble. These changes contribute to decreased stability and dispersity of casein micelles and increase the efficiency of the demineralization of calcium salts. When unripened reconstituted milk is used, the cheese ability to stretch into thin and elastic strands, when melted, decreases significantly ($p < 0.05$).

Sample 2 cannot be legally called PF cheese, as it does not correspond to the requirements for pizza cheese provided by the USDA (1980) which has stated that the cheeses of this type must be stretched not less than 30 cm, when heated.

CONCLUSIONS

It is necessary to carry out special preparation of RNFMP for the manufacture of PF cheese. This special operation includes the reconstitution of NFMP and ripening of RSM with the use of starter cultures containing different microorganism strains.

For PF cheese production made from NFMP it is necessary to hold and ripe milk for at least 10 hours.

The possibility of reducing the duration of cheddaring process by RSM ripening for about 50 min is shown.

The necessity of RSM ripening and its influence on stretchability and meltability of the finished product are demonstrated. The ripening of RSM increases stretchability and meltability by 90.2% and 19.7%, respectively, compared to the cheese produced from unripened RSM.

More research is needed to study diligently the influence of RSM holding and ripening on functional properties and quality of PF cheeses.

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