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The study of the microstructure of cheese before and after vacuum drying

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ABSTRACT

Scanning electron microscope allowed us to get screens of different cheese microstructure that form a base for further investigation of a cheese structure state before and after the process of drying and for their comparison. Any cheese structure presents a matrix of proteins penetrated with moisture capillaries; fat globules are located both inside the protein matrix and on a cheese surface. Shape of capillaries is either round or oval. Capillaries vary in size and number that has an impact on the cheese pattern which is described by hole and void shapes and order. Electron microscopy was also used for detecting deposition of calcium phosphate. Particles of calcium phosphate changed in size, before drying they were 10–12 µm, and after drying they reached 20–30 µ. These particles concentrate in the dried cheese and agglomerate into larger particles. The most concentrated calcium phosphate proportion was found in pores and micro-voids of the dry cheese. As for mature cheese samples, calcium lactate was established as well.

1. INTRODUCTION

Considering cheese as an object of drying, it should be noted that the change in the cheese properties during the drying process depends on both the physicochemical properties, the structure, the binding forms of moisture in the material, and the thermophysical characteristics that take into account the features of mass and energy transfer.

The main structural elements of the cheese are the macrograins, the interlayer between the macro grains, the microvoids and the micrograins. The basis of each macro-grain structure is a protein network, in the cells of which numerous micro-grains are interspersed in the form of fat drops, lipoid drops, crystalline formations.

The transition of fat from milk to cheese depends on many factors. Most of the fat balls are transferred (under all other conditions) to medium-sized fat, then small and large [1, 2]. Milk fat is considered to be the most valuable component of milk, although in terms of the nutrition physiology, milk proteins are superior in value to milk fat. Four factors determine the special significance of milk fat in milk and dairy products: economic value, nutritional value, taste and the physical properties of fat-containing dairy products caused by the presence of fat [2].

During maturation, all components of the cheese mass are exposed with profound changes, as a result of which the proper consistency and drawing of this type of cheese are acquired [3].

Cheese humidity depends on the technological mode of production: temperature and duration of rennet clotting, temperature of the 2nd heating stage, partial salting of the curd mass in the grain and adding water during the 2nd heating stage, as well as on the duration of the cheese grain processing. With a decrease in the clotting temperature and the temperature of the 2nd heating stage, the moisture capacity of the curd and the water content in the finished product increase. As the temperature rises, the moisture content in the cheese decreases. Loss of moisture occurs at the stage of salting (osmotic transfer of water), and during the period of maturation (evaporation). The intensity of the microbiological and biochemical processes occurring in it depends on the value of the initial moisture content of the cheese (after pressing) [4].

According to the GOST (the RF standards & regulations) 7616-85, GOST 11041-88, GOST R 52686-2003, the following dependence characterizes cheese: with an increase in the moisture mass fraction, the mass fraction of fat decreases. The mass fraction of fat and moisture of all objects of the current research is presented in Table 1.

Table 1. Mass fraction of fat and moisture of the research objects

Product name	Mass fraction, %	
	fat in the dry matter, no less than	moisture, no more than
Hard cheeses with a high temperature of the 2nd heat stage		
Sovetskiy	50	42
Swedish	50	42
Altaiskiy	50	42
Gornyiy	50	40
Moscowskiy	50	42
Semi-hard cheeses with a low temperature of the 2nd heat stage		
Dutch	45-50	43-44
Kostromskoy	45	44
Poshekhonskiy	45	42
Yaroslavskiy	45	44

For most solid and semi-hard cheeses, the mass fraction of fat in the dry matter is 45–50%, the mass fraction of moisture is 40–44%.

The fat in the cheese is in the form of micrograins with a diameter of 10-15 microns. There are also larger inclusions of fat, the so-called fat drops, which are allocated evenly throughout the thickness of the cheese. Fat drops and lipid micro-grains in cheese are milk fat destabilized in the process of cheese making and ripening. This judgment is justified since, at temperatures above 20° C, the fat in the cheese can be melted out of the cheese mass, which is the main obstacle in the thermal dehydration of the cheese.

2. EXPERIMENTAL SECTION

The objects of research were cheeses of the following brands: Soviet, Swiss, Altai, Gorny, Moscow, Holland, Kostroma, Poshekhonsky and Yaroslavsky.

For the experimental studies on the drying unit was used, the scheme of which is shown in Figure 1.

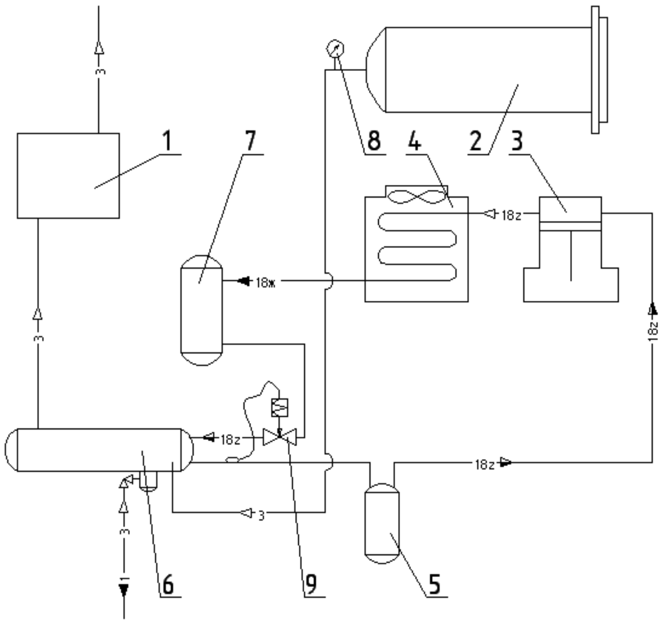


Figure 1. The scheme of the experimental setup: 1-vacuum pump; 2-chamber vacuum; 3-compressor; 4-capacitor; 5-liquid separator; 6 desublimator; 7 receiver; 8 vacuum gauge; 9 thermostatic valve

This drying unit is universal and can be used for drying almost any raw material of plant and animal origin. The drying unit consists of a drying chamber, a desublimator, a vacuum pump, a cooling machine, and a regulation and measurement system.

Two infrared lamps of the KGT 220 brand were used as sources of heat in the installation. Since the chamber volume is relatively small (36 liters), two sources are sufficient to ensure uniform heating of the dried product.

The design of the vacuum chamber provides for the possibility of changing the distance between the heaters and the tray on which the product is located during the drying process. Cylindrical walls of the vacuum chamber itself serve as screens to increase the amount of radiant flux incident on the product.

The product is heated by pulses of infrared radiation to the desired temperature. A characteristic feature of infrared lamps is low thermal inertia. This characteristic allows you to accurately maintain the required temperature of the product in the process of vacuum drying.

In the lower part of the chamber, there is a pipeline connecting the drying chamber with the desublimator. The desublimator is a shell-coil heat exchanger with in-line boiling of the refrigerant, which is the evaporator of the refrigerating machine. Desublimator is designed to remove water vapor from the vacuum chamber formed during the drying process. At the bottom of the desublimator, there is a valve for depressurizing the system and removing the moisture frozen on the evaporator upon completion of the drying process.

The vacuum in the system is maintained using a two-stage vacuum pump brand 2TW-1C. Evaporation of evaporated moisture and non-condensable gases occurs as follows: evaporated moisture from the product enters the desublimator through the pipeline, where it passes through the evaporator and freezes on its surface that portion of water vapor that is not frozen and the non-condensable gases are pumped out with a vacuum pump into the environment.

The content of the mass fraction of moisture in the cheeses before and after drying was determined by an accelerated method on a Chizhova device, by drying the weight of the product according to GOST 3626-73.

The content of the fat mass fraction in the cheeses before and after drying was determined by the Gerber acid method according to GOST 5867-90. The method is based on the separation of fat from milk and dairy products under the action of concentrated sulfuric acid and isoamyl alcohol, followed by centrifugation and measuring the amount of released fat in the graduated part of the fat meter.

Experiments on the study of the forms and the energy of the binding of moisture in semi-hard cheeses were carried out using non-isothermal analysis using a derivatograph. In the course of heating the sample of the samples under study, the change in mass, the rate of change in mass, and the rate of change in temperature of the product, obtained by thermogravimetry, were determined.

Thermophysical characteristics of cheeses were determined by the first buffer method of two temperature-time intervals.

3. RESULTS

Quality of the dried material is affected by some factors as the process of the material preparation, rate and evenness of drying. Original properties of the product can be retained on a maximum level, whether the material itself is of high quality, hence high-quality products are more appropriate for drying according to their physicochemical composition, and their structure remains whole; while they would be more fully-featured after drying.Therefore, only high-quality cheese was used for the research. Figure 2 shows cross section of freezedryed cheese.

During the process of vacuum drying, cheese dimensions became porous and slightly changed. Before drying, Sovetskii and Gollandskii cheese samples obtained linear dimensions of 117 and 120 mm, while after drying, they were 114 and 115 mm, respectively. the Ozernyi cheese sample also changed in diameter before and after drying from 130 mm to 124 mm. In the process of vacuum drying there occur some linear shrinkage of cheese by 3–5%. Water mass fraction in cheese samples were up to 5%. Vacuum drying was conducted at 2–3 kPa.

Figures 2–8 present microstructure pictures of cheese samples Sovetskii, Gollandskii, and Ozernyi before and after the vacuum drying process. To detect microstructure analysis and capillary structure comparison of the cheese mass in a simplier way, such magnification as 50, 200, and 2000-fold magnification, was used for all the samples.

(a)

(b)

(c)

(d)

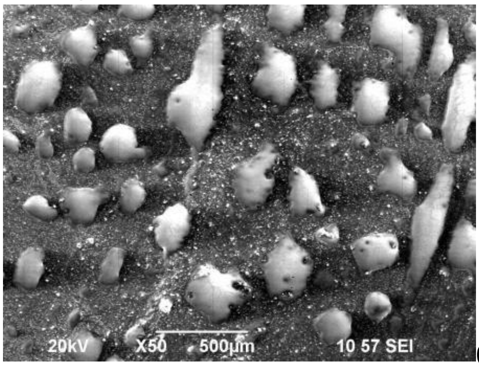
(e)

(f)

Figure 2. Cross sections of cheese of different After vacuum drying, structure of cheese unfolds. In dry varieties before (a, c, and e) and after (b, d, and f) cheese, due to low water content of 4–7 %, structure and freeze-drying: (a, b) cheese variety Sovetskii; capillaries, which were not detected in the microimages (c,d) Gollandskii; and (e, f) Ozernyi. of cheese before drying, are better seen.

The correctness of cheese production in terms of the development of biochemical and physicochemical processes is characterized with the cheese structure, texture, and pattern of upon. The dense product (e) structure is featured by the size and individual particles or components spatial arrangement.

Any cheese variety has a unique microstructure, but in general, the structure of all cheese types consists of the same elements. Macrograins contain various inclusions, or micrograins.



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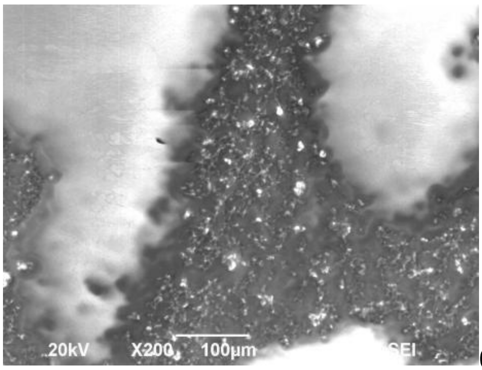

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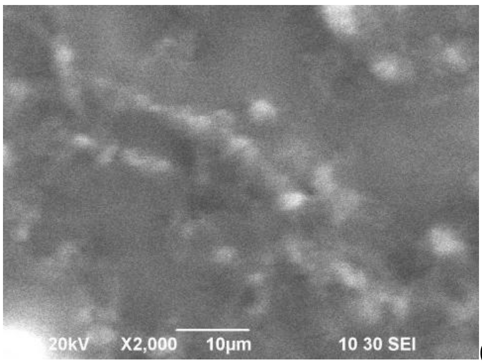
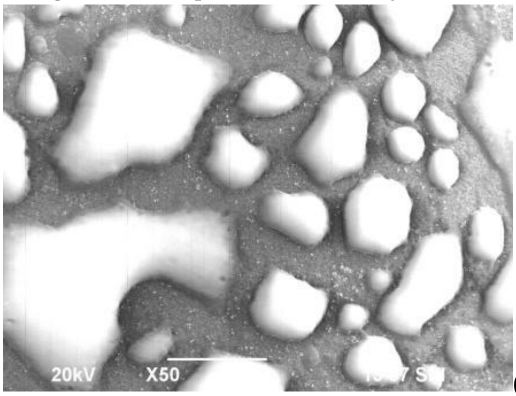


(c)

Figure 3. Sample of the Sovetskii cheese microstructure before drying: (a) magnification of 50×; (b) 200×; and (c) 2000×.

Usual globules of fat are from 50 to 300 µm in size, they evenly cover the cheese surface. If the magnification level is 1000×

and 2000×, there can be observed some cell-like structures in the cheese mass . These cell-like structures consist of a protein matrix with retaining moisture capillaries of 10–12 µm in size.



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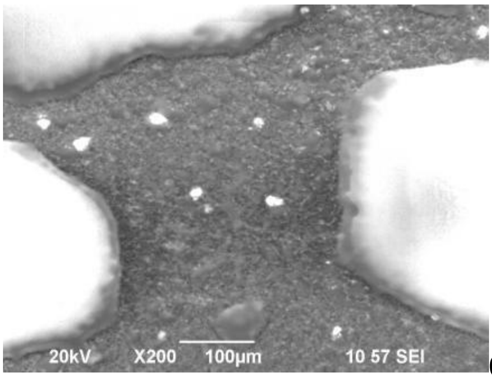

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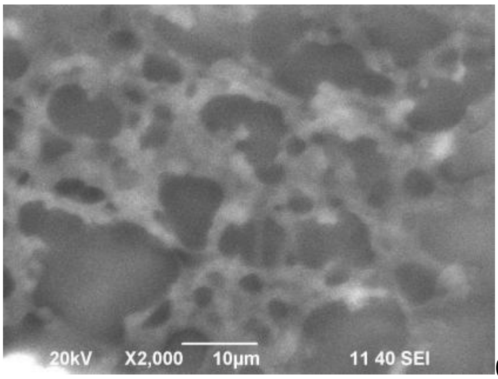
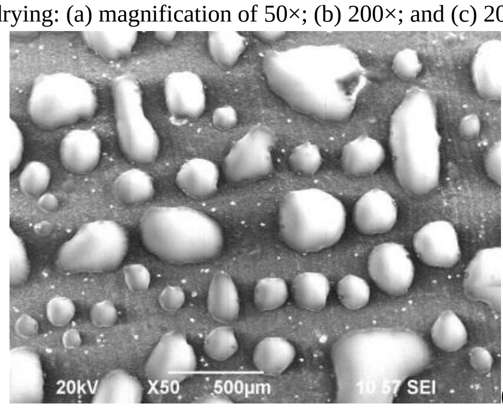


(c)

Figure 4. Sample of the Gollandskii cheese microstructure before drying: (a) magnification of 50×; (b) 200×; and (c) 2000×.



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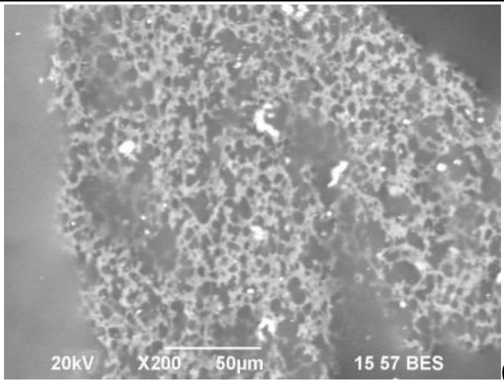

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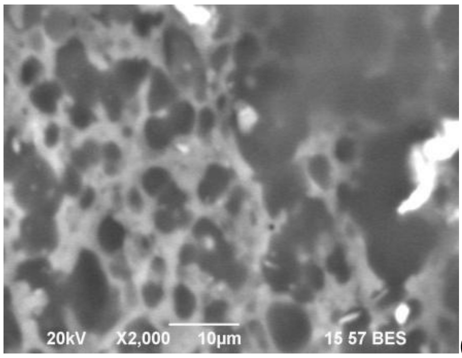
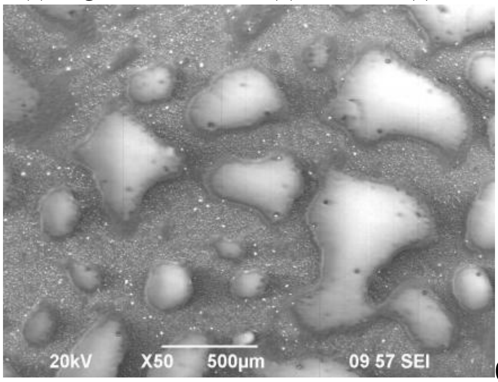


(c)

Figure 5. Microstructure of the Ozernyi cheese sample prior to drying: (a) magnification of 50×; (b) 200×; and (c) 2000×.



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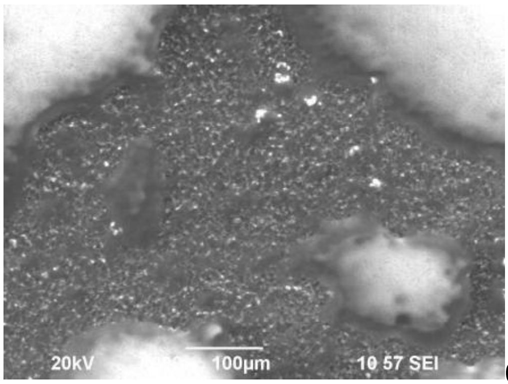

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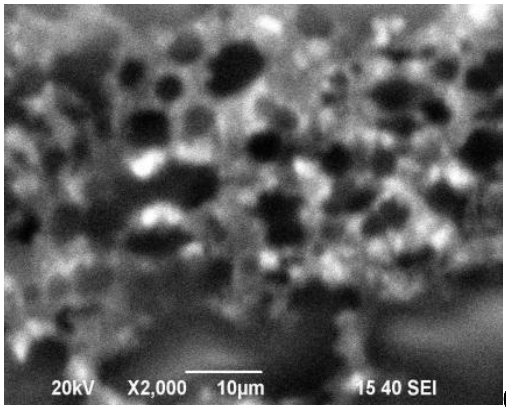

(c)

Figure 6. Microstructure of the Sovetskii cheese sample after drying: (a) magnification of 50×; (b) 200×; and (c) 2000×.

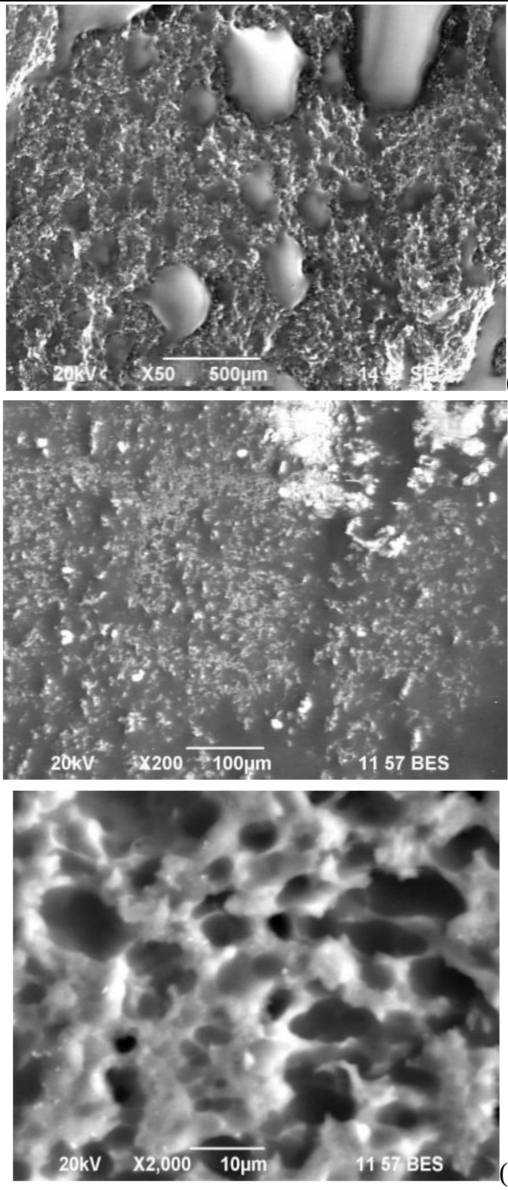
(a)
(b)
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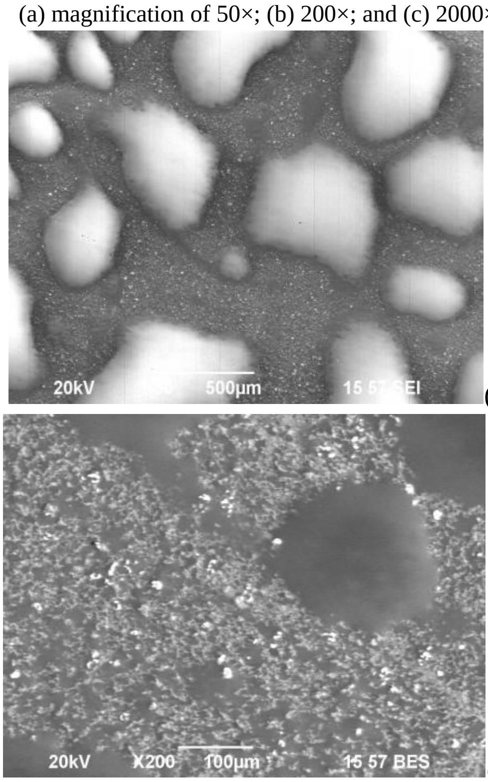
Figure 7. Sample of the Gollandskii cheese microstructure after drying: (a) magnification of 50×; (b) 200×; and (c) 2000×.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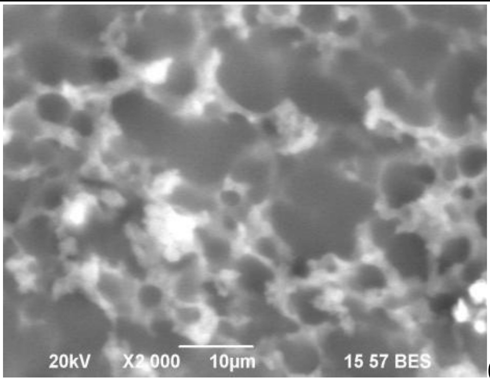

(c)

Figure 8. Sample of the Ozernyi cheese microstructure after drying: (a) magnification of 50×; (b) 200×; and (c) 2000×.

When the dryer reached the neededmode of residual pressure, heating switches on, and water boils rather soon at the low pressure, and the cheese protein mass dehydrates. Thus occur an intensive formation of vapor and diffusion of moisture outside the cheese surface. The size of capillaries, that keep water is not changed after drying and even increases up to 5–15 μm.

After dehydration, Globules of fat unites and form larger shapes reaching from 100 to 700 μm, in fact they become twice as large as ones in the cheese before drying. Studies on varieties of different solid cheese microstructure showed that there is no cheese shrinkage upon vacuum drying.

Electron microscopy proved deposition of calcium phosphate in cheese. The microstructure studies of cheese samples before and after drying established that cheese contained individual particles are ionized in the electron beam as it was pictured on the microimages (Figure. 9).

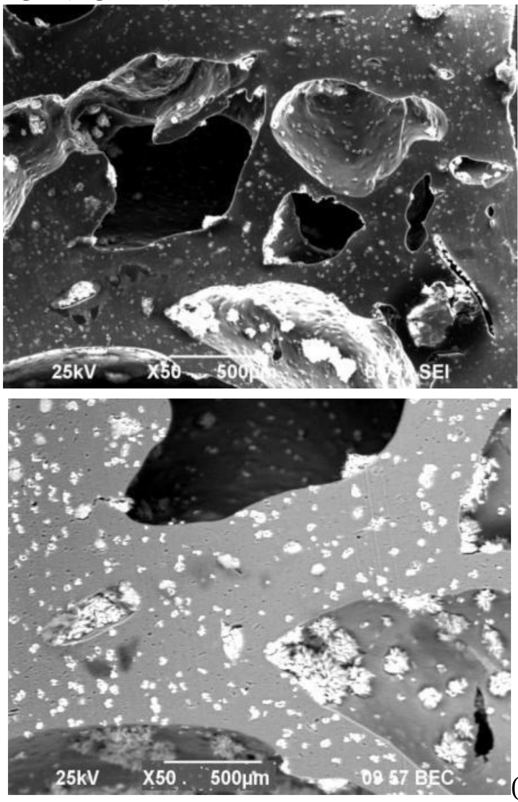

(a)
(b)

Figure 9. The sample of Kostromskoi cheesecontaining depositions of calcium salts: (a) before and (b) after drying.

An analysis of particle distribution over the cheese mass was conducted to identify the particles. Schemes of cheese element distribution before and after drying were developed. These maps detect the sites of phosphate and calcium localization. Locations of phosphate and calcium are vividly observed and overlap. Moreover, these locations overlap with the glowing particles in the images.

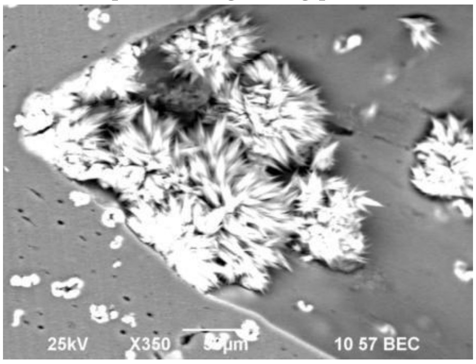
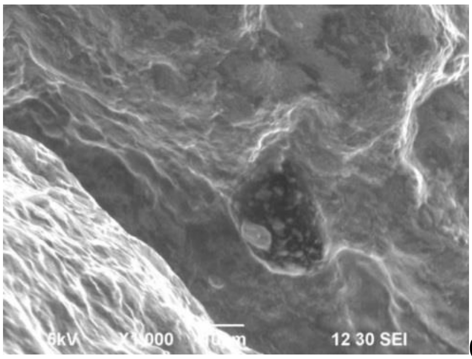


Figure 10. The sample of dry Kostromskoi cheese with calcium phosphate

However, weak conductivity is presented by calcium phosphate. Under the impact of electron beam it is ionized and produces glowing in the screens. As for dried cheese, calcium phosphate concentrates that leads to the particle size increase . Before drying, the Kostromskoi cheese sample has evenly spread particles of calcium phosphate of 10–12 µm. While after drying, these particles increased in size up to 20–30 µm. Thus, dry cheese containes concentrated calcium phosphate and aggregated particles, that are mostly concentrated in cheese pores and microvoids.

The form of calcium phosphate in cheeseis crystal micrograin accumulations. Crystal micrograins present round-shaped formations (Figure 10), including wedge-like crystals, 20–30 µm in diameter.



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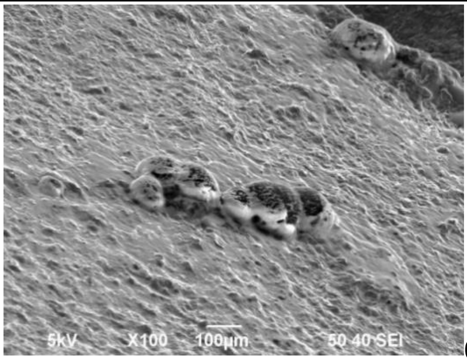
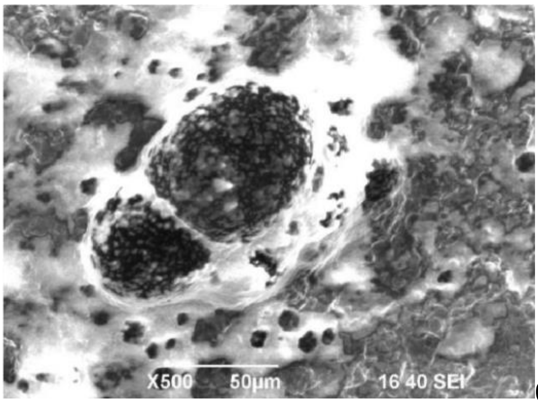


(b)

Figure 11. Calcium lactate in: (a) Kostromskoi and (b) Rossiiskii mature cheese samples.



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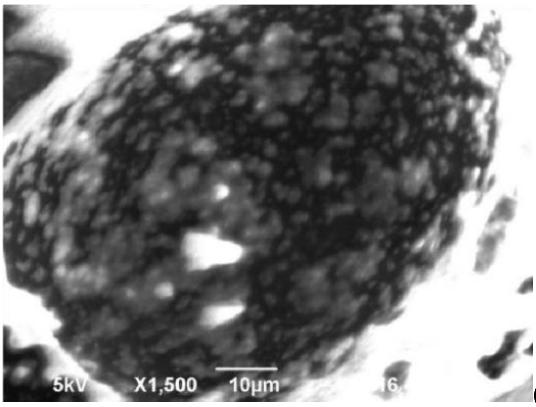

(b)

Figure 12. The sample of cheese Rossiiskii with calcium lactate at magnification of a, 500×, and b, 1500×.

Samples of mature cheese variety Kostromskoi and Rossiiskii possess calcium lactate (Figure 11). Its formation can be associated with cheese ripening itself, as it occurs only in mature cheeses. The size of calcium lactate particles in the samples of cheeses Kostromskoi and Rossiiskii was 200 × 150 µm. Figure 12 demonstretes screens of calcium lactate in the Rossiiskii cheese sample.

4. CONCLUSIONS

Scanning electron microscope allowed us to get screens of different cheese microstructure that form a base for further investigation of a cheese structure state before and after the process of drying and for their comparison. Any cheese structure presents a matrix of proteins penetrated with moisture capillaries; fat globules are located both inside the protein matrix and on a cheese surface. Shape of capillaries is either round or oval. Capillaries vary in size and number that has an impact on the cheese pattern which is described by hole and void shapes and order. Electron microscopy was also used for detecting deposition of calcium phosphate. Particles of calcium phosphate changed in size, before drying they were 10–12 µm, and after drying they reached 20–30 µ. These particles concentrate in the dried cheese and agglomerate into larger particles. The most concentrated calcium phosphate proportion was found in pores and micro-voids of the dry cheese. As for mature cheese samples, calcium lactate was established as well.

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