Доведено доцільність розробки технології цільових напівфабрикатів на основі молочної декальцифікованої сировини. Визначено раціональний вміст та співвідношення декальцифікованої молочної та жирової сировини у складі напівфабрикатів. Розроблено модель технологічної системи та експериментально обґрунтовано раціональні параметри технологічного процесу виробництва напівфабрикатів з емульсійною пастоподібною структурою на основі сирно-молочної суміші

Ключові слова: напівфабрикати, декальцифікована молочна сировина, сирно-молочна суміш, емульгуюча ємність, емульсійна пастоподібна структура

Доказана целесообразность разработки технологии целевых полуфабрикатов на основе молочного декальцифицированного сырья. Определено рациональное содержание и соотношение декальцифицированного молочного и жирового сырья в составе полуфабрикатов. Разработана модель технологической системы и экспериментально обоснованы рациональные параметры технологического процесса производства полуфабрикатов с эмульсионной пастообразной структурой на основы творожно-молочной смеси

Ключевые слова: полуфабрикаты, декальцифицированное молочное сырье, творожно-молочная смесь, эмульгирующая емкость, эмульсионная пастообразная структура

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DEVELOPMENT OF TECHNOLOGY FOR THE PRODUCTION OF SEMI-FINISHED PRODUCTS WITH AN EMULSION STRUCTURE BASED ON THE DECALCIFIED DAIRY RAW MATERIALS

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1. Introduction

Cottage cheese is widely used in the technology of culinary and confectionery products. The technological process of their production is regulated by normative documents with a simultaneous introduction of modern approaches to development of innovative products [1]. However, practical experience of using cottage cheese in the technologies of food products confirms the need for adjusting features of receipt mixtures when using it. In the manufacturing practice, this is achieved by applying additional production steps (wiping, removing excess whey) or changing (increasing or decreasing) the content of ingredients (wheat flour, farina, eggs, or poultry). The above-mentioned technological measures make it possible to regulate form stability, moisture-retaining and structure-forming power, cohesive properties and viscosity of both intermediate semi-finished and finished products [2].

Reduced functional and technological properties of cottage cheese as a final product of the dairy industry are related to the fact that priority in production is given to the product yield, protein and fat content, moisture content, etc. [3]. In order to achieve such goals, the technological process of production of cottage cheese can be carried out with the use of rigorous methods for processing dairy stock (use of elevated temperatures, acids, souring agents, etc.). All this greatly deteriorates functional properties of cottage cheese and results in obtaining of the product with non-standardized quality indicators. Concerning the restaurant sector, impossibility of obtaining cottage cheese with stable quality indicators makes producers to standardize properties of receipt formulations in a so-called “manual mode”. This, in turn, results in products with properties varying depending on the stock properties.

This determines necessity of involving dairy stock characterized by constant functional and technological indicators. It was proved that the decrease in calcium content in milk to definite limits makes it possible to materially correct functional, technological, structural and mechanical indicators of the dairy stock [4, 5]. This ensures production of decalcified dairy stocks which have high functional and technological properties (specifically emulsifying capacity).

Therefore, development of semi-finished products based on decalcified dairy stocks (cottage cheese and skim milk) is timely and in demand. The study urgency consists in creation of semi-finished products with an emulsion paste-like structure. In the proposed technology, the option of resource conservation (use of non-fat milk), multifunctionality according to the technological purpose (production of culinary and confectionery products), rational use of resources (time and labor) and others are realized.

2. Literature review and problem statement

Analysis of information sources [6–8] shows that an extensive experience in the field of emulsion systems based on protein-milk concentrates including cottage cheese was gained till now. It is well known that to form protein-fat emulsions, it is important to use functional and technological properties of proteins, specifically emulsifying capacity, which correlates with solubility. Given that protein (casein) in the cottage cheese is within the isoelectric point, it is necessary to determine the conditions under which solubility of proteins and hence the emulsifying capacity will grow.

Papers [9 12] discuss various ways of bettering solubility of proteins or content of soluble proteins. First of all, it is enzymatic methods (enzymatic hydrolysis of proteins with formation of peptides, dipeptides and amino acids) [9] and chemical methods (binding of lysine with reducing sugars in presence of cyanoborohydride) [10]. Such salts as phosphates and citrates [11] are also widely used. Technological methods of influence on protein substances (additional introduction of caseinates, co-precipitates, whey protein concentrates) [12] are more associated with an increase in concentration of soluble protein substances. However, the proposed methods have certain limitations. In particular, it is the accumulation of bitter taste as a result of fermentolysis [9], restriction and, in some cases, a ban on the use of food additives, presence of alkaline aftertaste [11], sandy consistency, increase in the cost of finished products [11, 12].

At the same time, the prospect of using modified milk proteins as emulsifiers in compositions of dairy products (yoghurts, cheese pastes, etc.) [13] was established. However, the resulting products are characterized by unstable quality indicators in storage and require introduction of additional stabilizing systems. Such a change in qualitative indicators is associated with a reduced value of the system pH and an increased content of Ca^{2+} ions which is characteristic of this type of products since under such conditions, emulsifying capacity of protein substances, specifically milk proteins, as well as stability of emulsion products are significantly reduced [14].

Therefore, an objective need appears to create semi-finished products with an emulsion paste-like structure based on cottage cheese and skim milk with modified properties. It is noted in works [4, 5] that decalcification of skim milk based on substantiated parameters makes it possible to modify properties of the dairy stock. For example, decalcified milk is characterized by an increased thermal and acid resistance, and the cottage cheese made on its basis has higher moisture content, dispersity and improved structural and mechanical properties. At the same time, to date, no systematic studies have been found concerning substantiation of technological parameters of production of semi-finished products with an emulsion paste-like structure. Therefore, development of a scientifically based technology of semi-finished products with an emulsion paste-like structure has both a theoretical value and the prospects for its practical implementation. Introduction of this technology into production will result in high-quality products and standardization of their quality indicators.

3. The aim and objectives of the study

This study objective was development of the technology of semi-finished products with an emulsion paste-like structure (hereinafter, semi-finished products) based on a decalcified dairy stock. This approach involves the use of semi-finished products, such as decalcified skim milk (DSM) and cottage cheese (DCC) made on its basis in the production process. This will maximize the technological potential of dairy stocks and create multifunctional semi-finished products.

To achieve this objective, the following tasks have had to be solved:

– to carry out an expert assessment of physical and chemical indicators of cottage cheese made according to the classical technology in order to prove feasibility of developing the technology of semi-finished products;

– to determine rational content and the decalcified dairy stock to the fat stock ratio in compositions of semi-finished products;

– to determine rational parameters of production of semi-finished products and develop a model of the technological system for their making.

4. Materials and methods used to study properties of emulsion systems based on cheese and milk mixtures

The subjects of the study were as follows:

– decalcified skim milk;

– low-fat cottage cheese made from decalcified skim milk according to the traditional technology;

– cheese and milk mixtures based on decalcified dairy stock;

– semi-finished products based on decalcified dairy stock and sunflower oil.

The decalcified dairy stock (skim milk and cottage cheese made on its basis) were prepared based on description of the technological process given in [5]. Cheese and milk mixtures were prepared by blending decalcified dairy stock at a ratio of cottage cheese to milk (90:10) to (10:90).

The methods for investigating physicochemical, functional, and technological properties of decalcified stock and emulsion systems based on cheese and milk mixtures are given in detail in [15].

5. Results obtained in the study of properties of cheese and milk mixtures on the basis of decalcified dairy stock

At the first stage, an expert estimation of non-fat cottage cheese (5 samples) of the leading Ukrainian producers for physical, chemical, and technological indicators was made (Table 1). To ensure an unbiased opinion of manufacturers, samples were identified by numbers. Summarizing the results of studying the samples of dairy cheese by physical and chemical indicators allowed us to reveal a full compliance with the current normative documentation (ND) according to such indicators as mass fraction of moisture and titrated acidity. A discrepancy between the figures declared on the consumer marking and the actual protein content (samples 3, 4, 5) was found.

Additional study of mass fraction of ash, moisture-retaining power (MRP) and the average size of protein particles was made. The two last indicators (along with the mass fractions of moisture and protein and titrated acidity) have a significant impact on the technological properties of the cottage cheese and the formulation mixtures prepared on its basis. It was established that the MRP of samples of the cottage cheese varied in rather wide ranges from 45.5±0.5 % to 57.8±0.5 %, the average size of protein particles varied from 29.5±0,1 μm to 54.3±0.1 μm. One can predict that the fluctuations of the MRP indicator will lead to mixtures of different consistencies which will affect form stability of the culinary products, structural and mechanical indicators, and juiciness. Dispersity of protein particles will also have a significant impact on quality of the finished culinary products. Protein particles in their colloidal state are a gel characterized by temperature lability. Also, in the presence of dehydrating components (white sugar), it is prone to compaction with separation of free moisture (whey). The determined fact shows that in technological practice, it is more appropriate to use cottage cheese which is characterized by a mono- and high-dispersion composition of protein particles. The foregoing is especially important for the use of nonfat cottage cheese in which the processes of separation of the free water phase in a form of whey are clearly pronounced in absence of fat layers. This will ensure formation of necessary organoleptic, physicochemical, structural, and mechanical indicators of the culinary products.

Thus, the physicochemical and technological properties of cottage cheese, even under the conditions of their correspondence to the current ND, differ from each other which affects the technological parameters of making products on its basis. Despite the high nutritional value of cottage cheese, its technological properties require bringing into line with the requirements of the production technology of restaurant facilities on the one hand, and modification and expansion due to the purposeful influence of technological factors at the stage of its production on the other hand. In a case of multivariate solution of this problem, one of them lies in the use of the cottage cheese made on the basis of decalcified dairy stock. This will enable creation of semi-finished products for targeted use in culinary and confectionery products.

Taking into account the aforementioned, a working hypothesis was formulated: formation of a cheese and milk mixture from a decalcified dairy stock will enable formation of systems with an emulsion paste-like structure by increasing the content of soluble proteins in a dispersion medium.

In order to prove this hypothesis, the effect of pH on solubility of proteins of the cottage cheese made from decalcified skim milk in comparison with the control sample was studied in the first stage (Fig. 1).

Analysis of the experimental data shown in Fig. 1 suggests that change of pH of the systems based on cottage cheese leads to an increase in the content of soluble protein in the aqueous dispersion phase.

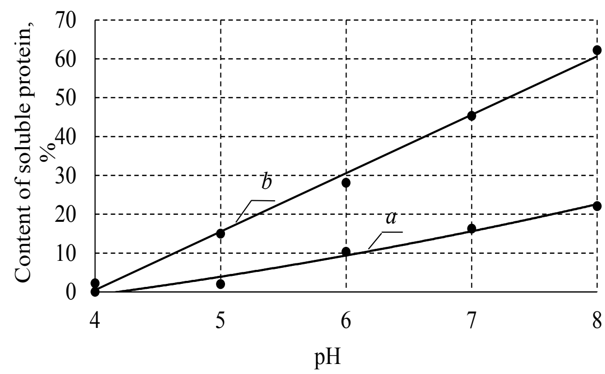

Fig. 1. Content of soluble protein in the systems based on the cottage cheese made from skim milk (*a*) and decalcified skim milk (*b*)

For example, for the systems based on the cottage cheese made from skim milk, a 40-fold increase in the content of soluble protein from 0.5±0.01 % to 20.4±0.1 % was observed in an interval of pH values from 4.0 to 8.0. For decalcified skim milk, this indicator reached a 104 times higher value: from 0.6±0.01 % to 62.4±0.1 %. It is important (considering the technological properties differing from the control sample of the cottage cheese) that there was a higher rate of accumulation of soluble proteins in the samples prepared based on the cottage cheese made from decalcified skim milk.

Table 1

Physical-chemical indicators of the studied samples of non-fat cottage cheese

Specimen No.	Indicator name								
	Mass fraction of protein, %, not less than		Mass fraction of moisture, %		Titrated acidity, °T		Mass fraction of ash, %*	MRP, %*	Average size of protein particles, μm*
	by ND	actual	by ND	actual	by ND	actual			
1	14	19.2±0.1	65–80	62.5±0.1	170–250	113±1.0	1.0±0.1	45.5±0.5	54.3±0.1
2		16.4±0.1		65.8±0.1		180±1.0	1.1±0.1	49.4±0.5	29.5±0.1
3		17.0±0.1		62.3±0.1		221±1.0	1.2±0.1	57.8±0.5	43.5±0.1
4		15.7±0.1		64.1±0.1		220±1.0	1.0±0.1	54.0±0.5	35.0±0.1
5		14.9±0.1		71.6±0.1		247±1.0	1.1±0.	50.3±0.5	40.0±0.1

*Note: * – this indicator is not standardized by DSTU 4554:2006 Cottage Cheese. Specifications*

It is evident from Fig. 1 that at equal values of pH, content of soluble protein (with the use of cottage cheese made from decalcified skim milk) at pH values of 5.0; 6.0; 7.0; 8.0 was 8.0, 3.3, 2.8, 2.7 times higher compared to the control specimen. This indicates a higher functionality of proteins of the cottage cheese made from decalcified skim milk. It is a prerequisite for the simulation of the technological process of production of semi-finished products with an emulsion paste-like structure.

According to the study tasks, physical and chemical properties of cheese and milk mixtures were determined. Their characteristics are given in Table 2.

It was established that with an increase in the content of decalcified skim milk in the mixture, an increase in pH of the systems is observed from 4.8 to 5.3 while the increase in the mass fraction of soluble protein in the aqueous phase of the dispersion was from 0.5±0.1 % to 2.0±0.1 %. The above patterns are likely to be explained by the fact that Na ions have a solvating effect on casein which is converted into sodium casein. It is worth to note that the total content of soluble proteins is the sum of the proteins contained in the non-fat decalcified milk, soluble sodium caseinate accumulated by solvation, and whey proteins.

It is well-known that properties of emulsion systems depend on many factors. First of all, this is the mass fraction and properties of surfactants, the ratio of water and fat phases, viscosity of the systems. Also, parameters of the emulsification process (temperature, duration, speed of emulsifier) are important. In order to determine rational parameters for obtaining the emulsion systems on the basis of cheese and milk mixtures, their apparent viscosity (Fig. 2, 3), emulsifying capacity (Fig. 4) and stability of emulsions were studied (Fig. 5). The study was conducted at various cottage cheese to decalcified skim milk ratios. It has been established that irrespective of the ratio of components, the cheese and milk mixtures are non-Newtonian fluids. Their apparent viscosity depends on the rate of shear. The rate of the viscosity curves shows that they have two regions: gradual structure degradation and the Newtonian plateau at high shear rates which is probably connected with destruction of inter-particle bonds.

Generalization of the experimental data of Fig. 2, 3 makes it possible to conclude that apparent viscosity of the cheese and milk mixtures varies considerably with variation of the component content. For example, in the range of component ratios of 90:10≤φ≤50:50, apparent viscosity lies in the range of 3.9 Pa·s≤η≤0.27 Pa·s. It is clear that viscosity fluctuation in such a wide range will have a significant effect on formation of emulsion systems. However, to elucidate rational parameters of their formation, a complex evaluation of the systems by many indicators is required.

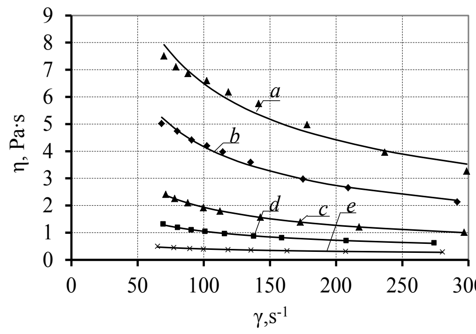

Fig. 2. Apparent viscosity of cheese and milk mixtures depending on the shear rate at various cottage cheese to decalcified skim milk ratios (φ): 90:10 (*a*); 80:20 (*b*); 70:30 (*c*); 60:40 (*d*); 50:50 (*e*)

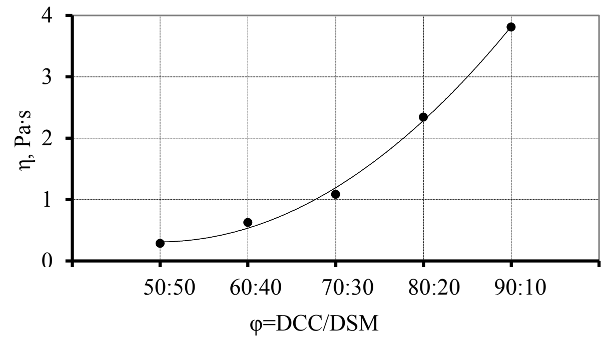

Fig. 3. Apparent viscosity of cheese and milk mixtures depending on DCC to DSM ratio (at a shear rate of $260 \cdot s^{-1}$)

In order to establish rational parameters for obtaining semi-finished products, emulsifying capacity of the systems based on decalcified dairy stock was studied in comparison with the systems based on the cottage cheese made according to the conventional technology (Fig. 4).

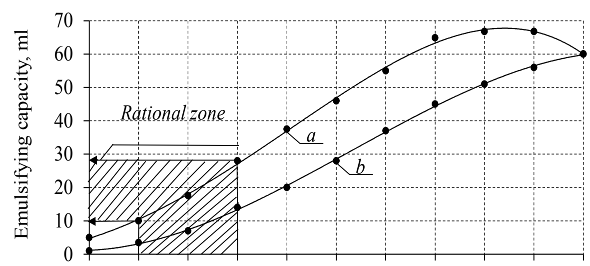

Fig. 4. Emulsifying capacity of cheese and milk mixtures for various ratios of components: decalcified skim milk (*a*); skim milk (*b*)

Table 2

Characteristics of physicochemical properties of cheese and milk mixtures

Indicator name	Indicator value for specimens at ratio (φ) of DCC to DSM					
	100:0	90:10	80:20	70:30	60:40	50:50
pH of the cheese and milk mixture	4.8	4.9	5.1	5.2	5.2	5.3
Mass fraction of whole protein, %	16.0±0.1	14.7±0.1	13.4±0.1	12.1±0.1	10.8±0.1	9.5±0.1
Mass fraction of soluble protein, %	0.5±0.1	0.9±0.1	1.2±0.1	1.4±0.1	1.7±0.1	2.0±0.1

It has been experimentally established that the introduction of decalcified skim milk into cheese resulting in an increase in pH and content of soluble protein leads to an increase in emulsifying capacity of the systems. For example, for the systems containing cottage cheese and decalcified milk at ratios of both 80:20 and 70:30, the point of phase inversion was observed at fat content of 17 ml and 28 ml, respectively.

Indicators of kinetic and aggregate stability of emulsions based on cheese and milk mixtures obtained from decalcified dairy stock presented in the form of stability diagrams in Fig. 5 were studied.

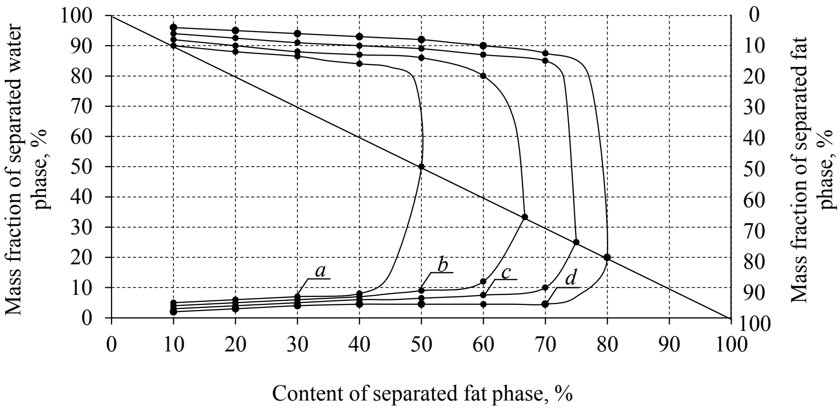

Fig. 5. Diagrams of stability of emulsions based on cheese and milk mixtures depending on fat content in emulsions at ratios of DSS to DSM: 90:10 (*a*); 80:20 (*b*); 70:30 (*c*); 60:40 (*d*)

The need for these studies was determined by the fact that emulsions are thermodynamically unstable systems and sedimentation, flocculation and coalescence of the fat phase may occur in them with time. Analysis of the studies (Fig. 5) allows us to determine the following laws. Firstly, emulsions on the basis of cheese and milk mixtures are characterized by sufficiently high stability (the mass fraction of undamaged emulsion varies within 79–92 %) throughout the entire fat content range. Secondly, the mass fraction of the separated water and fat phases decreases with an increase in the content of DSM in the system. The increase in the content of soluble proteins positively affects both the aggregative and kinetic stability indicators which tend to grow.

It was established that depending on the ratio of DSS to DSM, emulsions are characterized by high values of aggregate and kinetic stability. It is seen from the data in Fig. 5 that fat content in the emulsions at the point of phase inversion is 50 %, 65 %, 75 %, and 80 %, respectively at component ratios of 90:10, 80:20, 70:30 and 60:40.

Proceeding from the results of experimental data which show an increase in emulsifying capacity and stability of systems during increase in the mass fraction of skim milk, it is important to introduce additional restrictions within the framework of creation of semi-finished products. Firstly, given the fact that the semi-finished product is made on the basis of cottage cheese, the mass fraction of the latter should not be less than 70 %. Secondly, introduction of water (in a form of DSM) or fatty phase (sunflower oil) into the cottage cheese will result in a correction of its properties (MRP, viscosity, plasticity) which will affect the finished product. Taking into account the aforementioned, component ratios in a range (90:10) – (70:30) were accepted as rational.

6. Discussion of the results obtained when determining a rational content of components in semi-finished emulsion products

Generalization of analytical and experimental studies has allowed us to determine rational parameters of functioning of the technological system in terms of the receipt composition and individual technological operations (Table 3). According to the study results, a model of a technological system for producing semi-finished products with an emulsion paste-like structure (Fig. 6) was developed.

In the course of technological tests in laboratory and production conditions, rational emulsifying parameters for a 100 kg batch were determined.

Table 3

Rational parameters for obtaining a semi-finished product with an emulsion paste-like structure

Parameter name		Unit	Limit value
Content of cottage cheese		%	65–78
Content of decalcified skim milk		%	16–19
Ratio of cottage cheese to decalcified skim milk			(90:1)–(70:30)
Duration of mixing cottage cheese with skim milk		60 s	5–7
pH of the cheese and milk mixture		–	4.5–5.5
Fat content (deodorized refined sunflower oil)		%	5–20
Emulsifying parameters			
Stage 1	Duration	60 s	7–10
	Work member rotation speed	s^{-1}	1500
Stage 2	Duration	×60 s	2–3
	Work member rotation speed	s^{-1}	3,000

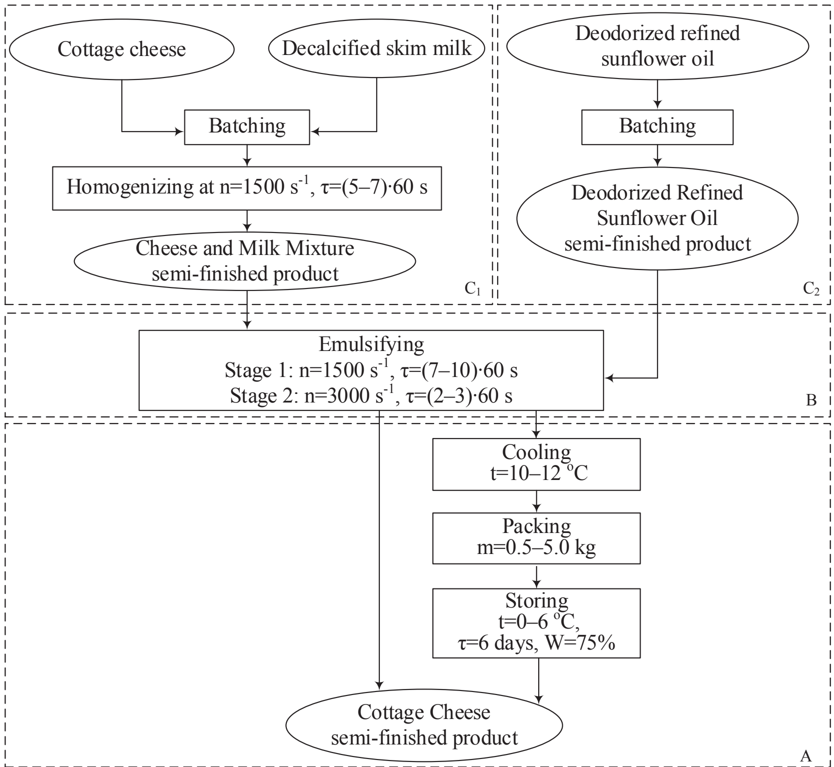

Fig. 6. Model of technological system for the production of semi-finished products with an emulsion paste-like structure

Microstructure (Fig. 7) and the average diameter of fat particles were investigated using the example of an emulsion system with fat content of 10 % (CC to DSM ratio of 80:20).

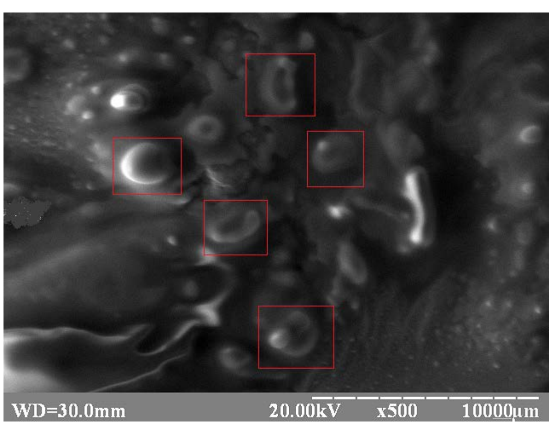

Fig. 7. Microstructure of the cottage cheese semi-finished product

The electron microscopy data confirmed formation of an emulsion structure within which the fraction of fat particles with diameter (0.25–0.45)·10^{-6} m is prevailing.

Generalization of the study results has proved availability and feasibility of using cottage cheese with DSM as the base for emulsion semi-finished products. Since the main protein (casein) in the cottage cheese is in an insoluble form because of coagulation processes, it is evident that its transfer to a soluble state is a prerequisite for the creation of stable emulsion systems based on cottage cheese. The following is fundamentally important in this case:

– the use of DSM as a stock for production of cottage cheese which in the technological flow of food production is capable of demonstrating functional and technological properties: emulsifying, stabilization of heterogeneous systems;

– enhancement of the technological properties of the cottage cheese produced from DSM in a dispersion medium containing a larger mass fraction of soluble proteins (whey proteins, casein);

– regulation of solubility of casein proteins during formation of the cheese and milk mixture. Introduction of DSM to the cottage cheese results in a change in pH (from 4.8 to 5.3) resulting in a transfer to a soluble state of 0.5–2.0 % casein which was in a coagulated state.

The undoubted advantage of the proposed technology is increase in the dairy stock resource potential. In comparison with existing prototypes (introduction of protein concentrates in order to increase the mass fraction of soluble proteins and salts which are food additives), this technology makes it possible to realize functional and technological properties of the dairy stock proteins within the frames of its complex processing.

What is important is elucidation of the prospects of further development of this study in view of creation of an emulsion paste-like structure of the semi-finished product by using vegetable oils (sunflower, corn). Their action consists in regulating nutritional value, in particular, enrichment of semi-finished products (and hence the products based on them) with ω-3-fatty acids, fat-soluble vitamins, creation of new consumer properties through the use of essential oils, CO^2 extracts.

Thus, the conducted studies have allowed us to develop the technology of semi-finished products with an emulsion paste-like structure based on decalcified dairy stocks. Taking into account the organoleptic, physicochemical, structural and mechanical indicators, the semi-finished products can be used in the technology of meals of cottage cheese (cheesecakes, puddings, baked puddings, cheese sauces, decorating and baked semi-finished products for confectionery products).

7. Conclusions

1. Expert estimation of physicochemical parameters of the cottage cheese conducted according to the classical technology was made. It was determined that physicochemical and technological properties of cottage cheese under the conditions of compliance with requirements of current ND differ from each other which affects the technological parameters of production on the basis of this cheese. The above does not make it possible to use such stock in the technology of multi-purpose semi-finished products with an emulsion paste-like structure. This determines the need for using decalcified dairy stock characterized by stable quality indices in the technological cycle.

2. Comprehensive experimental studies have been conducted. They have allowed us to find rational content and the ratio of decalcified dairy and fatty stocks as components of semi-finished products. It has been proved that introduction of decalcified skim milk into the cottage cheese resulting in an increase in pH and content of soluble protein increases emulsifying capacity of the systems. It has been found that for the systems containing cottage cheese and decalcified milk in ratios of 90:10 to 70:30, the phase inversion point occurs in the fat phase from 10 ml to 28 ml, respectively.

3. Rational parameters of production of semi-finished products were determined. It was proved that it is expedient to carry out the emulsification process in two stages with a gradual increase in the number of revolutions from 1500 to 3000 s^{-1} at a fixed processing time (7–10)·60 s at the first stage, and (2–3)·60 s at the second stage. Based on this, a model of the technological system for production of semi-finished products was developed. It ensures making products with an emulsion structure within which the fraction of fat particles with diameters of (0.25–0.45)·10^{-6} m is predominant.

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