UDC 664.9.022: 637.344.6
DOI: 10.15587/1729-4061.2019.174302

STUDY OF DIETARY FIBER PROPERTIES IN DAIRY MIXES CONTAINING MODIFIED FAT COMPOSITIONS

O. Grek
PhD, Associate Professor*
E-mail: grek.nupt@gmail.com
A. Tymchuk
PhD, Associate Professor*
E-mail: 589112@ukr.net
S. Tsygankov
Doctor of Technical Sciences, Senior Researcher
Institute of Food Biotechnology and Genomics of National Academy of Sciences of Ukraine
Osypovskoho str., 2A, Kyiv, Ukraine, 04123
E-mail: tsygankov.iht@gmail.com
O. Savchenko
PhD, Associate Professor**
E-mail: 63savchenko@gmail.com
K. Ovsiienko
Postgraduate student*
E-mail: kvovsiienko@gmail.com
O. Ochkolyas
Assistant**
E-mail: lenokochkolyas@gmail.com
*Department of Technology Milk and Dairy Products
National University of Food Technologies
Volodymyrska str., 68, Kyiv, Ukraine, 01601
**Department of Technologies of Meat, Fish and Marine Products
National University of Life and Environmental Sciences of Ukraine
Heroiv Oborony str., 15, Kyiv, Ukraine, 03041

Представлено дослідження властивостей харчових волокон різного ступеня оброблення в молочних сумішах з модифікованим жировим складом для запобігання витікання молочного жиру.

Встановлено технологічні характеристики пшеничних харчових волокон Вітацель, борошна пшеничного екструдованого та шроту з плодів шипшини, а саме здатність до волого– та жиропоглинання і та набухання. Найвище значення жиропоглинальної здатності було визначено для харчових волокон Віцеталь на рівні (59,0±0,5 %). Визначено оптимальні параметри набухання рослинних інгредієнтів: температура – (40±2) °С, тривалість – 30…40 хв.

Методом ІЧ-спектроскопії ідентифіковано та порівняно форми зв'язку вологи в сумішах харчових волокон з водою та маслянкою. Встановлено, що спектри пропускання Іч-променів для дослідних зразків мають однотипний характер. Це свідчить про утворення Н-зв'язаних поліасоціатів води з гідрофільними функціональними групами дисперсної системи, за рахунок яких відбувається гідратація та набухання вуглеводів харчових волокон.

За показниками термостійкості та витікання рідкого жиру встановлено раціональну кількість харчових волокон в сумішах з максимально можливою (до 25 %) заміною вершкового масла на олію з плодів шипшини. Для зразків, що містять Вітацель у кількості 0,3 % та шрот з шипшини – 2,0 %, ступінь витікання жиру зафіксована на рівні 19,1 %. Достатньо низький цей показник є результатом взаємодії харчових волокон різного ступеня оброблення з водною та жировою фазами молочних сумішей. Заміна частини молочного жиру оліями у виробництві продуктів модифікованого жирового складу призводить до зміни консистенції та зниження стійкості в процесі маслоутворення і диспергуванням вологи в готовому продукті. Додавання харчових волокон, як технологічних інгредієнтів, забезпечує необхідну консистенцію сумішей з модифікованим жировим складом

Ключові слова: суміші, харчові волокна, олія та шрот з шипшини, волого– та жироутримувальна здатності

Received date 31.05.2019
Accepted date 01.08.2019
Published date 09.08.2019

1. Introduction

Dairy products with the modified fat composition are indispensable in the rations of nutrition of people in many countries. Extending the product range makes it possible to increase the degree and integrity in the application of fats of different origin as raw materials and to provide consumers with products with the balanced fatty acid and vitamin content and reduced cholesterol [1].

It is a relevant task to improve the qualitative indicators for products with the modified composition by devising the formulations of fatty mixtures made exclusively from milk fat (in the form of butter or cream) and oils without the use of substitutes for milk fat. Oils are the source not only of polyunsaturated fatty acids, but also natural antioxidants, they do not contain trans-isomers [2]. It is also possible to enrich such products with plant-derived ingredients with multifunctional properties in the functionally substantiated quantities. Typically, the effectiveness of such components is correlated with the amount and the application technique. Therefore, special attention must be paid to the issue of the preparation of plant-based ingredients to their uniform distribution throughout a raw material. To this end, it is necessary to assess the structural condition of all components, to choose a stage in the technological process, modes and amount of application. To consider a commercial form of the drug (in the form of a solution, emulsion, dry powder, granules), the content of substances (an immobilized drug on a carrier, a composition, concentrate) and technological properties (fat- and water-retaining capabilities, swelling in various environments), etc.

Replacing a part of milk fat with oils in the manufacture of products with the modified fat composition changes the consistency of a resulting product. The differences in the nature of fats are associated with a change in the process of joint crystallization when exposed to a thermomechanical influence, which manifests itself in the structural indicators [3]. As regards the MFC products with a lower fat content, there is an additional issue related to stability in the process of butter-formation and the dispersion of moisture, as well as a possible reduction of plasticity, the outflow of liquid fat from a monolith, or the occurrence of excessive hardness [4, 5].

Compliance with high quality indicators for products is achieved by using a variety of stabilizers, emulsifiers, etc. [6, 7], which leads to additional costs of production. Such ingredients perform a certain technological function but they do not enrich a product.

In this regard, it is relevant not only to extend a product range but to improve the technology of products with the modified fat composition with fillers. This can be achieved by introducing components of plant origin with multifunctional properties – extrudates and dietary fiber [8].

It is expedient to study formulation components – the products from rosehip processing – in the form of oil and meal. The integrated use of such ingredients could probably maximally provide ready products with specific consumer and qualitative properties.

There is a practice of using dietary fiber (DF) that has the moisture-retaining capability to increase viscosity in dairy products [9]. It is relevant, for the stabilization of consistency of milk mixtures with the modified fat composition (MFC), to select, and study in detail, DF with a high fat-retaining capability.

In order to substantiate the technologies of MFC dairy mixtures with food fibers, it is necessary to solve several tasks. It is required to select plant-based ingredients specially treated to ensure and/or execute technological functions (including fat-retention). Priority task is to define the maximally possible content of oils in the MFC products, which would not degrade the consistency of a resulting product and would not lead to the outflow of liquid fat.

2. Literature review and problem statement

Papers [1, 10] provide information about the structure and approaches to developing technologies for products with the modified fat composition (mainly spreads). The formulations may include butter, milk fat substitutes, buttermilk, skimmed milk restored in water, etc. Their production utilizes a variety of oils, fats and their compositions, which are selected considering their quality indicators, cost and affordability [11].

An important criterion of the MFC dairy products quality is the capability to retain over a long time the fine-crystalline structure and a homogeneous plastic consistency in a wide temperature range. To obtain such properties, a product must possess a fat base, which contains a wide range of triglycerides. That can be achieved by optimizing the ratio of fats – milk and plant-based [7].

There is a problem related to the economical and affordable raw materials for the components of dairy products, associated with the lack of scientifically-grounded recommendations on their use. There is a need foir their partial or complete replacement with domestic raw materials of plant origin with varying degrees of treatment.

One option to improve the chemical composition and consistency of MFC products is the introduction of technological ingredients. Such an approach was used in work [12] to promote an increase in food value by applying vegetable fats, proteins, carbohydrates, which are easily absorbed, dietary fiber, vitamins, minerals, etc. Most experts on nutrition think that the diet of an adult must contain not less than 30...40 g of DF [13].

There is technology to make spread for children, whose formulations, in addition to butter, includes corn and sunflower oils in the amount of 10 % [14]. There are data on that enhancing the content of oils leads to the emergence of a shortcoming – the outflow of fat from a monolith [15].

Adding oil is carried out to adjust the quality indicators for a fatty mixture as the base for products with the modified fat composition (such as reducing the content of trans-isomers).

It is advisable in the dairy industry to use the oil and DF derived from perennial plants that have enough resources and opportunities for integrated application [16].

Thus, rosehip oil contains saturated fatty acids, vitamins C and A and tocopherols, carotenoids, micro elements – manganese, copper, strontium, molybdenum, as well as macro elements – iron, magnesium, potassium, calcium, phosphorus [17]. Such a composition provides the possibility of using oils in spreads on the type for children. Substantial coloring, pink, which when combined with the creamy butter changes the composition's color, is an advantage for use in compositions. For the prevention of defects, additional research needs to address determining the maximum amount of oil (over 10 %) when introducing technological ingredients with an elevated fat-retaining capability – specially treated DF.

Rosehip (*Rosa canina L.*) is also a source of DF, whose fruits are widely used for the production of medicines and special foods.

Meal from *Rosa canina L.* is obtained when extracting oil from the fruits of rosehip by pressing or in other ways [18].

The content of flavonoids (recalculated for rutin) in rosehip meal is 380 mg/100 g. Flavonoids are represented by aglycone flavonols in the form of quercetin (1.3...11.5 mg/100 g) and kaempferol (0.3...6.5 mg/100 g). In addition, by flavonol glycosides – rutin (3...4.9 mg/100 g) and hyperoside (1...3 mg/100 g), catechins in the amount of (58...78 mg/100 g) [19]. The mineral composition of rosehip meal demonstrated a high content of potassium and negligible – of sodium and magnesium.

The functional and technological properties of the above-specified DF include fat- and moisture-retaining capability, solubility of various degree, the earlier specified compatibility with raw milk at the level of an organoleptic assessment, the appropriate rheological characteristics [20]. It is the fat-retaining capability of some DF that underwent special treatment that may be considered, when combined with a modified fat mixture, as a barrier to the emergence of the defect – the outflow of liquid fat.

Vitacel is a natural plant-based product produced from the vegetative part of wheat, which has high fat- and moisture-retaining properties. Such dietary fiber is widely used in the meat industry in order to stabilize systems [21].

Considering the above, one can predict that it would be promising to apply Vitacel WF400 for the production of dairy products with the modified fat composition, specifically, spreads, to bind oil and for enrichment.

Additional research is needed into the stage of preparation and introduction to a dairy base (including that with an elevated content of fat) of DF, depending on their technological capabilities (a fat-retaining agent and/or enricher).

It is important to take into consideration the sorption properties of plant polysaccharide complexes when studying the mechanism of their interaction with moisture (buttermilk and water), which is a formulation component of products. The sorption of moisture by DF should be considered as the absorption of a polar sorbate, water, by a polymeric adsorbent, with a change in the structure and properties of the polymer. In this connection, it is advisable to establish the effect of temperature on the moisture sorption process by dietary fibers (meal from the fruit of *Rosa canina L.*, extruded wheat flour (EWF), and Vitacel). The swelling process depends on the type of a raw material, the degree of dispersion, the type and concentration of a solvent, temperature, and other parameters [9, 22]. There is a need for additional study into the state of moisture and fat in mixtures with MFC when adding DF.

The relationship between moisture and the present components of mixtures defines stability of products during storage, which is one of the most important indicators of quality. Total moisture content indicates the amount of moisture, but does not characterize its relationship to the chemical, biochemical, and microbiological changes in a product. When ensuring stability at storage, an important role belongs to the ratio of free to bound moisture. Positive effect can be probably achieved by adding DF that possess moisture and fat-retaining capability. Such a statement requires additional research on specific MFC mixtures.

The main processes in the transformation of a milk-fat dispersion is the crystallization of glycerides, which proceeds first in fat globules and then in the molten fat by reversing the phases and structuring the product. These are the interrelated processes, which over short intervals ensure certain rheological characteristics of spreads. It is known that the mechanical properties of solid bodies are predetermined by their crystalline structure and adhesion due to the action of van der Waals forces. In this case, there forms a coagulating structure through the thin layers of a dispersed environment, which defines their low strength, ductility, and a specific property – thixotropy, that is the ability to self-recuperate. The thinner the layer of a liquid medium (a possible positive effect of DF with a moisture-retaining capability), the greater the molecular interaction forces and the stronger the structure. Therefore, when developing formulations for products with the modified fat composition, it is necessary to take into consideration the ratio between the solid and liquid phases, the dispersion of crystalline fat, the nature of relationship between the dispersed particles. Respective dependences are an indicator for the formation of stable plastic properties [10, 15, 23].

Important physical and chemical indicators for fats of different origin, which are used in the manufacture of products with MFC, is the melting point, the hardness and content of a solid phase [24].

An actual problem is the lack of a comprehensive approach to solving the tasks defined in the framework of this review. Therefore, it is appropriate to study the functional and technological properties of various DF in the form of meal from the fruits of *Rosa canina L.*, EWF, and specially treated with DF Vitacel. The base is mixtures with the modified fat composition with a maximally possible replacement of milk fat with oil without compromising the required consistency.

3. The aim and objectives of the study

The aim of this work is to study the properties of dietary fibers of different origin (wheat, rosehip) and degree of treatment in dairy mixtures with the modified fat composition in order to prevent the occurrence of defects in the consistency of a product.

To accomplish the aim, the following tasks have been set:

– to explore the technological properties of dietary fibers for use as components of products;

– to establish the forms of moisture bonds in mixtures with dietary fibers;

– to determine the maximally possible replacement of butter with oil in mixtures with dietary fibers.

4. Materials and methods to study dietary fiber in dairy mixtures with the modified fat composition

It is implied that a variety of mixtures with the modified fat composition should be added with butter, a mass fraction of fat of 73 %, oil, and meal from the fruits of *Rosa canina L.*, the dietary fiber Vitacel, extruded wheat flour, and buttermilk.

The oil *Rosa canina L.* was produced according to TU U 15.8-32062796-001:2007 [25].

Meal from the fruits of *Rosa canina L.* is used in rations at diets as an additional source of DF and carotenoids, vitamins, pectin, organic acids, flavonoids [17].

Vitacel WF400 (made by J. Rettenmaier Sohne GmbH, Germany) is the dietary fibers, with up to 90 % of particles the average size of <300 μm, obtained by a physical-mechanical technique from the vegetative part of wheat, with a neutral taste and smell. The composition of DF is dominated by cellulose, 72.0 %. The total content of cellulose and hemicellulose in fibers is 98.0±0.5 %. Vitacel WF400 has a water activity of 0.44 and a capillary structure, so moisture and oil are bound both from the surface of the fibers and inside the capillaries; it is strongly retained. The fixed moisture-retaining capability is at the level of 11 g per 1 g of product, and the absorption of fat – 12 g, respectively [26].

Extruded wheat flour is produced in Ukraine according to TU U 00883403.002-99 using an extrusion technology. Combining the thermo-, hydro- and mechanical treatment of flour wheat makes it possible to obtain a product with the predefined and stable properties. EWF demonstrates the following characteristics: pH, 6.4; mass fraction, %: protein – 11.9, fat – 2.3, carbohydrates – 68.2, cellulose – 1.2 [21].

The process of flour wheat extrusion is accompanied by the destruction of secondary bonds in the molecules of protein, which leads to an increase in the amount of peptides and free amino acids in the resulting product. Complex proteins and carbohydrates break down into simple, cellulose – into secondary sugar, starch – into simple sugars. The distinctive features of EWF are the high content of protein and the low content of fat, the enhanced emulsifying, moisture- and fat-retaining properties [27, 28].

All the above described DF were used in model samples and mixtures for products with MFC.

The following factors exert a significant effect on the indicators for mixtures with a maximum replacement of butter with oil in the amount of 25 %: *C*1 – the amount of DF Vicetal, %, *C*2 – the amount of rosehip meal, %. The upper level of factor *C*1 max=0.6; the lower level of factor *C*1 min=0.1, and for *C*2, respectively, max=3.5; min=1.

The plan of and results from FFE 2^2 for mixtures of MFC with a maximal replacement of butter with the oil *Rosa canina L.* in the amount of 25 % are given in Table 1.

The accuracy of results obtained is ensured by the three-time repeated experiments and their subsequent mathematical treatment using the software Microsoft Excel 2007 and STATISTIKA (StatSoft, USA).

The course of the experiment, as well as definitions and calculations, are described in more detail in [29].

of special mechanical treatment of wheat dietary fiber – the disclosure and dissolution of the fiber's structure. A low capability to retain fat and moisture was recorded for the meal *Rosa canina L.* at the level of 21.0±0.5 % (in butter) and 19.0±0.7 % (in oil) and, respectively, 49.0±0.4 % (in buttermilk) and 56.0±0.5 % (in water). For the extruded wheat flour, the parameters are in the middle of the specified ranges.

Enrichment with such dietary fibers as meal from the fruits of *Rosa canina L.* is appropriate; the technological effect (fat- and moisture-retention) must be strengthened by adding EWF or Vitacel.

The swelling kinetics of DF in buttermilk are shown in Fig. 2.

According to the research results (Fig. 2), the most intense swelling takes place over the first 5 minutes. In this case, the coefficient of swelling in buttermilk is 4.7 for Vitacel; for extruded wheat flour, 3.65l and 2.25 for meal from the fruits of *Rosa canina L.*, respectively. One should pay attention to that the rational duration of swelling of plant-based ingredients is from 15 to 20 minutes, which is highlighted by the relevant region.

The results from studying the degree of swelling of DF in buttermilk due to temperature are shown in Fig. 3.

When studying the influence of temperature on the conformational changes of dietary fiber with a different degree of treatment (Fig. 3), it was found that the highest indicators of the degree of swelling were observed at a temperature of 40 °C. In this case, a given indicator is 8.5±0.2 for Vitacel, for EWF – 6.7±0.1, and 4.9±0.1 for rosehip meal, respectively.

Table 1

The plan of and results from FFE 2^2 for mixtures of MFC with a maximal replacement of butter with the oil *Rosa canina L.* in the amount of 25 %

Number of examined samples, *j* (*N*)	Factor value (composition of examined samples)				Value for process output, Y_{ij} (optimization parameter)						Mean value	
	*C*1	*C*2	amount of DF Vicetal, %	amount of rosehip meal, %	degree of liquid fat outflow (*Y*1), %			coefficient of thermal stability (*Y*2)			$\overline{Y1}$	$\overline{Y2}$
					Repeatability, *i* (*m*)							
					1	2	3	1	2	3		
1	–	–	0.10	1.00	21.82	21.76	21.75	0.77	0.80	0.75	21.78	0.77
2	+	–	0.60	1.00	15.94	16.15	16.08	0.85	0.82	0.83	16.06	0.83
3	–	+	0.10	3.50	18.10	18.21	18.13	0.81	0.79	0.80	18.15	0.80
4	+	+	0.60	3.50	15.00	15.05	15.10	0.90	0.85	0.88	15.05	0.88
5	+	0	0.60	2.25	15.40	15.25	15.30	0.87	0.83	0.84	15.32	0.85
6	–	0	0.10	2.25	18.70	18.50	18.60	0.79	0.77	0.78	18.60	0.78
7	0	+	0.35	3.50	16.60	16.55	16.59	0.85	0.83	0.84	16.58	0.84
8	0	–	0.35	1.00	19.40	19.35	19.20	0.80	0.82	0.82	19.32	0.81

5. Results of studying the properties of dietary fiber in dairy mixtures with the modified fat composition

5. 1. Determining the technological properties of dietary fiber for use as components of products

The results from determining the fat-retaining capability of meal from the fruits of *Rosa canina L.*, EWF, and Vitacel in the melted butter and oil, as well as the moisture-retaining capability of the above-specified DF in water and buttermilk, are shown in Fig. 1.

According to values from Fig. 1, the highest FRC was demonstrated by Vitacel: in the melted butter the indicator was 59.0±0.5 %; in the oil *Rosa canina L.*, 55.0±1.0 %. At the same time, these DF demonstrated high WRC: in water – 99±1.0 %, in buttermilk – 95±1.0 %. A given effect for Vitacel, according to the manufacturer's data, is a result

Fig. 1. Fat- (⟵) and moisture-retaining (⟶) capability of meal from the fruits of *Rosa canina L.*, EWF, and Vitacel, in different environments

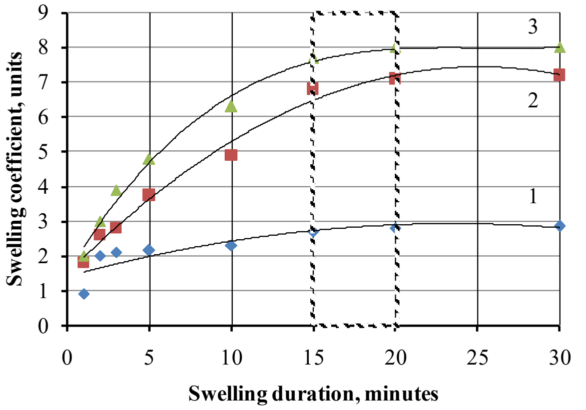


Fig. 2. Swelling kinetics of meal from the fruits of *Rosa canina L.* (1), extruded wheat flour (2), and Vitacel (3), at a temperature of 20±2 °C in buttermilk

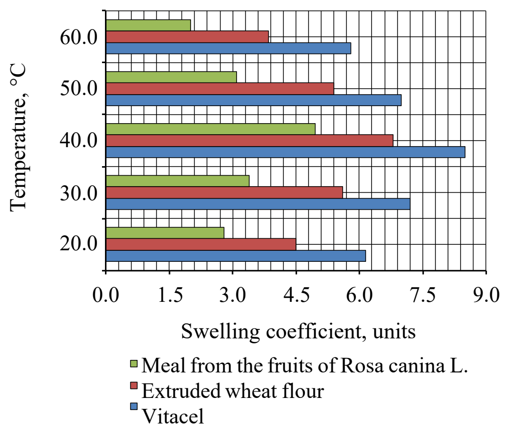


Fig. 3. Dependence of the degree of DF swelling in buttermilk on temperature

5. 2. Defining the form that binds moisture in mixtures with dietary fiber

The transmission spectra of infrared rays for the examined samples were acquired from the FTIR-spectrophotometer "Nexus"; they are shown in Fig. 4.

The infrared spectra of the examined samples of EWF mixtures with buttermilk and water (Fig. 4) are similar in character. We compared the spectra of air-dry sample of extruded wheat flour (1) with the corresponding spectra of water-plant (2) and plant-dairy (3) mixtures. It was determined that in the region of OH-valent fluctuations in the spectra from sample (3) (EWF and buttermilk) one observed, accordingly, the two bands of 3,402 cm^{-1} and 3,301 cm^{-1} (a region of the organically bound water). These bands correlate with the two types of H-bound water. The interaction between a disperse phase and the dispersed environment changes the properties of both components of the dispersed system.

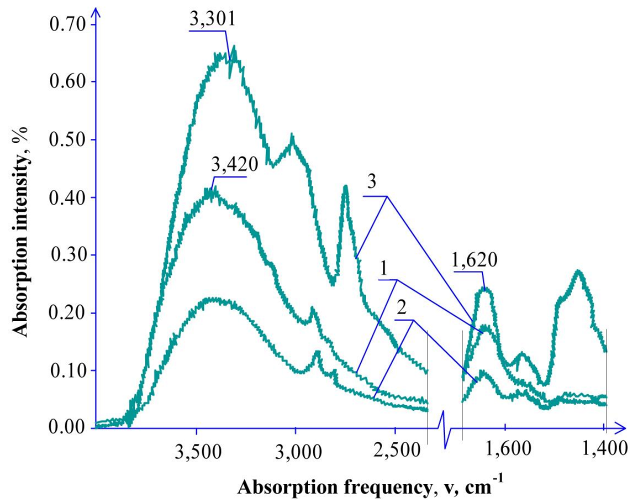


Fig. 4. IR-spectra of transmission: 1 – extruded wheat flour; 2 – extruded wheat flour + water (control); 3 – extruded wheat flour + buttermilk

5. 3. Determining maximally possible replacement of butter with oil in mixtures with food fibers

Fig. 5 shows the values for hardness of dairy mixtures with MFC when adding different dietary fibers and oil.

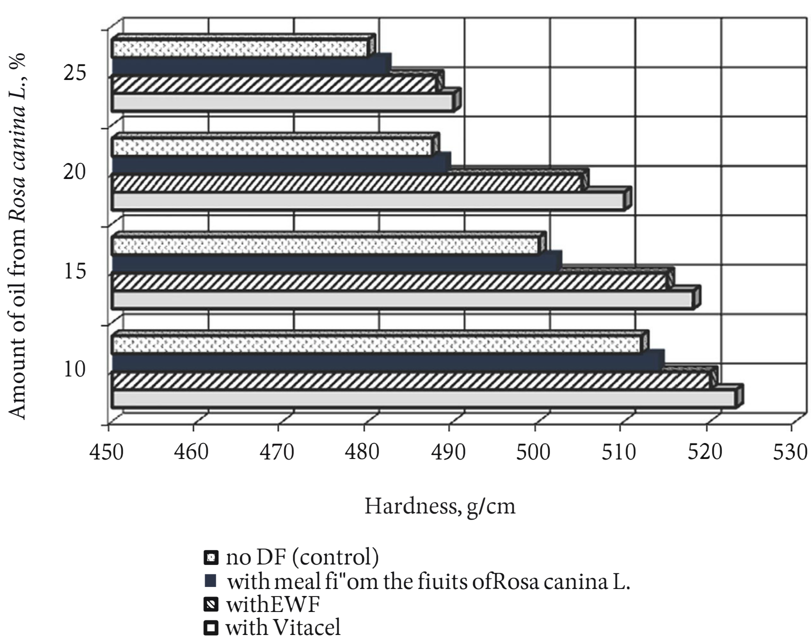


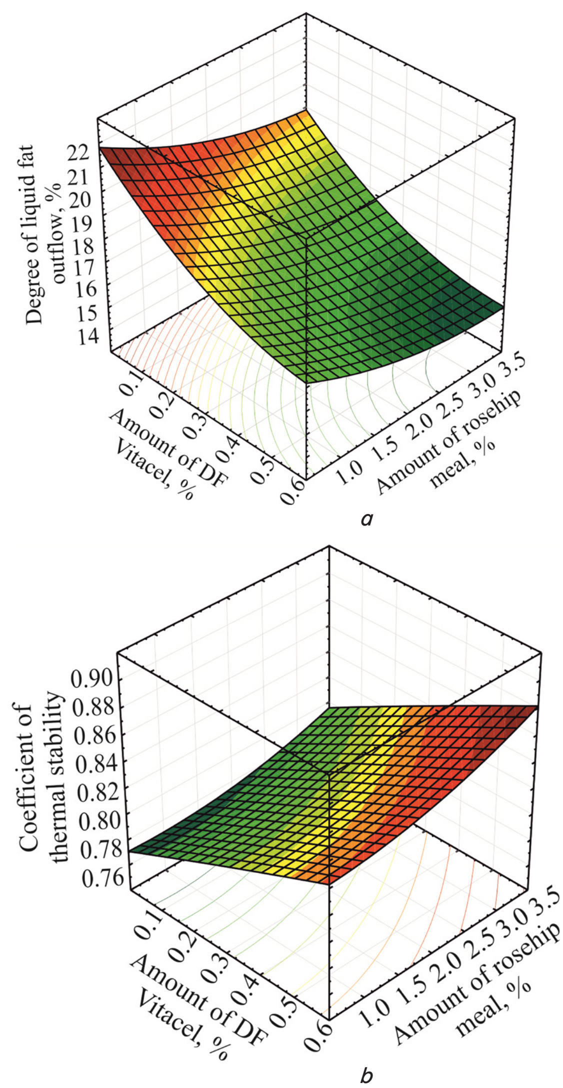
Fig. 5. Hardness of dairy mixtures with MFC with different amounts of oil from *Rosa canina L.* and DF

Control is the mixtures without dietary fiber, but with varying amounts of oil, from 10 to 25 %. According to the results (Fig. 5), the greatest hardness was observed in control sample with a minimal replacement – 10 %. Despite the almost same content of solid triglycerides in control, the presence in the fatty phase of different dietary fibers (especially Vitacel, as the most effective for fat-retention) has a positive effect on the texture of milk mixtures with MFC.

At the next stage, we identified indicators for the degree of outflow of *Rosa canina L.* in the amount of 25 %. The content of DF ranged depending on the type. Vitacel was added to the mixture in the amount from 0.1 % to 0.6 %; rosehip meal – from 1.0 % to 3.5 %. To determine the optimal amount of Vicetal (taking into consideration the maximal indicator for fat-retention) in a combination with rosehip meal (a minimum value for FRC), we applied a full factorial experiment (FFE).

By using the mathematically-statistical treatment of experimental data (chapter 4.4), we derived the adequate regression equations for dairy mixtures with MFC and DF.

The dependence of the degree of outflow of liquid fat (Y_1) and the coefficient of thermal stability (Y_2) for dairy mixtures of MFC with DF in the amounts of Vicetal (C_1) and rosehip meal (C_2) is shown in Fig. 6, *a, b*.



$$Y_1 = \frac{16,63}{C_1^{0,1} \cdot C_2^{0,06}}$$

$$Y_2 = \frac{C_1^{0,04} \cdot C_2^{0,02}}{3,35}$$

Fig. 6. Response surfaces and mathematical models of MFC mixtures with different DF (N=8) for: *a* – degree of outflow of liquid fat; *b* – thermal stability

According to data, the maximum degree of outflow of liquid fat at the level of 22.6 % was observed for the smallest mass share of DF (Vitacel). Increasing the amount of fat-forming ingredients leads to the reverse effect. In this case, the indicator has a minimum value at the level of 15.8 % (for meal).

An optimum for the function is observed for samples (with a maximally possible replacement of milk fat with oil from *Rosa canina L.* in the amount of 25 %) that contain Vitacel, 0.3 %, and rosehip meal, 2.0 %. The degree of the outflow of fat is 19.10 %. A rather low indicator is the result of interaction between DF of varying degrees of treatment and the water and fatty phases of dairy blends MFC.

6. Discussion of results of studying the properties of food fibers in mixtures with the modified fat composition

We have established the technological properties (capability of moisture- and fat-retention, swelling) and the mechanisms of action of dietary fiber in the MFC mixtures. This information makes it possible to use Vicetal, EWF, and rosehip meal, to stabilize the structure and to ensure the appropriate consistency of products.

The highest indicators for the degree of swelling in buttermilk are observed in samples containing Vitacel, slightly lower values were demonstrated by rosehip meal and extruded wheat flour. The capability of the latter to bind moisture at different temperatures depends on the behavior of protein and starch. Protein substances absorb more moisture, while at the same time starch has a high temperature coefficient of swelling. Increasing the duration of exposure to moisture to 30 minutes reduces the swelling rate. As a result of the increase in the volume of dietary fiber at swelling, the spatial grid is probably experiencing the stress, which leads to the termination of swelling.

At low and moderate temperatures of 20...40 °C, the swelling of EWF occurs mainly due to the hydration of proteins. Increasing the temperature above 40 °C leads to the strengthening of this process as a result of the hydration of starch. Increasing the temperature leads to the processes of denaturation and promotion of polypeptide chains of the protein. As a result of the deployment of the polypeptide chains of protein, there form the cavities that receive the additional amount of osmotic water, which enhances the endothermic reactions of hydration and, along with it, the protein denaturation processes. It is obvious that the changes predetermined by these processes will be reflected in the formation of the physical-chemical and consumer indicators for dairy mixtures with MFC containing EWF. Increasing the temperature leads to the acceleration of swelling, while the degree of swelling is reduced. In this regard, it is not advisable to increase the temperature of swelling. The mechanism of swelling for Vicetal and meal is much simpler and is related, for a first case, to the special treatment technique, in order to enlarge the surface of dietary fiber, and, for a second case, to the mechanical destruction of plant tissue.

We have obtained data on the form of bonds that arise in the interaction between plant-based ingredients and the moisture of the milk base, specifically buttermilk. The results of research from IR spectroscopy indicate the formation of H-bound poly-associates of water with the hydrophilic functional groups of the dispersed system, owing to which there occur the hydration and swelling of carbohydrates in EWF. One can probably predict a similar mechanism of action for all dietary fibers. Based on the infrared spectral analysis, the band of 3,301 cm^{-1} belongs to the water that is naturally associated with the functional groups of the dispersed system, the band of 3,402 cm^{-1} – to the surface adsorbed water. This indicates the formation of H-bound poly-associates of water with the hydrophilic functional groups of the dispersed system, owing to which there occur the hydration and swelling of carbohydrates in EWF.

It is important when designing dairy mixtures with MFC to know the value for the indicator of milk fat hardness, which to a certain extent reflects the content of the solid phase and the liquid phased (oil) and predetermines the texture and consistency of a resulting product. This indicator is positively affected by the presence of Vitacel in the composition. A given effect is due to the high fat-retaining capability of the above-specified dietary fiber derived from the vegetative part of wheat without the use of chemical reagents by applying a mechanical treatment – through the disclosure and dissolution of the structure of fiber cells. Somewhat higher indexes of hardness, by 5...7 %, in comparison with the samples containing Vitacel, are demonstrated by mixtures with the addition of EWF. In general, we recommend that one should introduce to the formulations of dairy mixtures with MFC up to 25 % of oil from *Rosa canina L.*, with mandatory addition of DF of varying degrees of treatment in order to prevent the outflow of liquid fat.

By analyzing the derived mathematical models of the degree of outflow of liquid fat aimed at predicting the consistency of mixtures with MFC and DF, we can conclude that the amount of dietary fiber with a high fat-absorbing capability (Vicetal) is the most significant factor. In this case, the degree of outflow of liquid fat is 19.10 %, which is the result of interaction between dietary fiber and the aqueous and fat phases of milk mixtures. Probably, additional coagulation links form in the system, which cause the formation of a secondary spatial grid, which, accordingly, makes it possible for the structure to retain the liquid fat. This increases the homogeneity and plasticity. The thermal stability of dairy mixtures with MFC is directly proportional to the ratio of DF and inversely proportional to the amount of the introduced oil from *Rosa canina L.* An optimum of the coefficient of thermal stability is within 0.81...0.82, which corresponds to the amount, in the dairy mixtures with MFC, of the dietary fiber Vitacel – 0.3 %, and rosehip meal – 2.0 %. The obtained values are within the boundaries of permissible ones and correlate with data from earlier research.

It was experimentally proven and justified that the use in the mixtures with MFC of dietary fiber in the functionally significant quantities results in preventing the defects in consistency when combining butter and oil. In addition, we took into consideration the different degree of treatment of extruded wheat flour, wheat dietary fiber Vitacel, and rosehip meal from *Rosa canina L.*

A limitation for the practical implementation of the results of current research is the compatibility between the plant-based ingredients and the milk base at the organoleptic level.

Prospects for the further research are related to the selection of other plant components with similar properties in order to solve technological tasks.

7. Conclusions

1. The highest moisture-retaining capability in buttermilk is demonstrated by the wheat dietary fiber Vitacel, 95±1.0 %, and the lowest is registered for rosehip meal, at the level of 49±0.4 %, in the same environment. Similar patterns were observed when determining the fat-retaining capability. Thus, the highest value for the specified indicator, (59.0±0.5 %), was demonstrated by the dietary fiber Vitacel in the melted butter with a mass fraction of fat of 73 %. In oil from the fruits of rosehip, the indicator for fat-retaining ability is at the level of 55.0±1.0 %. The highest coefficient of swelling in buttermilk was observed for Vitacel (4.7±0.1), medium – for extruded wheat flour (3.65±0.1). We have also established the rational parameters for swelling for all plant-based ingredients: temperature is 40±2 °C, duration is 30...40 min.

2. According to the analysis of infrared spectra, the bands of deformative fluctuations in the polymer adsorption of moisture for the samples of extruded wheat flour with water or buttermilk are in the region of 1,700...1,400 cm^{-1}. Their relative intensity is 3 times higher in comparison with original samples. This indicates that the addition of extruded wheat flour makes it possible to increase the amount of bound water in mixtures.

3. Based on the results from simulating the dependences of the degree of outflow of liquid fat and the coefficient of thermal stability, we have established the rational ratios of DF in the mixtures. It is implied that butter is replaced with 25 % of oil, and Vitacel is introduced at the level of 0.3 %, meal – 2.0 %.

References

1. Gandhi, K., Sarkar, P., Aghav, A. et. al. (2013). Modified Milk Fat and Its Applications in Food Products. Research & Reviews: Journal of Dairy Science and Technology, 5, 16–24.
2. Belemets, T., Yushchenko, N., Lobok, A., Radzievskaya, I., Polonskaya, T. (2016). Optimization of composition of blend of natural vegetable oils for the production of milk-containing products. Eastern-European Journal of Enterprise Technologies, 5 (11 (83)), 4–9. doi: https://doi.org/10.15587/1729-4061.2016.81405
3. Kholodova, O. J. (2013). Arrangements of the protection of consumer rights. Kharchova nauka i tekhnolohiya, 4, 17–20.
4. Guichard, E., Galindo-Cuspinera, V., Feron, G. (2018). Physiological mechanisms explaining human differences in fat perception and liking in food spreads-a review. Trends in Food Science & Technology, 74, 46–55. doi: https://doi.org/10.1016/j.tifs.2018.01.010
5. Mohylianska, N. O., Lysohor, T. A. (2010). Vyznachennia zaminnykiv molochnoho zhyru v vershkovomu masli ta spredakh. Kharchova nauka i tekhnolohiya, 2, 71–76.
6. Tasneem, M., Siddique, F., Ahmad, A., Farooq, U. (2014). Stabilizers: Indispensable Substances in Dairy Products of High Rheology. Critical Reviews in Food Science and Nutrition, 54 (7), 869–879. doi: https://doi.org/10.1080/10408398.2011.614702

7. Savchenko, O. A., Hrek, O. V., Petryna, A. B., Topchii, O. A, Krasulia, O. O. (2018). Tekhnolohiyi produktiv z modyfikovanym zhyrovym skladom: realiyi ta tendentsiyi. Kyiv, 250.
8. Grek, O., Tymchuk, A., Chubenko, L., Ovsiienko, K. (2017). Research of quality indicators of curd products on basis of protein-herbal clots. Food and Environment Safety, Food and Environment Safety, 4, 262–268.
9. Tsygankov, S., Grek, O., Krasulya, O., Onopriichuk, O., Chubenko, L., Savchenko, O. et. al. (2018). Study into effect of food fibers on the fermentation process of whey. Eastern-European Journal of Enterprise Technologies, 1 (11 (91)), 56–62. doi: https://doi.org/10.15587/1729-4061.2018.120803
10. Mortensen, B. K. (2011). Butter and Other Milk Fat Products | Milk Fat-Based Spreads. Encyclopedia of Dairy Sciences, 522–527. doi: https://doi.org/10.1016/b978-0-12-374407-4.00329-0
11. DSTU 4599:2006. Zhyry roslynni ta yikh kompozytsiyi dlia zastosuvannia pid chas vyrobnytstva sprediv i sumishei zhyrovykh (2007). Kyiv: Derzhspozhyvstandart Ukrainy, 9.
12. Nazarenko, L. O. (2011). Identyfikatsiya yakosti ta otsiniuvannia konkurentospromozhnosti sprediv, shcho realizuiutsia v Ukraini. Naukovyi visnyk Poltavskoho universytetu ekonomiky i torhivli, 1, 106–112.
13. Yangilar, F. (2013). The Application of Dietary Fibre in Food Industry: Structural Features, Effects on Health and Definition, Obtaining and Analysis of Dietary Fibre: A Review. Journal of Food and Nutrition Research, 1 (3), 13–23.
14. DSTU 4557:2006. Produkty zhyrovi dlia dytiachoho ta dietychnoho kharchuvannia. Spredy dytiachi. (2008). Kyiv: Derzhspozhyvstandart Ukrainy, 18.
15. Rønholt, S., Mortensen, K., Knudsen, J. C. (2013). The Effective Factors on the Structure of Butter and Other Milk Fat-Based Products. Comprehensive Reviews in Food Science and Food Safety, 12 (5), 468–482. doi: https://doi.org/10.1111/1541-4337.12022
16. Tsygankov, S., Ushkarenko, V., Grek, O., Tymchuk, A., Popova, I., Chepel, N. et. al. (2018). Influence of grain processing products on the indicators of frozen milkprotein mixtures. Eastern-European Journal of Enterprise Technologies, 6 (11 (96)), 51–58. doi: https://doi.org/10.15587/1729-4061.2018.147854
17. Burdo, O. G., Yusef, A. (2015). Puti povysheniya energeticheskoy effektivnosti protsessov pererabotki plodov shipovnika. Naukovi pratsi Odeska natsionalna akademiya kharchovykh tekhnolohiy, 47, 118–121.
18. Evdokimova, O. V., Fuks, S. G. (2011). Biologicheski aktivnye veschestva poroshka iz shrota plodov shipovnika. Tovaroved prodovol'stvennyh tovarov, 3, 54–56.
19. Petrova, S. N., Ivkova, A. V. (2014). Chemical Composition and Antioxidant Properties Species of Rosa L. Himiya rastitel'nogo syr'ya, 2, 13–19. doi: https://doi.org/10.14258/jcprm.1402013
20. Cui, S. W., Nie, S., Roberts, K. T. (2011). Functional Properties of Dietary Fiber. Comprehensive Biotechnology, 517–525. doi: https://doi.org/10.1016/b978-0-08-088504-9.00315-9
21. Pryanishnikov, V. V., Mikolaychik, I. N., Giro, T. M., Glotova, I. A. (2016). Pischevaya kletchatka v innovatsionnyh tekhnologiyah myasnyh produktov. Mezhdunarodniy zhurnal prikladnyh i fundamental'nyh issledovaniy, 11, 24–28.
22. Subbotina, M. A. (2009). Study of process of the absorption of a moisture and solubility of a cedar flour. Tekhnika i tekhnologiya pischevyh proizvodstv, 3, 111–114.
23. Ivashina, O. A., Tereschuk, L. V., Trubnikova, M. A., Starovoytova, K. V. (2014). Issledovanie vliyaniya komponentov moloka na pokazateli kachestva rastitel'no-slivochnogo sereda. Tekhnika i tekhnologiya pischevyh proizvodstv, 1, 30–34.
24. Viriato, R. L. S., Queirós, M. de S., Neves, M. I. L., Ribeiro, A. P. B., Gigante, M. L. (2019). Improvement in the functionality of spreads based on milk fat by the addition of low melting triacylglycerols. Food Research International, 120, 432–440. doi: https://doi.org/10.1016/j.foodres.2018.10.082
25. Negmatulloeva, R. N., Dubtsova, G. N., Baykov, V. G., Bessonov, V. V. (2010). Lipidniy kompleks produktov pererabotki shipovnika. Hranenie i pererabotka sel'hozsyr'ya, 6, 42–44.
26. Gorlov, I. F., Giro, T. M., Pryanishnikov, V. V., Slozhenkina, M. I., Randelin, A. V., Mosolova, N. I. et. al. (2015). Using the Fiber Preparations in Meat Processing. Modern Applied Science, 9 (10), 54–64. doi: https://doi.org/10.5539/mas.v9n10p54
27. Balaeva, E. V., Kraus, S. V. (2013). Sovershenstvovanie tekhnologii proizvodstva keksov i maffinov s ispol'zovaniem krahmalosoderzhaschego syr'ya. Tekhnika i tekhnologiya pischevyh proizvodstv, 3, 3–8.
28. Kraus, S. V., Balaeva, E. V., Bochagov, E. A., Denisyuk, I. A. (2012). Ispol'zovanie ekstrudirovannoy pshenichnoy muki pri proizvodstve konditerskih izdeliy. Hleboprodukty, 8, 58–60.
29. Grek, O., Tymchuk, A., Tsygankov, S., Savchenko, O., Ovsiienko, K., Ochkolyas, O. (2019). Determination methods of food fibers characteristics in milk mixtures with the modified fat composition. EUREKA: Life Sciences, 4, 45–53. doi: http://dx.doi.org/10.21303/2504-5695.2019.00963