Influence of wheat food fiber on the structure formation process of whey-creamy cheeses

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Abstract

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Introduction. Influence research of wheat food fiber (Vitacel WF400) have been carried out in order to rationalize the structure formation process of whey-creamy cheeses.

Materials and Methods. Cheese whey, cream and Vitacel WF400 were the raw materials for the production of whey-creamy cheese. The technological properties of food fiber were determined by the amount of retained fat and adsorbed water, respectively, in the infusion process and suspension centrifugation. The yield value and the water activity in model samples of whey-creamy cheeses, the optimal addition amount of Vitacel WF400 the temperature and the mixing duration of the condensed whey have been determined.

Results and discussion. The water-retaining capacity in cheese whey and fat holding capacity in cream with mass fat fraction 33 were 104.2 ± 1.0 and 82.0 ± 0.5 , respectively. With an increase in the addition amount of Vitacel WF400 (from 1.0 to 4.0) and an increase in the temperature of structure formation (from 62 to 74 °C), the index of yield value increases from 350 ± 1.1 Pa to 430 ± 1.3 Pa. Increasing the temperature to 68 °C, increasing the amount of Vitacel WF400 to 2.5 and reducing the mixing duration to 70 min leads to a decrease in the amount of dispersion medium and the structure coagulation of the samples of whey-creamy cheeses is dehydrated. Model samples of the above products with different amounts of Vitacel WF400 (from 2 to 3) are characterized by a decrease in water activity compared with the control sample. a_w is 0.898 for the control sample.

Upon reaching a dry solids content of 66 and a corresponding decrease in the content of the liquid phase, the index of yield value reaches 427 Pa. The consistency of whey-creamy cheeses samples turns into a plastic pastes state, in which the structure restoration is possible only under the load action, that causes irreversible deformation, which acts on the entire surface area of the phase separation.

With a further temperature increase to 74 °C and a mixing time to 70 min, a further structure compaction occurs – the layers' thickness of the liquid medium decreases, thixotropy and plasticity disappear.

Conclusions. The optimum values of the Vitacel WF400 amount have been justified at the level of 2.5 ± 0.5 , temperature – 68 ± 1 °C and mixing time during structure formation – 70 ± 2 min. Whey-creamy cheeses with the rational addition amounts of food fiber are characterized by a decrease in water activity values from 0.885 to 0.823.

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Introduction

One way to process whey by concentrating proteins is to produce whey cheese. In addition to the most famous ricotta cheese, whey can be used to produce brown cheese, characteristic and famous especially in the Scandinavian countries [1-3].

For example, Brunost is made from a mixture of whey and cream or sour cream (Rømme), Gjetost – from goat whey and Mysost – from a mixture of milk and/or goat whey [4-6].

The production of brown cheese is based on the moisture evaporation from whey or milk mixture at a temperature of 65 ± 1 °C and a pressure of 0.8 MPa to a dry solids weight ratio of 60 ± 2 . After the fat component addition, mass formation occurs up to $73 \pm 2\%$ of dry matter under certain conditions in order to avoid uncontrolled growth of lactose crystals and, as a result, granularity of finished products [2]. The physical-chemical indicators of this product are in the following ranges: moisture mass fraction – 17.4–28.2; fat – 1.9–28.7; ashes – 4.0–4.8; pH – 5.1–5.7 [7, 8]. The above processes correspond to the parameters for obtaining a similar product – whey-creamy cheese [7, 9]. The structure formation process is complex and takes place for 90 minutes under an elevated temperature and a mixing speed of 3–4 r/min and requires additional research. Next, the mixture is sent to cooling, with the simultaneous lactose crystallization, packaging and after-cooling.

The consistency of whey-creamy cheeses is characterized by rheological indicators, of which the yield value of the product is the most sensitive to technological changes.

An indicator of water activity (a_w) is one of the important parameters for determining the storage conditions of whey-creamy cheeses. Whey-creamy cheeses are food products with average moisture, a_w values are from 0.60 to 0.91 [10]. Scientific interest has minimal a_w values that are critical for certain types of microorganisms and limit their growth.

It is relevant to improve the technology of whey cheese using modern ingredients to rationalization processes. Probably, that the addition of such components as food fiber with multifunctional properties in functionally significant amount will contribute to the process of structure formation in the finished product [11, 12].

It is expedient to study Vitacel WF400 with a high moisture and fat-holding capacity for use in the technology of whey-creamy cheeses. The stage of preparation and addition into the milk base of the above food fiber, depending on their expected technological effect, requires clarification. As a result, a change in quality indicators, including rheological ones. The real problem is the lack of an integrated approach to solving the problems identified as part of the review.

The aim of this work is to determine the influence of wheat food fiber on the structure formation process of whey-creamy cheeses.

Materials and methods

Materials

The object of research was the technology of whey-creamy cheese with food fiber – Vitacel.

Cheese whey (CW) had the following physical-chemical indicators: mass fat fraction – (0.2 ± 0.1) , dry solids – (6.30 ± 0.02) , titrated acidity – (18.0 ± 0.1) °T, pH – 5.32 ± 0.02 .

The **cream** had the following physical-chemical indicators: mass fat fraction – (33.0 ± 0.1) , dry solids – (38.00 ± 0.01) , titrated acidity – (17.0 ± 0.1) °T, pH 6.57 ± 0.02 .

Cream is a compound of whey-creamy cheese, added to condensed whey during structure formation, followed by concentration to 70–80 dry solids.

The **control sample** was whey-creamy cheese obtained according to the above technology without food fiber, which had the following sensory parameters: consistency – homogeneous, plastically, soft, slightly fragile; flavor and aroma – pure milk with a pronounced caramelization flavor, salty; color – light brown, uniform throughout the mass. Physical-chemical indicators: mass solids fraction – 73 ± 2 , mass lactose fraction – 48.0 ± 1.5 , pH – 5.1 ± 0.1 .

For research, model samples of whey-creamy cheese were made with the Vitacel addition in an amount of 1.0 to 4.0 [11].

Food fiber Vitacel WF400 (manufactured by J. Rettenmaier Sohne GmbH, Germany) has the following technological properties: water-holding capacity and fat absorption (per 1 g of product) – 11 g and 6 g, respectively. Water activity is fixed at 0.44, and pH is (6.5 ± 1.5). The bulk mass of Vitacel is 40 ± 2.5 g/dm³. Average sizes of 90 fiber particles <300 μm. The total amount of food fiber is (98.0 ± 0.5), including cellulose – (72.0 ± 2.0), hemicellulose – (25.5 ± 1.5), lignin – 0.5 ± 0.1 . For food fiber, the indicated chemical indicators are follows: mass fat fraction – (0.2 ± 0.02), protein – (0.4 ± 0.06), moisture, not more than 8, ash, not more than 3. According to the manufacturer, Vitacel WF400 has the following microbiological indicators: QMAFAnM (CFO in 0.1 g) – 5×10^4 , mold (CFO in 0.1 g) – not more than 50, pesticides and fungicides – < 0.002 mg/kg. Pathogenic microorganisms (salmonella), in 25 g of FF, aflatoxins, Coliform bacterias in 0.1 g were not found. The energy value in 100 g of Vitacel WF400 is 0.09 kcal [13].

Methods

Fat-holding and water-retaining capacities of Vitacel WF400. At the first stage of experimental research, the water-retaining (WRC) and the fat-holding (FHC) capacities of food fiber have been investigated.

Fat-holding and water-retaining capacities of Vitacel WF400 were determined by the amount of retained fat and adsorbed water, respectively, in the infusion process and suspension centrifugation. The process was carried out at a temperature of 20 °C in cream and whey.

Fat-holding capacity was calculated by the formula, in:

$$\text{FHC} = (c - a) \cdot 100 / m \quad (1)$$

where a – is the supernatant mass, g

c – is the mass of added liquid, g

m – is the sample mass, g [14].

The method for determining WRC of food fiber is similar to FHC, but the process takes place in cheese whey.

Obtaining process of whey-creamy cheeses. The condensation process of whey was carried out to a mass solids fraction in the mixture – (60 ± 2), in a laboratory setup in which the vacuum evaporation conditions in circulating-type apparatuses were simulated.

The structure formation process was carried out at a temperature of 65.0–70.0 °C in a container with mechanical mixing of condensed whey and cream with mass fat fraction (33 ± 1) in the amount of (10 ± 0.3). The mixing speed was 3–4 r/min, hold time – 90 ± 1 min. Whey-creamy cheese was cooled at a rate of 14–16 °C/h to a temperature of 20 °C for 3–4

hours and packaged in hermetic container.

Then the whey-creamy cheese was kept for 12 hours at a temperature of 14–16 °C. In this case, the structure formation process occurs due to the growth of lactose crystals, fat and the swelling of whey proteins. Next, the finished product was stored at a temperature of 2–6 °C and changes in quality indicators were analyzed.

Yield value of model whey-creamy cheese samples. The yield value of model whey-creamy cheese samples was determined on Ulab 3-31 M penetrometer (5 s exposure time, in identical containers using measuring cone with apex angle of $2\alpha = 60^\circ$).

The principle of the penetrometer operation is based on measuring the depth of the needle (cone) immersion in the sample at a certain test temperature and load for a certain time. The value is fixed in penetration units.

Sample preparation is carried out as follows: container filling with a pallet; prepressing for 180 s; thermostat control by temperature control device to the set temperature; device preparation for measurements: put a predetermined indenter and install an additional load; taking penetration measurements using a conical indenter with an angle of 60° at the apex.

Data experimental computing was carried out as follows:

1. Calculate the average value of the maximum immersion depth of the indenter in the product according to the formula:

$$h_{cp} = (h_1 + h_2 + h_3)/3, \text{ m} \quad (2)$$

2. Determine the error in investigation the value of h:

$$\Delta_h = [(h_{cp} - h_i)/h_{cp}] \cdot 100, \% \quad (3)$$

3. Calculate the yield value taking into account the proportionality coefficients:

$$\theta = k_a \frac{F}{h_{cp}^2} \quad (4)$$

Determine the optimal amount of Vitacel WF400 food fiber. To determine the optimal amount of Vitacel WF400 food fiber, modeling method based on Wilson-Box plan was used [9].

The temperature and the mixing duration of the condensed whey with dry solids weight ratio 60 ± 2 during structure formation in the technology of whey-creamy cheese, the mathematical modeling method was applied using the Wilson-Box plan on a cube. The method is specific samples from a complete factorial experiment of type $3k$, where k – is the factors number, 3 – is the levels number at which each variable varies. These plans do not have simple generators and have a complex interrelationship. However, they allow to carry out research with the least of time and resources expenditure.

Experiment planning matrix. In the preparation of the test samples, the amount of Vitacel food fiber (X_3), the temperature of structure formation (X_2), and the mixing duration (X_1) during structure formation were varied according to experiment plan presented in Table 1. Factor variation levels are given in Table 2.

Table 1

Experiment planning matrix by the Wilson-Box method on the cube

N	Independent variables (coded values)						Yield value, Pa (Y ₁)
	Mixing duration, min (X ₁)		Temperature of structure formation, °C (X ₂)		Vitacel amount, (X ₃)		
1	+	90	+	74	+	4	430,00
2	-	50	+	74	+	4	410,00
3	+	90	-	62	+	4	420,00
4	-	50	-	62	+	4	390,00
5	+	90	+	74	-	1	400,00
6	-	50	+	74	-	1	390,00
7	+	90	-	62	-	1	380,00
8	-	50	-	62	-	1	370,00
9	+	90	0	68	0	2,5	400,75
10	-	50	0	68	0	2,5	390,00
11	0	70	+	74	0	2,5	400,75
12	0	70	-	62	0	2,5	390,00
13	0	70	0	68	+	4	400,00
14	0	70	0	68	-	1	350,00
15	0	70	0	68	0	2,5	370,50

Table 2

Factor variation levels

Factor	Designation	Units measure	Factor variation levels		
			upper	zero	lower
			+	0	-
Mixing duration (τ)	X ₁	XB	90	70	50
Temperature of structure formation (t)	X ₂	°C	74	68	62
Vitacel WF400 amount (v)	X ₃	%	4	2,5	1

According to the research results, the regression equation coefficients were calculated, the significance analysis of which was determined by the Fisher criterion (Fp). The criterion essence is the decomposition of total dispersion of statistical complex into its constituent elements. Their next assessment makes it possible to determine the change proportion of the effective sign from the factor signs action, that is, to narrow the research scope. This confirms the adequacy of the obtained equations. To determine the functional dependence, which most accurately reproduces the change in indicators, an approximation confidence coefficient (R₂) of each function was found [9]. The results accuracy is ensured by three-five times repeatability of the experiments.

Water activity of model whey-creamy cheese samples

Determination of water activity of model whey-creamy cheese samples (control sample) and with food fiber was carried out on a Rotronic instrument modified by Hygro Palm AW (manufacturer Rotronic AG (Switzerland)). The measurement range is as follows: 0–1 a_w , sample temperature 5–50 °C, accuracy $\pm 0.01 a_w$, ± 0.1 °C. The water activity analyzer consists of an instrument unit, HC2-AW station, a case for transportation and storage, calibration solutions, plastic cups for samples. The operation principle of the analyzer is to use a dielectric moisture sensor to determine the water activity. Between the two porous electrodes of sealed chamber, a porous polymer is placed. The electrical properties of the polymer vary with the relative moisture in the chamber. The electrodes give a signal based on relative moisture in a closed chamber. This signal is converted by software and displayed on the screen as a value of water activity. The measurement cycle lasts from 3 to 5 minutes. In balanced state the relative moisture in the chamber is equal to the water activity in the test sample. The value of water activity is determined to the third decimal place [13].

Results and discussion

Rational addition amount of Vitacel WF400 to whey-creamy cheeses

Water-retaining capacity of Vitacel WF400 in cheese whey and fat holding capacity in cream with mass fat fraction 33% have been determined, which were 104.2 ± 1.0 and 82.0 ± 0.5 , respectively.

In order to reduce the technological cycle (process) duration of structure formation according to the classical technology, it is 90 min, and obtaining whey-creamy cheese of appropriate quality with FF, experimental data were processed. In addition, it is necessary to prevent the dissolution of the formed lactose crystals in the finished product, to ensure the required quality.

The process of lactose crystallization in the whey-creamy cheese production is carried out during the operation of structure formation. In this case, the crystals size and number can be regulated using several technological methods [15]: supersaturation degree of the aqueous lactose solution, cooling rate, mechanical mixing, seed addition [2, 16].

The optimal addition amount of Vitacel WF400 in whey-creamy cheeses has been found, which ensures the maximum realization of the technological potential of food fiber to obtain a product with quality indicators as closely to control sample as possible.

The determination of yield value at the penetrometer confirms the effect of Vitacel WF400 on the rheological parameters of whey-creamy cheeses with FF. The restrictive factor for adding the maximum amount of wheat fiber is the over-compaction of finished product.

The graphs (response surfaces) illustrating the influence of the Vitacel WF400 amount, the temperature of structure formation and the mixing duration on the index of yield value of the product are presented in Figure 1.

$$\Theta = 434,97 - 1,01\tau - 60,33t + 0,08\tau^2 - 0,06\tau t + 0,45t^2;$$

$$R^2 = 0,98$$

$$90 \leq \tau \leq 50$$

$$74 \leq t \leq 62$$

a

$$\Theta = 432,29 - 4,79\tau + 23,45v + 0,13\tau^2 + 0,12\tau v - 4,31v^2$$

$$R^2 = 0,97$$

$$90 \leq \tau \leq 50$$

$$4 \leq v \leq 1$$

b

Figure 1. Response surfaces and mathematical models of the influence on the index of yield value of whey-creamy cheeses from:
a – the mixing duration and the temperature of structure formation;
b – the Vitacel WF400 amount and the mixing duration;
c – the Vitacel WF400 amount and the temperature of structure formation

c

Figure 1 (Continue). Response surfaces and mathematical models of the influence on the index of yield value of whey-creamy cheeses from:

a – the mixing duration and the temperature of structure formation;

b – the Vitacel WF400 amount and the mixing duration;

c – the Vitacel WF400 amount and the temperature of structure formation

According to the visualized data, with an increase in the addition amount of Vitacel WF400 (from 1.0 to 4.0) and an increase in the temperature of structure formation (from 62 to 74 °C), the index of yield value increases from 350±1.1 Pa to 430±1.3 Pa. The experimental data correlate with the corresponding quality indicators for whey-cream cheeses without food fiber, obtained by the classical technology [2, 7].

The Vitacel WF400 addition promotes the new bonds formation in the structure of whey-creamy cheese. It is a multicomponent system, the basis of which consists of interwoven chains of unfolded denatured whey protein molecules. This net covers and deprives the fluidity system and holds the lactose crystals in a suspended state, which prevents their sedimentation [17]. Water molecules and other components of the concentrate are somehow connected with the skeleton [18].

The dependence of the yield value from the addition amount of Vitacel WF400 in whey-creamy cheeses obtained at a formation temperature of 62, 68 and 74 °C and the mixing duration for 50, 70 and 90 minutes has been established. It has proved that the above indicator increases to 430±1.3 Pa with an increase all variable factors and is inversely related to the

penetration degree. An increase in the FF amount from 3.5 to 4.0 almost does not change the yield value, but leads to a deterioration in the sensory characteristics of the finished product.

Influence of temperature and duration of structure formation process on the consistency of whey-creamy cheeses

At the beginning of structure formation, the coagulation structure prevails in all samples due to the Van-der-waals adhesive power between colloidal particles and dispersed phase molecules – dry solids (proteins, fats, carbohydrates) of whey-creamy cheeses through moisture layers of the dispersion medium – whey [19]. In this case, the mat thickness corresponds to the minimum free energy of the system. This cheese structure keeps stable as long as the the molecules fragments are firmly bound to the particles surface of the dispersed phase and are able to dissolving without bond loss with them in the dispersion medium [20]. At this stage of the process, the coagulation structure of whey-creamy cheeses is able to thixotropy [21]. The Vitacel WF400 addition change the structural and mechanical characteristics of whey-creamy cheeses.

The temperature raising to 68 °C, increasing the Vitacel WF400 amount to 2.5 and reducing the mixing time to 70 min leads to a decrease in the amount of dispersion medium (free moisture in whey). The coagulation structure of cheese samples is dehydrated – their strength increases, and after a certain limit they stop to be reverse-thixotropic. Samples in this state acquire a visco-plastic structure. Independent structure reconstruction in them is preserved, while the spatial skeleton is destroyed without violating the integrity [22].

Upon reaching a dry solids content of 66 and a corresponding decrease in the content of the liquid phase, the index of yield value reaches 427 Pa. The consistency of whey-creamy cheeses samples turns into a plastic pastes state, in which the structure restoration is possible only under the load action, that causes irreversible deformation, which acts on the entire surface area of the phase separation [2].

With a further temperature increase to 74 °C and a mixing time to 70 min, a further structure compaction occurs – the layers' thickness of the liquid medium decreases, thixotropy and plasticity disappear [20, 21].

Further process continuation of structure formation to 90 min leads to biochemical phase transformations of dry solids in whey-creamy cheeses by agglomeration or growing together. The samples' structure acquires a relatively high strength, elasticity and fragility, which is not characteristic for the consistency of such products [22].

So, whey-creamy cheeses are among systems with a viscous-plastic consistency with a controlled yield value. Probably, the indicator change is associated with the technological abilities of wheat fiber for water retention and fat absorption.

Regression analysis of the experimental data carried out in the Statistica 10.0 program made it possible to obtain analytical dependences which reflect the factors influence on the response function in the form of a polynomial equation of the second degree.

Coefficient values of the polynomial equations are presented in Figure 1. Coefficients in which $p < 0.05$ are significant, namely are not equal to zero with a probability of more than 95%. High values of the determination coefficients (R^2) confirm the adequacy of models with experimental data.

It has been established that it is possible to obtain whey-creamy cheeses with the same value of yield value at different temperatures and mixing duration. However, the process prolongation to 90 min at a lower temperature of 62 °C is irrational and energy-consuming. The Vitacel WF400 addition in an amount of 2-3 sufficiently intensifies the process of structure formation. The obtained mathematical model allows to control the structure

rheological parameters depending on the temperature of structure formation and the mixing duration.

Analysis of the obtained dependencies allows to justify the optimal values of Vitacel WF400 amount (X_1) – 2–3, the temperature (X_2) at 68 ± 1 °C, and the mixing duration (X_3) during structure formation – 70 ± 2 min.

The obtained regression equations (mathematical models) can be used in practical purposes for the operational management of the structure formation process by combination of condensed milk whey, cream and food fiber with further concentration.

Determination of water activity in whey-creamy cheeses with Vitacel WF400

The determining results of the water activity in whey-creamy cheeses with different Vitacel WF400 amounts are presented in Figure 2.

Figure 2. Water activity of whey-creamy cheeses with different Vitacel WF400

Data analysis (Figure 2) showed that whey-creamy cheeses with different amounts (from 2 to 3) of Vitacel WF400 are characterized by a decrease in water activity compared with the control sample. This is due to the technology ability of the water-retaining capacity and fat absorption by food fiber. The index a_w ranged from 0.885 to 0.823 in all samples of whey-creamy cheeses with FF. For the control sample, a_w is 0.898. Microorganism growth and hydrolytic chemical reactions will be somewhat slowed down at such values.

An analysis of priori information [23, 24] and the obtained results allow to suggest that food fiber addition in the above amounts in the structure formation process leads to decrease of water activity rate in whey-creamy cheeses. This confirms its transition from free to bound state.

By determining the water activity (a_w) it is possible to confirm the Vitacel WF400 effect on the storage parameters of whey-creamy cheeses with food fiber at standard temperatures 2–6 °C.

A limitation for the practical realization of research results is the reconcilability of food fiber with a milk base at the sensory level.

The prospects for further research are related to the selection of other vegetable components with similar properties for solving technological problems in the whey-creamy cheese production.

Conclusions

1. Vitacel WF400 effect, which has a complex of technological properties, on the rationalization of structure formation process in whey-cream cheeses with food fiber has been confirmed. The optimum values of the Vitacel WF400 amount have been justified at the level of 2.5 ± 0.5 , temperature – 68 ± 1 °C and mixing time during structure formation – 70 ± 2 min.
2. Data reduction process allows to obtain analytical correspondence in the form of regression equations to calculate the amount effect of the Vitafel WF400, the temperature of structure formation, and the mixing duration on the yield value.
3. Whey-creamy cheeses with the Vitacel WF400 addition $2.5 \pm 0.5\%$ are characterized by a_w (from 0.885 to 0.823), which provides growth inhibition of vegetative bacteria forms, partly yeast and creates unfavorable conditions for the development of spore forms of bacteria and mold fungi.

References

1. Zadow J.G. (2012), *Whey and Lactose Processing*, Springer Science & Business Media, DOI: 10.1002/9781118810279.ch15.
2. Hramcov A.G. (2011), *Fenomen molochnoj syvorotki*, Professija, Sankt-Peterburg.
3. Hramcov A.G. (2012), Ispolzovanie molochnoj syvorotki v produktah funkcionalnogo pitaniia, *Pererabotka moloka*, 7 (153), pp. 50–53.
4. Fox P.F., Guinee T.P., Cogan T.M., McSweeney P.L.H. (2017), *Fundamentals of Cheese Science*, Boston Springer, Boston.
5. Karpova D.A. (2017), Proizvodstvo grupy norvezhskih syvorotochnyh syrov tipa Brjunost kak sposob pererabotki molochnoj syvorotki, *Aktualnye voprosy sovershenstvovanija tehnologii proizvodstva i pererabotki produkcii sel'skogo hozjajstva*, 19, pp. 165–166.
6. Honcharenko I.V., Ahii V.M (2019), Bazova tekhnolohiia vyhotovlennia deiakykh vydiv albuminovykh syriv, *Tavriiskyi naukovyi visnyk*, 107, pp. 205–208, DOI: 10.32851/2226-0099.2019.107.28.
7. Skeie S, Abrahamsen R. (2017), Brown Whey Cheese, *Cheese*, 2, pp.1117–1132, DOI: 10.1016/B978-0-12-417012-4.00045-4.
8. Hramcov A.G., Kubanskaja D.M., Sujunchev O.A. (2006), Kompleksnye sistemy syvorotochnogo syra «Laktochiz», *Syrodellie i maslodellie*, 6, pp. 20–21.
9. Grek O., Onopriychuk O., Tymchuk A. (2015), Optimization of the composition of the mixture by simplex method, *Ukrainian Food Journal*, 4 (1), pp. 15–25.

10. Barbosa-Cánovas V.G., Fontana J.A., Schmidt J.S., Labuza P.T. (2007), *Water Activity in Foods: Fundamentals and Applications*, Blackwell and the Institute of Food Technologists, Oxford, DOI:10.1002/9780470376454.
11. Grek O., Tymchuk A., Tsygankov S., Savchenko O., Ovsiienko K., Ochkolys O. (2019), Study of dietary fiber properties in dairy mixes containing modified fat compositions, *Eastern-European Journal of Enterprise Technologies*, 4, pp. 6-13, DOI: 10.15587/1729-4061.2019.174302.
12. Pryanishnikov, V.V. (2006). «Pischevyye volokna «Vitacel» v myasnoy otrasli, *Myasnaya industriya*, 9, pp. 43–45.
13. Grek O., Tsygankov S., Tymchuk A., Onopriichuk O., Savchenko O., Ochkolys O. (2019), Research of recipe components influence on the properties of dairy-protein mashes for semi-finished products, *Eastern-European Journal of Enterprise Technologies*, 6/11 (102), pp. 41–48, DOI: 10.15587/1729-4061.2019.183549.
14. Dubrovskaja N.O., Nilova L.P. (2010), *Sovremennye problemy pishhevoj cennosti i kachestva hlebobulochnykh izdelij i vozmozhnye puti ih resheniya*, Michurinskij agrouniversitet, Michurinsk.
15. Hramcov A.G., Pavlov V.A., Nesterenko P.G., Holodov G.I., Evdokimov I.A., Lodygin D.N. (1989), *Pererabotka i ispol'zovanie molochnoj syvorotki*, Rosagropromizdat, Moscow.
16. Zolotoreva M.S., Evdokimov I.A., Volodin D.N., Somov V.S. (2013), Analiz pererabotki molochnoj syvorotki i sozdanie perspektivnykh resursoberegajushhih tehnologij, *Nauka. Innovacii. Tehnologii*, 1, pp. 37–44.
17. McSweeney P., O'Mahony J. (2016), *Advanced Dairy Chemistry. Volume 1B, Proteins : applied aspects*, Springer, New York, DOI: 10.1007/978-1-4939-2800-2.
18. Evdokimov N.S., Petrova L.V. (2012), Fiziko-himicheskie processy pri strukturirovanii koncentrata molochnoj syvorotki, *Dinamika sistem, mehanizmov i mashin*, 5, pp. 111–114.
19. Hiroyuki O. (2016), Van Der Waals Interaction Between Colloidal Particles, *Encyclopedia of Biocolloid and Biointerface Science*, 2, pp. 1087–1094, DOI: 10.1002/9781119075691.ch88.
20. Lamichhane P., Kelly A., Sheehan J. (2018), Structure-function relationships in cheese, *Journal of Dairy Science*, 101 (3), pp. 2692–2709, DOI: 10.3168/jds.2017-13386.
21. Fox P.F., Guinee T.P., Cogan T.M., McSweeney P.L.H. (2017), *Fundamentals of Cheese Science*, Springer, Boston, DOI: 10.1007/978-1-4899-7681-9_14.
22. Everett D., Auty M. (2008), Cheese structure and current methods of analysis, *International Dairy Journal*, 18(7), 759–773.
23. Sukmanov V. A., Sklyarenko E. V. (2012), *Issledovanie aktivnosti vody v svezhih myagkih syrakh*, Naukovi pratsi Odeskoï natsionalnoi akademii kharchovykh tekhnolohii, 41(1), 18–22.
24. Barbosa-Cánovas G., Fontana Jr. A., Schmidt S., Labuza T. (2007), *Water Activity in Foods: Fundamentals and Applications*, Blackwell Publishing and the Institute of Food Technologists, Iowa, DOI:10.1002/9780470376454.