Original scientific paper - Izvorni znanstveni rad UDK: 637.131.2

Development of low fat UF cheese technology

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Received - Prispjelo: 24.05.2010.
Accepted - Prihvaćeno: 12.01.2011.

Summary

The production procedure of low fat cheeses produced from ultrafiltered milk (UF cheese) was developed in this study. The production procedure, that includes utilization of UF milk with 2 % of lactose, addition of 1.5 % inulin and salting with 2 % of mixed salt (NaCl/KCl in ratio 3:1) was defined based on the investigation that included the influence of coagulation parameters, different lactose content of UF milk, different inulin content, and different salt type and content on the properties of low fat UF cheeses. Presented production procedure enables the production of a product with satisfactory dietetic and functional properties. Reduced lactose content of UF milk contributes to stabilisation of pH value at an adequate level and achievement of acceptable texture properties of low fat UF cheeses. Defined inulin content (1.5 %) improved cheese texture, as well as its functional properties, enabling the cheese produced to be marked as a “good source of fibre”. Reduced sodium content, due to partial substitution of NaCl with KCl, also contributes to the improvement of dietetic properties of cheeses. Low fat UF cheeses, produced according to defined production procedure, were analysed during 8 weeks of ripening and storage periods. Composition, pH values and proteolytic pattern were typical for brined cheeses. Uniform microstructure and acceptable sensory properties, especially the texture, confirm the validity of the developed production procedure of low fat UF cheeses from UF milk.

Key words: low fat UF cheese, proteolysis, microstructure, sensory properties

Introduction

Modern medical research studies indicate the increasing importance of diet in the maintenance and improvement of health. In this regard, the recent expansions of food product assortments, as well as new research studies, were based on the promotion and investigation of products with dietetic and functional properties that could be beneficial for human health. Milk products, including cheeses, especially those with reduced fat content, represent a good base for the development of such products.

Fat, apart from its nutritional significance in cheese, also contributes to sensory and functional properties of dairy products. Hence, cheeses with a reduced fat content, especially hard varieties, are usually characterized as having atypical and/or unacceptable sensory properties, especially textural and rheological (Mistry, 2001). Numerous research works were performed worldwide in order to investigate the possibility of producing different cheeses with reduced fat content i.e. Cheddar (Guinee et al., 2000; Nelson and Barabano, 2004), Mozzarela (Rudan et al., 1999), Feta (Katsiari and Voutsinas, 1994a; Michaelidou at al., 2003a), Brine cheeses (Romeih et al., 2002; Madadlou et al., 2007), Kefalograviera (Katsiari and Voutsinas, 1994b; Michaleidou et al., 2003b), Edam (Tungjaroen-

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chai et al., 2001), Danbo (Madsen and Ardo, 2001), UF cheese in brine (Puđa et al., 2008). Production of reduced fat cheeses often requires modification of the production procedure, using adjunct cultures and/or ingredients - fat substitutes, in order to achieve their acceptable sensory properties.

UF cheeses are a very popular cheese group in the Mediterranean region. They are usually produced as full fat cheeses. Utilisation of milk protein concentrate for the production of brine cheeses represents an alternative procedure to ultrafiltration and is especially important for underdeveloped countries and countries with low milk production (Madsen and Bjerre, 1981; Newstead, 1982). If dried dairy products are used for cheese production, it is very important to know their composition, especially the level of whey proteins, as well as the heat treatment to which liquid substrates were subjected prior to drying (Robinson and Tamime, 1991).

Low fat cheeses belong to dietetic products and represent a good base for creating products that may be classified as functional food. However, these cheeses are often characterized by a high salt content which influences a number of their quality aspects, such as nutritive and sensory quality, growth and activity of microorganisms, changes during ripening (Guinee and Fox, 2008). Numerous physiological disorders, including hypertension, osteoporosis etc. could be related to excessive salt consumption, especially of sodium (Berlin, 1999; Kaplan, 2000). Hence, modern research works are aimed at facilitating the production of different cheese types with a reduced NaCl content, or its substitution with other salts (Katsiari et al., 1997, 2000.; Güven and Karaca, 2001; Topçu et al., 2008; Puđa et al., 2008).

Functionality of dairy products is usually based on the application of probiotic bacteria and fibre - prebiotics (Mattila-Sandholm and Saarela, 2000). Fibre may have a beneficial effect on health (Niness, 1999; Huebner et al., 2007; Wang, 2009). There are only few research works on fibre usage in cheese production (Modzelewska-Kapitula et al., 2007; Buriti et al., 2007; Cardarelli et al., 2008). An important property of fibre is its potential effect on the improvement of sensory properties of dairy products, especially those with a reduced fat content (Güven et al., 2005; Kip et al., 2006; Guggisberg et al., 2009).

The aim of this study is to define the cheese production procedure by means of modifying processing parameters in such a way to enable the production of low fat UF cheese of high quality, as well as good dietetic and functional properties, due to a reduced fat content, partial substitution of NaCl and adequate content of fibre - inulin.

Material and methods

The research, aimed at defining the technological procedure of low fat UF cheese production, encompassed a determination of influences as follows: (1) coagulation parameters; (2) lactose content of UF milk; (3) incorporation of fibre and; (4) reduction of salt content on the cheese properties during ripening and storage. At the beginning of the experiment, initial production procedure of low fat UF cheese was used, followed by later modifications in accordance with the results obtained throughout the research.

Results of these experiments enabled the definition of the final production procedure for low fat UF cheese. The developed procedure was verified by cheese quality parameters during 8 weeks of ripening and storage analysis.

Initial cheese production procedure

Formulation and production of low fat UF cheeses were conducted by using the following raw materials: milk protein isolate Promilk 852 (Ingredia, France), as a source of protein component, skim milk powder (Dairy plant "Subotica", Subotica, Serbia), as a source of lactose component, cream (Dairy plant "Polimark", Belgrade, Serbia), as a source of lipid component of UF milk and water, which was used as solvent for hydration of milk protein isolate and skim milk powder, as well as for the final dry matter standardization of UF milk.

At the beginning of the experiment, standard composition of UF milk was as follows: 24.3 % dry matter (DM), 3.7 % milk fat (MF), 14 % total protein (TP) and 4.2 % lactose, as 15.2 % fat in dry matter (FDM) and 78.6 % moisture in non fat basis (MNFB). Reconstitution of milk protein powder was done in water at the ratio of 1:3.5, while skim milk powder was dissolved in water at the ratio of 1:1.5. Dissolution, hydration and intensive mixing of milk powders were performed at 50 °C during 1 h, followed by heating of concentrate obtained at 85 °C and cooling at inoculation temperature of 35 °C. Inoculation was done with 2 % of starter culture consisting of *Lactococcus lactis* ssp. *lactis* and *Lc. lactis* ssp. *cremoris* (LL50°, DSM, Netherland), and coagulation by rennet addition (Fromase, DSM, Netherland). The concentrate was poured in the package unit of 0.5 kg, where the coagulation and fermentation took place at 29-30 °C for the duration of 17-18 h. Cheeses were salted with a defined quantity and type of salt in accordance with the experiment schedule. Cheese ripening took place at 12 °C during 7 days, followed by storage of cheeses at 5 °C during 7 weeks.

The assessment of the influence of: *(a) coagulation parameters* on the production of low fat UF cheeses from UF milk included different contents of MNFB (~77 and 80 %), and a variation of fermentation and coagulation temperature (26 °C and 28 °C); *(b) UF milk lactose content* (lactose level of 4 %, 3 %, 2 %, 1.5 % and 1 %); *(c) concentration and type of salt used in cheese salting process* included salting of 1.3 % salt, 1.3 % and 2 % mixed salt (Kristal so, Belgrade, Serbia), where the mixture consisted of NaCl and KCl at 3:1 ratio; and *(d) inulin content added* in cheese production before concentrate inoculation (with no inulin added, and with 1 %, 1.5 %, 2 % and 3 % of inulin, Cosucra, Belgium).

Analytical methods

Sampling, determination of composition, proteolysis parameters, electrophoresis, microbiological status and sensory properties of low fat UF cheeses were performed after fermentation (day 0), after 7 days of ripening and 21, 35 and 56 days of storage. Microstructure of low fat UF cheeses was analysed after 56 days of ripening and storage.

Cheese composition

Grated cheese samples were analyzed in duplicate for dry matter (DM) by the oven drying method at 102 ± 2 °C (*IDF standard 4A:1982*), fat (MF) by Van Gulik method (*IDF standard 5B:1986*), total protein (TP) by Kjeldalh method (*IDF standard 20-1:2002*) on a Kjeltec System (Tecator 1002, Sweden). The pH of cheese slurry was measured by a pH meter (Consort, Belgium).

Starter bacteria

Starter lactococci were enumerated on M17 agar (Merck, Germany) and incubated at 30 °C in aerobic conditions for 48 h.

Assessment of proteolysis

Cheeses were analyzed for water-soluble nitrogen content (WSN) according to the method of Kuchroo and Fox (1982), 5 % phosphotungstic acid soluble nitrogen (PTAN), according to Stadhousers (1960) method, expressed as a percentage of the total nitrogen matter.

Urea polyacrylamide gel electrophoresis (Urea PAGE)

Urea PAGE was performed according to Andrews (1983) method. Electrophoresis was performed using a vertical slab unit TV200YK (Consort, Belgium) with 100x200x1 mm slabs, Tris-glycine electrode buffer, constant current of 60 mA, a maximum voltage of 300 V for 3 h, with 4 % stacking gel (pH 7.6), and 12 % separating gel (pH 8.9).

Sodium dodecil sulphate polyacrylamide gel electrophoresis (SDS PAGE)

SDS PAGE was performed according to Laemmli (1970) method. Electrophoresis was done with the same equipment as Urea PAGE, Tris-glycine electrode buffer, with stacking gel of 4 % (pH 6.8) and 15 % separating gel (pH 8.9), constant current of 80 mA, maximum voltage of 300V for 4 h.

Detected polypeptides were identified using the standards of α- and β-casein (Sigma, USA) and the low molecular weight kit (LKB-Pharmacia, Sweden) consisted of phosphorilase B (94000), bovine serum albumin - BSA (67000), ovalbumin (43000), Carbonic anhydrase (30000), Trypsin inhibitor (20100) i α-lactalbumin (14400).

The gels were stained with a staining solution (0.23 % Coomassie Brilliant blue R-250, 3.9 % trichloroacetic acid (TCA), 17 % methanol, 6 % acetic acid) for 1.5 h and de-stained in a de-staining solution (8 % acetic acid, 18 % ethanol). The gel images were recorded using a scanner Bear Paw 2448TA+ (Mustek, Germany).

Scanning electron microscopy

Cheese samples were cut and prepared according to Kuo and Gunasekaran (2009) and immediately critical point dried with liquid carbon dioxide using a CPD 030 critical point dryer (BAL-TEC, Scan, Germany). The dried, fractured samples were coated with gold in a sputter coater (SCD 005, BAL-TEC, Germany). The samples were examined in a JEOL JSM-6390 LV scanning electron microscope operated at an accelerating voltage of 13 kV and 1000x, 5000x, 10000x and 20000x magnification.

Sensory analysis

Sensory analysis of cheeses was performed by a modified five-point score system (Radovanović and Popov Raljić, 2001). The total sensory quality (100) was expressed as a percentage of the maximum quality.

Statistical analysis

Data were analysed using STATISTICA 6.0 (StatSoft, USA) data analysis software. LSD test was used to determine differences among cheeses at a 0.05 statistical level.

Results and discussion

Development of low fat cheese production procedure

Influence of coagulation parameters on the properties of low fat UF cheeses

Cheeses after coagulation and fermentation showed a limited level of syneresis (about 10 %). pH values after fermentation were 4.77 on average, which is an adequate value for this type of cheese. After 7 and 21 days, pH values decreased significantly, to 4.42 and 4.31, respectively. The significant decrease of pH was mostly reflected on the textural and rheological properties. It was noticed that texture of the cheeses deteriorated during ripening and storage periods, followed by significant serum drainage which resulted in non-homogeneous, granular and mealy cheese curd. Also, the taste of the cheeses was too acidy. These results brought the conclusion that an excessive drop in pH is unacceptable for low fat UF cheeses.

Influence of lactose content on the properties of low fat UF cheeses

Further work was undertaken in order to prevent excessive pH drop, by reducing lactose content of UF concentrate. Assumed compositions of UF milk with different lactose content for production of low fat cheeses are shown in Table 1. Cheeses with different lactose content did not differ notably in protein content, as well as in protein content expressed as a percentage of cheese without fat and lactose.

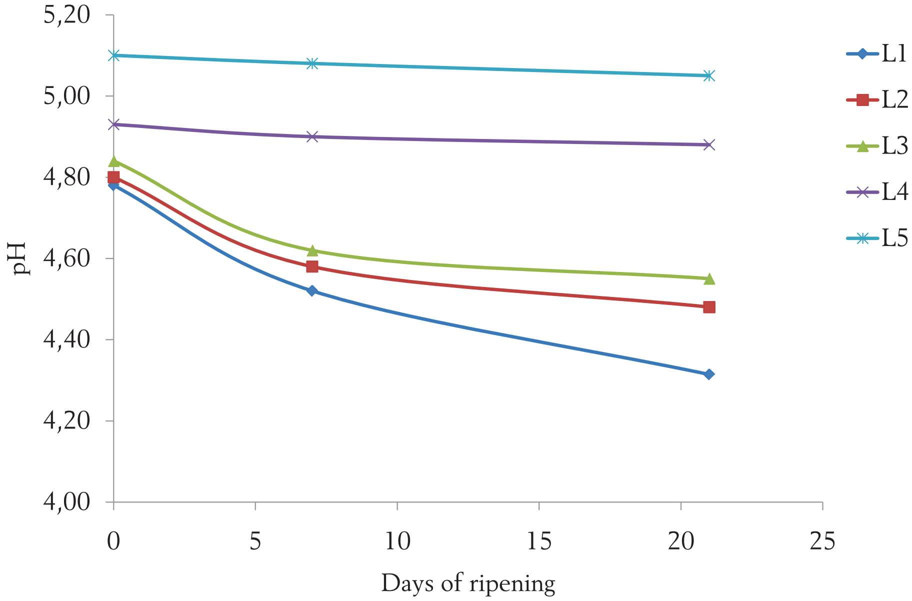
According to MNFB and FDM, cheeses were classified into soft cheese group and low fat category (data not shown). The composition of cheeses with different lactose content was slightly different. Cheeses with low lactose content had lower dry matter. The higher moisture content was probably a result of the higher pH value of cheeses with low lactose content.

Significant differences in pH of cheeses with various lactose content during ripening and storage

Table 1. Composition of UF milk with different lactose content

Cheese*	DM (%)	FDM (%)	MNFB (%)	TP (%)	Lac. (%)	Lac/M (%)	MNFL (%)	PNF (%)	PNFL (%)
L1	24.10	14.52	78.65	14.5	4.2	5.5	82.23	15.03	15.71
L2	22.70	15.42	80.10	14.5	3.0	3.9	82.67	15.03	15.51
L3	21.70	16.13	81.14	14.5	2.0	2.6	82.86	15.03	15.34
L4	21.20	16.51	81.66	14.5	1.5	1.9	82.95	15.03	15.26
L5	20.70	16.91	82.18	14.5	1.0	1.3	83.04	15.03	15.18

*L1, L2, L3, L4 AND L5 - Cheeses produced from UF milk with 4 %, 3 %, 2 %, 1.5 % and 1 % of lactose, respectively
**DM - dry matter; FDM - fat in dry matter; MNFB - moisture in non fat basis; TP - total protein; Lac. - lactose; Lac/M - lactose in moisture; MNFL - moisture in non fat and lactose basis; PNF - proteins in non fat basis; PNFL - proteins in non fat and lactose basis



L1, L2, L3, L4 AND L5 - Cheeses produced from UF milk with 4 %, 3 %, 2 %, 1.5 % and 1 % of lactose, respectively

Figure 1. pH values of low fat UF cheeses with different lactose content

periods were established (Figure 1). pH values of cheeses with high and medium lactose content differed slightly after fermentation, having typical pH value for this type of cheese. Adversely, cheeses with low lactose content had an extremely high pH (4.93 and 5.10). Also, it is important to notice that pH values were uniform among different cheeses during ripening and storage periods. Cheeses produced from UF milk with high lactose content (4 %) showed an intensive decrease of pH, while pH of cheeses with medium lactose content was kept on an acceptable and adequate level. Very low content of lactose of cheeses (1.5 and 1 %) resulted in constant pH values during storage, remaining at a high and atypical level.

Sensory evaluation has shown significant differences between some low fat cheeses made from UF milk with different lactose content. The main differences were determined in terms of texture and consistency, even though the protein contents of all cheese samples were very similar. Cheese with a high lactose content showed significant non-homogenous, grainy and sandy texture. Within 3 weeks of ripening, a significant drainage of serum was observed, which is the result of an excessive pH decrease. Also, it was followed by very high acidity of the cheese curd. In case of longer storage period, acidity may become even more pronounced, followed by a progressive deterioration of cheese sensory properties. Medium lactose content resulted in acceptable and typical texture and consistency of low fat cheeses. Cheese with 2 % lactose had better texture properties compared to cheeses with 3 % of lactose, while their taste profiles did not differ notably. Texture properties remained constant during the ripening and storage periods. Texture of cheeses with low lactose content (1.5 and 1 %) was very smooth, glazy, soft and generally atypical. Therefore, such texture could be regarded as fully unacceptable. Also, acidity of the cheese curd was slight, which is atypical for this type of cheese. It is important to emphasize that the low level of fermentation, imposed by low lactose content of UF milk, could have a negative effect on safety of these products. Generally, cheeses with high moisture content, especially cheeses in brine, due to low pH values in the conditions of moderate salt content, may be subjected to water absorption, prominent proteolytical changes, which in turn promote taste faults, and rapid deterioration (Alichanidis, 2007).

Influence of inulin content on low fat UF cheeses properties

Addition of different amounts of inulin did not have a significant influence on the composition of the low fat UF cheeses (data not shown). pH values of cheeses with different inulin content varied between 4.80 and 4.55, but did not differ significantly ($p>0.05$). These results are in accordance with the literature data, based on the research about the influence of fibres on the composition and quality of fermented dairy products (Dello Staffolo et al., 2004.; Güven et al., 2005; Aryana, 2006; Guggisberg et al., 2009; Benković et al., 2008; Šimunek and Evačić, 2009). The influence of fibres on the activity of starter cultures and pH value of the product depend on the type of bacteria used in dairy products, as well as the type of the prebiotic used, especially on the length of their chains (Aryana and McGrew, 2007).

Microstructure of low fat cheeses with different inulin content was examined by scanning electron-microscopy and it showed no noticeable difference (Figure 2). Nevertheless, the low fat cheese manufactured without inulin had a relatively course protein matrix structure, with large pores, while cheeses manufactured with 3 % of inulin, compared to other cheeses, were characterized by compact structure, dense protein matrix and uniform disposition of protein chains and pores between them. Literature data about the influence of dietary fibers on cheese microstructure is very deficient. Franck (2002) reported that inulin forms a particle gel network in water phase insoluble sub-micron crystalline inulin particles. Kip et al. (2006) speculated that inulin may become a part of the protein structural network by complexion with protein aggregates if inulin is present during fermentation and coagulation process.

Sensory evaluation of cheeses indicates an improvement in their sensory characteristics with an increase in the inulin content. Cheese manufactured without added inulin had a lower, but still satisfactory level of sensory characteristics, with a certain extent of grainy, mealy and non-homogeneous texture. The most obvious effect of inulin addition is the overall improvement of the cheese mouthfeel. It is most likely that the sensory improvement may be a result of inulin capability to form microcrystals when dissolved in water or milk. These microcrystals cannot be felt in the mouth, but they directly influence the formation of the smooth and creamy structure of the product (Niness, 1999). In comparison with the inulin-free control variety of cheese, low fat UF cheeses with different inulin content had improved creaminess. The effect of creaminess increased with the rise of the inulin content in cheese (Guggisberg et al., 2009).

Influence of salt level and type on low fat UF cheeses properties

Low fat UF cheeses salted with different content and type of salt did not show any notable differences in compositional parameters. This is in agreement with the results of other authors (Reddy and Marth, 1993; Aly, 1995; Katsiari et al., 1997, 2000).

pH values of cheeses varied between 4.85 and 4.55. The differences in pH values between cheese varieties during a 3 weeks maturation period were not determined. Proteolysis during the ripening of low fat UF cheeses with different content and type of salt were studied by Urea-PAG electrophoresis (data not shown). Casein degradation during ripening, as expected, did not differ significantly, because the contents of salt in moisture in all cheese varieties are relatively small and do not have a significant effect on the acidic activity of lactic acid bacteria, or

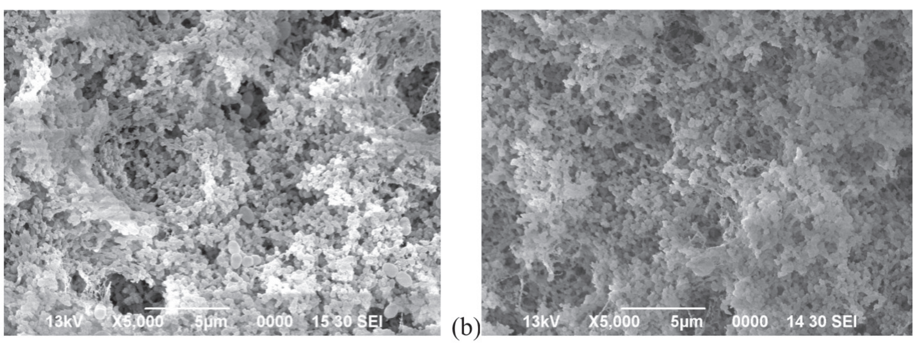
(a) (b)


Figure 2. SEM micrographs of low fat UF cheeses without (a) and with 3 % inulin (b); magnification 5000x

on the activity of the other ripening agents (Katsiari et al., 1997, 2000; Gűven and Karaca, 2001).

Sensory properties, such as exterior and interior appearance, texture and consistency, were quite acceptable and did not differ between cheese varieties with different salt content and type. Low fat UF cheeses with 1.3 % mixed salt and 1.3 % NaCl were characterised by very mild and insufficiently expressed taste. Cheese manufactured with the addition of 2 % mixed salt showed acceptable salinity and good acceptability in terms of taste. Bitter and atypical tastes were not determined. Our results show that the level of sodium, reduced by partial substitution of NaCl with KCl, can be achieved without a deterioration of good sensory properties of this type of cheese. The presented data are fully in accordance with a literature data (Reddy and Marth, 1993; Katsiari et al., 1997, 2000).

Result evaluation and definition of the cheese production procedure

Based on the conducted research, it was established that in order to achieve an appropriate cheese texture, the crucial step is the reduction of the lactose content in the concentrate to the level of 2 %, which provides stabilization of pH value in the optimal range between 4.8-4.6. Stabilization of cheese pH disables a reorganization of the protein matrix and consequent excessive syneresis, which in turn prevents the appearance of brittle texture. Stabilization of the initial level and disposition of serum within matrix helps to retain the soft and creamy texture. The addition of 1.5 % of inulin further improves the creamy texture and enables the achievement of full, rich mouthfeel. At the same time, it provides the functionality of the product, which may be marked as a good source of fiber, with the inulin content of 1.5 g/100 kcal (418.6 KJ) (Codex alimentarius, 2003). Reduction of the lactose content, besides enabling a favourable texture, provides an improvement in preservation effect, which enables the possibility of the salt content reduction from the usual 3 % to 2 %, without deteriorating the ripening process or the cheese sensory profile. Partial substitution of NaCl with KCl provides an additional decrease in the sodium content, which in turn improves the dietary status of the product.

Ripening of low fat UF cheeses

Cheese composition

Composition of low fat UF cheeses during 8 weeks of ripening and storage is shown in Table 2. Dry matter increased significantly ($p<0.05$) after 7 days of ripening. The increase in dry matter during this period was due to salt absorption in cheese, as well as water diffusion from cheese into brine. Generally, it could be noticed that compositional parameters were slightly changed during the investigated period, which is similar to the conclusion of Karami et al. (2009), who stated that UF cheeses produced with LPC concept are characterised by close structure and a very low rate of syneresis during ripening and storage. Within the ripening period, the levels of dry matter, fat and salt did not indicate any significant changes.

pH values were maintained on the adequate level (4.85-4.52), typical for this type of cheese, during the overall ripening and storage periods. The decrease in pH values was a result of a high level of starter bacteria (number of starter lactococci was within range from 8.46 to 6.82 log cfu/g. pH values

Table 2. Composition and pH values of low fat UF cheeses

Days	DM	MF	MNFB	FDM	pH
0	24.69±0.42a	3.83±0.24a	78.31±0.61a	15.54±1.19a	4.85±0.03a
7	27.03±0.59b	3.83±0.24a	75.88±0.70b	14.20±1.10a	4.71±0.05b
21	26.31±0.24b	3.83±0.24a	76.63±0.42bc	14.58±1.00a	4.59±0.07c
35	26.57±0.18b	3.83±0.24a	76.36±0.26bc	14.43±0.89a	4.60±0.08c
56	26.11±0.26b	4.00±0.00a	76.97±0.27c	15.32±0.15a	4.52±0.03c

*DM - dry matter; MF - milk fat; MNFB - moisture in non fat basis; FDM - fat in dry matter
**Results are expressed as mean ± standard error of means; **Means of each parameter in the same column with same letter do not differ significantly ($p>0.05$)

Table 3. Proteolysis parameters of low fat cheeses produced from UF milk

Days	WSN/TN	PTAN/TN	PTAN/WSN
0	8.55±0.07a	0.90±0.09a	10.48±1.07a
7	9.49±0.61b	1.28±0.11b	13.48±0.54b
21	10.35±0.27c	1.41±0.04c	13.61±0.68b
35	10.46±0.10cd	1.38±0.06c	13.21±0.66b
56	11.12±0.26d	1.76±0.12c	15.84±0.75c

*WSN/TN - water soluble nitrogen/total nitrogen; PTAN/TN - phosphotungstic acid soluble nitrogen/total nitrogen; PTAN/WSN - phosphotungstic acid soluble nitrogen/water soluble nitrogen
**Results are expressed as mean ± standard error of means; Means of each parameter in the same column with same letter do not differ significantly (p>0.05)

decreased significantly (p<0.05) during 21 days of ripening and storage, and remained constant until the end of the storage period. This can be related to the low lactose content and high buffering capacity of UF milk that significantly influences the acidification kinetics with lactic acid bacteria (Mistry and Maubois, 2004).

Proteolysis

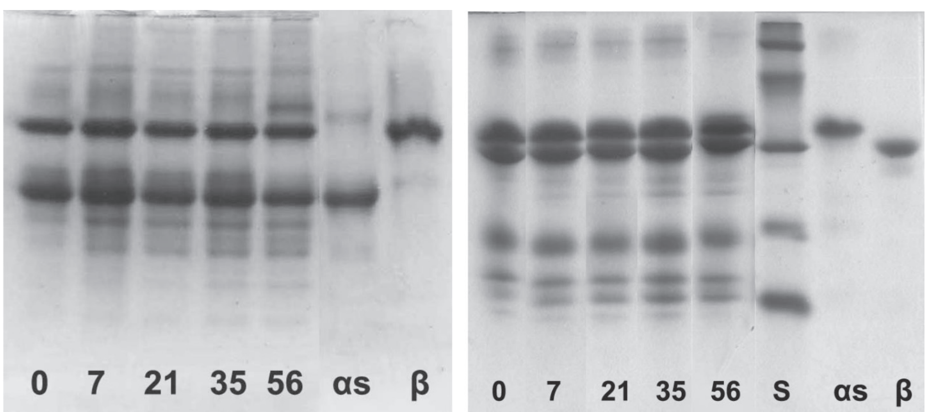
Parameters of proteolysis in low fat cheeses produced from UF milk, during ripening and storage period are shown in Table 3.

WSN/TN content marked a constant increase during the ripening and storage periods, especially during the initial phase of ripening (p<0.05). Michaelidou et al. (2003a) and Karami et al. (2009) reported that the most intensive changes of WSN/TN content of feta cheese with low fat content were recorded during the first 20 days when ripening was subjected to a higher temperature (16-18 °C). The content of WSN/TN was about 11.12 % at the end of ripening, which is significantly lower compared to WSN/TN of traditionally made feta cheese (Kandarakis et al., 2001).

The content of PTAN/TN increased constantly during the overall ripening and storage periods. Statistically significant increase of PTAN/TN (p<0.05) was noticed after 7 and 21 days. The content of PTAN/TN at the end of the examined period was 1.76 %. It was significantly lower compared with PTAN/TN of traditionally made cheeses, which is often within 3-5 % (Abd El Salam and Alichanidis, 2008).

Urea and SDS electrophoregram of low fat UF cheeses during ripening and storage periods are shown in Figure 3.

Degradation of α_{s1}-casein was more pronounced than the degradation of β-casein. This indicates



Lines 0, 7, 21, 35, 56 - days of ripening and storage; S-standard; αs-casein; β-casein

Figure 3. Urea PAGE and SDS PAGE electrophoregram of low fat UF cheeses during ripening

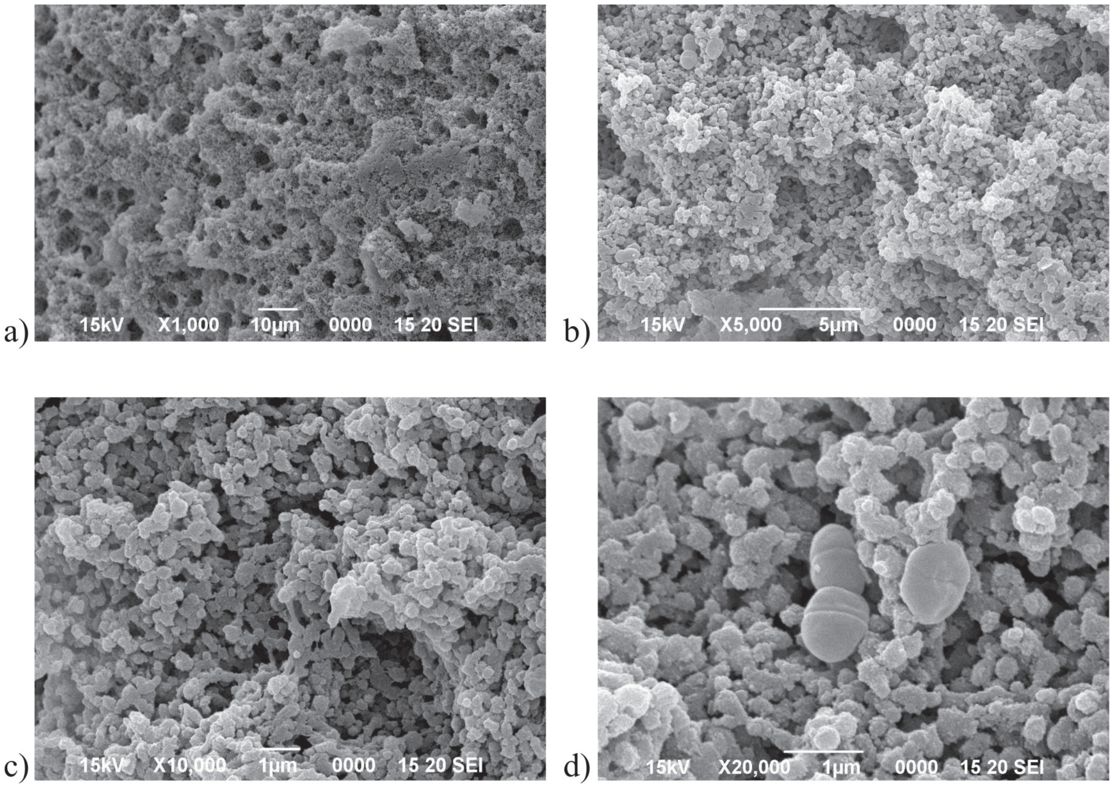


Figure 4. SEM micrographs of low fat UF cheeses; magnification 1000x (a), 5000x (b), 10000x (c), 20000x (d)

more pronounced activity of residual chymosin than of plasmin. According to the results of proteolytical parameters and casein degradation scheme, determined by electrophoresis, it can be concluded that proteolytical changes of low fat UF cheeses are weak. It is well known that UF cheeses are characterized by slow and weak proteolytical changes during ripening (Puđa, 1992).

Microstructure

Microstructure of low fat UF cheeses after 8 weeks of ripening and storage is shown in Figure 4. Cheese microstructure appears to have dense and compact interlaced protein chains. The cheese protein network was characterised by uniform aggregates of paracasein micelles. The average size of paracasein micelles was about 297 nm and pore size was about 3.4 μm. The level of fat reduction in cheese (Sipahioglu et al., 1999), pH values of UF concentrate before coagulation (Karlsson et al., 2005), as well as the quantity of added rennet (Wium and Qvist, 1998) are generally the main factors that influence the rate of aggregation and formation of protein network microstructure. SEM micrographs of cheeses were similar to the micrographs of feta cheese with reduced fat content published by Sipahioglu et al. (1999).

Sensory analysis

Results of a sensory analysis of low fat UF cheeses are shown in Table 4.

Sensory analysis indicated that exterior and interior appearance was very satisfactory and graded with the highest score after 7 days. These attributes did not change significantly during the investigated period ($p>0.05$). During the last stages of ripening, slight deterioration of texture, as well as the aroma, was observed. In subsequent researches it is necessary to achieve further improvement of sensory properties of low fat UF cheeses by adding adjunct cultures and/or ingredients.

Conclusion

Low fat UF cheeses, produced according to the established production procedure, are distinguished

Table 4. Sensory properties of low fat UF cheeses during ripening and storage

Days	Exterior appereance	Interior appearance	Texture and consistency	Aroma	% of max. quality
7	4.97±0.05a	4.92±0.14a	3.71±0.18ac	3.50±0.10a	78.17±1.04a
21	4.97±0.05a	4.97±0.05a	3.78±0.17ac	3.49±0.15a	78.62±2.53a
35	4.89±0.02a	4.92±0.14a	3.50±0.00ab	3.46±0.07a	76.66±0.63a
56	4.89±0.07a	4.92±0.13a	3.50±0.13ab	3.46±0.19b	76.66±2.03b

*Results are expressed as mean ± standard error of means
**Means of each parameter in the same column with same letter do not differ significantly ($p>0.05$)

by very acceptable sensory qualities and satisfactory dietetic and functional properties, due to a low content of fat and salt and adequate fibre-inulin content.

Maintenance of pH values within an optimal interval enables the retaining of the initial texture of cheeses throughout the storage period with soft and creamy consistency. The appearance of this type of product on the market may be significant in terms of expanding the assortment of cheeses, as well as in terms of meeting the increasing needs of consumers that are more in line with modern trends in functional food production.

Razvoj tehnologije niskomasnih sireva od ultrafiltriranog (UF) mlijeka

Sažetak

U radu je razvijen tehnološki postupak proizvodnje niskomasnih sireva od ultrafiltriranog (UF) mlijeka. Ispitivanjem utjecaja parametara koagulacije, različitog udjela laktoze, dodavanja različitog udjela inulina, kao i vrste i sadržaja soli na svojstva niskomasnih sireva od UF mlijeka, definiran je tehnološki postupak koji obuhvaća upotrebu UF mlijeka sa 2 % laktoze, dodavanje 1,5 % inulina i soljenje sa 2 % kombinirane soli (NaCl/KCl u omjeru 3:1). Takav postupak u potpunosti omogućava dobivanje proizvoda s dobrim dijetetskim i funkcionalnim svojstvima. Smanjen udjel laktoze u UF mlijeku doprinosi postizanju i zadržavanju pH vrijednosti na adekvatnoj razini, što rezultira prihvatljivim teksturalnim svojstvima niskomasnih sireva. Definirana količina inulina (1,5 %) poboljšava teksturalna, kao i funkcionalna svojstva sireva, što omogućava da se proizvod deklarira kao "dobar izvor vlakana". Također, smanjen udjel natrija uslijed djelomične supstitucije NaCl sa KCl pridonosi poboljšanju dijetetskih svojstava sireva. Niskomasni sirevi od UF mlijeka, proizvedeni prema definiranom postupku proizvodnje, ispitivani su tijekom 2 mjeseca zrenja i skladištenja. Parametri sastava, pH vrijednosti i proteolize ukazuju na mali obujam promjena, tipično za sireve u salamuri. Ujednačena mikrostruktura i veoma dobra senzorska svojstava, osobito tekstura, potvrđuju validnost razvijenog postupka proizvodnje niskomasnih sireva od UF mlijeka.

Ključne riječi: niskomasni sir od ultrafiltriranog (UF) mlijeka, proteoliza, mikrostruktura, senzorska svojstva

Acknowledgements

This work was support by Ministry of Science and Technological Development, Republic of Serbia.

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