

The appropriateness of using the phospholipids of egg products has been considered as an alternative to synthetic emulsifiers in the technology of making milk-containing curds-based sour milk products (hereinafter, milk-containing products) of the functional purpose.

Underlying the development is the improvement of conventional technology by replacing 50 % of milk fat with a blend of natural vegetable oils (based on the mathematically calculated ratios). This could increase the content of essential fatty acids to the level commensurate with the physiological norms of their consumption. Adding the products of chicken egg processing as a useful and safe natural emulsifier would prevent the separation of the product's fatty phases. The emulsifying mixture "Prottekt 01" has been used as control.

The rational dosage for introducing the selected natural emulsifiers has been determined, based on the calculation of 1...4 % to the mass of the introduced vegetable fats (blend), which ensure the highest fat-retaining capacity (FRC) indicator and do not affect the organoleptic characteristics of the product.

It has been established that the stability of direct emulsifiers (DE) «o/w» is 100 % in the case of using egg yolk powder or the emulsifier "Prottekt 01" in the amount of 3 %; egg powder or albumin – 4 %.

The rational ratio of the formulation components has been determined for such emulsions – water phase:vegetable oil blend:egg yolk powder – as 21:76:3, provided the lowest possible percentage of a water phase (whey) is introduced.

The dependence of a moisture-retaining capacity indicator on the moisture content in a milk-containing product that included the experimental samples of emulsions has been confirmed. The dependence established is in good agreement with a phenomenon of the reduced moisture-retaining capacity in a food product when its fat content increases as a result of the lower moisture-retaining capacity of the fatty phase compared with the protein phase.

The derived dependence of lecithin content on the indicators of FRC and DE proves the appropriateness of choosing the egg yolk powder as an emulsifier for making a milk-containing curds-based sour milk product. The highest indicators of FRC, 5 cm³/g, and the formation of 100 % of DE, are observed when using 3 % of the egg yolk powder (with a lecithin content of 10.3 g/100 g of the product) in the emulsifier composition

Keywords: blend of vegetable oils, milk-containing curds-based sour milk product, egg yolk powder

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DETERMINING THE EFFICIENCY OF USING EGG PRODUCTS FOR THE STABILIZATION OF EMULSION WHEN MAKING MILK-CONTAINING CURDS-BASED PRODUCTS

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1. Introduction

The issue of nutritional and healthy food has always been one of the most important problems of mankind worldwide. The anthropogenic pollution of the environment, daily emotional burden, constant psychological stress, and other negative factors of the biological, chemical, and physical nature, require the enhanced and over-the-norm functioning of all organs and systems of the human body. Given this, more attention should be paid to the quality of life, which could improve the resistance of the body and prevent the emergence of diseases.

It is known in the world and scientifically proven that human health depends by 70 % on the balance of the daily diet: the degree of quality, biological completeness, and the environmental-friendliness of products consumed. Therefore, the issue of useful and healthy food, especially under the conditions of the lively rhythm of the present life, is one of the most urgent problems of modernity [1, 2].

When analyzing the qualitative composition of food in different population groups, one can observe a significant violation of the diet structure within the past decades. Moreover, this negative trend has become particularly acute

in recent years. Significant deviations from the formula of “balanced diet” are observed, in particular in terms of the supply of macro- and micronutrients, dietary fibers, essential amino acids, and polyunsaturated fatty acids (PUFA), which play an important role in metabolic processes. In parallel, one can note the excess consumption of simple carbohydrates, high-calorie products with a significant fat content (specifically, trans-fats), and harmful food additives [3–5]. The consequences of a given tendency are the emergence of a series of diseases associated with the consumption of products that have a zero biological value. These include obesity, cardiovascular disease, type 2 diabetes mellitus, stroke, and various forms of oncological pathology. These and other diseases become increasingly dangerous causes of disability and premature lethal consequences [6, 7].

An alternative to the described conditions is balanced nutrition, capable of ensuring the normal functioning of all body systems, carrying out preventive action against the above diseases, as well as prolonging life and improving labor efficiency. That is why high-quality food products are one of the most important factors, which determine the level of health of a country's population.

The very concept of the “positive”, “functional”, or “healthy” food originated in Japan in the 1980 90s. It includes all the necessary links for creating healthy (functional) food products, starting with the development of theoretical foundations, setting production, the choice of product sale sites, up to their direct consumption. In this case, the products must possess the following characteristics:

- the nutritional (energy) and biological value;
- the organoleptic properties pleasant for the consumer (taste, smell, texture, the color of the product);
- a clearly defined positive effect on the organ, a system of organs, or the physiological state of the body in general.

Of all the above characteristics, it is the level of the organoleptic indicators that determines by 90 % the amount of food sales. The results of comprehensive studies confirm the direct effect of macro- and micronutrients, dietary fibers, PUFA, essential amino acids, vitamins, and minerals on human health [8, 9]. Therefore, there is a growing interest in the development of new foodstuffs based on natural raw materials whose composition maximally meets the requirements of nutritionology.

According to world standards, functional food products include those able to reduce the risk of diseases provoked by pernicious food habits. Their consumption contributes to improving and maintaining health due to the presence of polyfunctional food ingredients in their composition [10, 11]. It should also be noted that functional products are intended for daily (systematic) consumption by all age groups of the population. At present, functional products account for not more than 3 % volume of all existing food products. However, as estimated in [12], the market potential of these products will, in a few decades, exceed the level of 30 %. It should be borne in mind that the consumer at his/her sole discretion determines the composition of a daily diet depending on taste and aesthetic preferences, the needs of the body, as well as for economic reasons. In this regard, it is a relevant task is to provide the population not only with useful and safe products that meet modern scientifically grounded norms of healthy nutrition but also economically affordable and organoleptically attractive. In other words, when creating functional products of the new generation, it is necessary:

- to improve the existing technologies by optimizing the parameters of the technological process in order to achieve a social effect and cheaper production;
- to use plant-based ingredients (especially natural dietary supplements) in order to provide food products with treatment and prophylactic (functional) properties.

2. Literature review and problem statement

The development and introduction to the food industry of the functional food products of the “new generation” with the enhanced physiological and biological value that would positively affect the human health and are intended for the consumption by the wide sectors of the population is a relevant task [13, 14].

To meet the needs for food by different segments of the population, there is a need to manufacture fermented milk products with a combined composition of raw materials. Adding or partial replacement of milk fat with natural fats of plant origin could solve a series of issues in the dairy industry related to the shortage of raw milk and seasonal fluctuations in its chemical composition [15, 16]. In this case, the task to increase the nutritional value of combined products and to provide them with functional properties is often overlooked. Therefore, it is a relevant task to expand the range of milk-containing products with an adjustable composition that meets the modern requirements of nutritionology.

We propose technology for making a milk-containing curds-based sour milk product, specifically a 50 % replacement of the mass fraction of milk fat with a specially developed blend of natural vegetable oils. The obtained experimental data testify to the expediency of the inclusion of a milk-containing curds-based sour milk product to the daily diet. This could increase the level of essential fatty acids and improve the ratio of polyunsaturated acids from the ω -6/ ω -3 families [17, 18].

However, along with the increase in the biological value of the developed product, there is the issue of preventing phase separation with the release of a plant component from the product environment. Therefore, the task of further studies is the choice of a rational emulsifier (a food additive) in the technology of a milk-containing curds-based sour milk product implying the identification of a technique and the optimum dosage of its introduction.

Currently, the studies are underway related to the use of polysaccharides – pectins of different origin, their derivatives, as well as inulin, as emulsifiers by structuring the disperse environment in the emulsions of direct type «o/w» [19, 20]. However, the problematic issue in the cited papers is that the use of polysaccharides in the technology of protein products is limited in view of the formation of a non-natural jelly-like structure.

The most effective properties are exhibited by emulsifiers in combination with lecithin. The basic physical-chemical and, consequently, technological properties depend on the structure of the molecule of a surface-active substance (SAS), and the ratio of the hydrophilic and lipophilic groups in its composition. The universal factor of stability of disperse systems is the structural mechanical factor, whose essence is that the emulsifiers should possess both surface activity and the property to form the structured colloidal-adsorption layers [21, 23].

According to works [22–25], lecithin is an important structural component of the lipid bilayer of cell membranes

and other biological membranes, which ensures their barrier function. The essential acids of phospholipids and lecithin contribute to the increased activity of the membranes and cell enzymes, taking part in inhibiting the processes of lipid peroxide oxidation. All cells in the body need lecithin as a structural substance that is part of the vitamin B complex; it stimulates the formation of erythrocytes and hemoglobin and helps the body produce energy. Therefore, scientific studies in the area of food enrichment by the lecithin-containing ingredients are relevant and timely under conditions of a stable tendency to the deterioration of the general state of public health, the increased level of non-infectious diseases, caused, among other reasons, by metabolic disorders at the cellular level and by the accumulation of toxic compounds.

Paper [7] reports the results of adding lecithin to dispersed systems. There is a decrease in the surface tension between the water and fat phases and, as a consequence, the improvement of a phase distribution process in various heterogeneous systems. In this case, the stability of the emulsion would depend on the strong energy barrier that prevents the coagulation of individual droplets. Such an energy barrier is created by the presence of an emulsion film, which is formed on the surface of a droplet due to the presence of lecithin in the water-fat emulsion.

It was determined that the phospholipids of chicken eggs have a high emulsifying capacity, in particular, phosphatidylcholine and phosphatidylthanolamine, and provide stable emulsions as compared to other phospholipids [24], which makes it possible to recommend egg products as a full alternative to synthetic emulsifiers in the composition of milk-containing products.

It was found in [25–27] that phospholipids with unchanged native properties have high physiological activity. In this connection, their use is beyond solving only technological tasks. The presence of essential nutrients in phospholipids predetermines the possibility of their use not only as a stabilizer-emulsifier for food products but also gives an opportunity to apply phospholipids in order to develop products of functional purpose. Therefore, the use of phospholipids in protein products technology with a partial replacement of milk fat could, in addition to solving technological tasks, render them functional properties.

In addition, the effectiveness of the absorption of biologically active phospholipids from a natural chicken egg is higher compared to the pharmaceuticals that contain them. It was established that natural choline from the phospholipids of egg yolk is more effectively digested compared with choline bitartrate [28], which confirms the prospect of using egg yolk powder in the technology of a milk-containing product.

It is proved in [29] that eating chicken eggs is one of the aspects of health improvement. The experiments on rats show the high hypocholesterolemic effect of the phospholipids of egg yolk and egg whites' proteins. In addition, an introduction to the diet of egg yolk powder phospholipids and, consequently, egg yolk powder, promotes the recovery of cognitive functions, improves memory, reduces cholesterol, and slows aging. Therefore, milk-containing products with egg yolk powder will not have restrictions on consumption for consumers of older age groups and those suffering cholesterol metabolisms.

Given the fact that the selected technology for making a milk-containing curds-based sour milk product takes into consideration the basics of the concept of “healthy eating”

and the main principles of creating functional products, we confirm the earlier chosen strategy of choosing the emulsifier only of natural origin. Such emulsifying components can include egg powder, egg yolk powder, albumin (egg protein), etc. The indicators of fat-retaining capacity (FRC) for the selected emulsifiers will be mandatorily subject to comparison with a synthetic emulsifier, namely the complex emulsifying mixture “Prottekt 01” (mono- and diglycerides of fatty acids E471, E472) [31].

To develop the technology for making a milk-containing curds-based sour milk product, the selection of experimental samples of emulsifiers focused on natural emulsifiers that contain phospholipids in their composition, given the safety of phospholipids (phosphatidylcholine, in particular) even in the excess quantity in the daily diet (the need in phospholipids by humans is 5–7 g/day). The United Committee of the FAO experts on food additives established an unconditional permissible dosage of phospholipid consumption per person – up to 50 mg (in addition to a regular diet), as well as conditionally permissible, 50...100 mg per 1 kg of body weight. And given that the diet of the average statistical adult contains 1–5 g of lecithin, it is practically impossible to exceed the conditionally admissible dosage of phospholipid consumption. The physiological effect on the human body exerted by phospholipids from plant and animal sources is similar [25]. It is important to take into consideration that it is impractical to control the amount of any food supplement consumed by people in the products of everyday use.

The technology of milk-containing products implies, in order to prevent the stratification of phases and the separation of non-milk fat, the use of emulsifiers but there are no scientific studies on use of egg products for this purpose. The choice of egg products is favorable in view of the following factors: naturalness, biological activity, as well as the functional-technological properties. These reasons substantiate the selection of emulsifiers that contain phospholipids as experimental samples for the development of technology for making a milk-containing curds-based sour milk product.

3. The aim and objectives of the study

The aim of this work is to study the emulsifying properties of egg products in the technology for making a milk-containing curds-based sour milk product with a 50 % replacement of the mass fraction of milk fat with a blend of natural vegetable oils. The condition is that a given developed product should maintain the stability of consistency without a phase stratification and the separation of the introduced vegetable fats in a combination with the high level of its organoleptic properties.

To achieve the set aim, the following tasks have been solved:

- the theoretical and experimental studies into the possibility and appropriateness of the use of egg products as natural emulsifiers in the technology of a milk-containing curds-based sour milk product;
- the establishment of the technological parameters and the rational amount of the introduction of egg products to a milk-containing curds-based sour milk product;
- the determination of the efficiency of using egg products to ensure the stability of the fat phase of milk-containing curds-based sour-milk products.

4. Materials and research methods to determine the efficiency of using egg products as emulsifiers in the technology of milk-containing curds-based sour milk products

Based on the analysis of literary sources, the chosen objects of our study were the following emulsifiers of direct emulsions: the emulsifying mixture "Prottekt 01" (mono- and diglycerides of fatty acids E471, E472) produced by "Vianoks" Company (Ukraine). The experimental study involved the following egg products: egg yolk powder (dry yolk, fermented, thermostable), egg powder, and albumin (from chicken eggs), produced at the "Imprevo FOODS" plant according to the standards ISO 22000:2005, ISO 9001:2015, FSSC 22000, confirming its compliance with all requirements at each stage of production.

At the first stage of our experiments, based on literary data, we produced emulsifiers whose ratio of the water to fat phases did not change (70:30). The water phase is represented by milk whey and the fat phase is a blend based on natural vegetable oils (corn, rapeseed, and walnut oil, of which the latter two are not refined and deodorized). All the investigated emulsifiers were prepared from the fat and aqueous phases with the addition of the above-mentioned natural emulsifiers in the amount of 1...4 % (of the emulsion mass). We introduced the emulsifier to the fat phase of the system followed by its subsequent emulsifying with water at a speed of 1,000 rpm using a laboratory homogenizer. The finished emulsion was pasteurized at temperature $t=60...62$ °C during $T=2...3$ min in a water bath and cooled to the temperature $t=20...22$ °C. The cooled emulsion was used for the subsequent introduction to a milk-containing curds-based sour milk product. The total fat mass content (t.f.m.c.) of a milk-containing curds-based sour milk product after the addition of the emulsion was 9 % (of which 50 % accounted for a blend of vegetable oils). The selection of a curds-based sour milk product with a t.f.m.c. of 9 % was substantiated by earlier studies. According to the results obtained, at a 50 % of the fat replacement in milk-containing curds-based sour milk product with a blend of vegetable oils, there is no phase stratification with the release of plant fat drops at the surface of the product, provided that its t.f.m.c. <9 %.

In the second stage of our experiments, we selected the rational quantity of the introduction of the chosen natural emulsifiers by using procedures for determining the stability of a protein-fat emulsion (PFE) and its FRC.

In the third stage, we studied the selection of the optimum ratio of the water and fat phases of the investigated emulsions. The objective of the experiment was to examine the FRC of the structured curds-based sour milk product (t.f.m.c., 9 %) depending on the percentage content of the emulsion aqueous phase at a steady amount of the emulsifier introduced (egg yolk powder) of 3 %.

To this end, 5 g of a sample is stirred with 25 g of oil at a temperature of 35 °C in a weighted centrifuge tube for 1 minute 2 times with a break of 5 minutes. Centrifugation is carried out within 15 minutes at a centrifuge rotation speed of 1,500 min⁻¹. After centrifugation, the liquid over sediment (free fat) is drained, the tube is rotated upside down to the filter paper, and weighed.

The fat-retaining capacity is determined from the following formula:

$$\text{FRC} = ((c-b)/(b-a)) \cdot 100 \%,$$

where a is the mass of an empty centrifuge test tube, g; b is the mass of a test tube with a sample after centrifugation and fluid draining, g; c is the mass of a cup with emulsion before being centrifuged, g [32].

To determine the stability of the emulsion, the test tube from the centrifuge is filled up to the upper tick with the examined sample and arranged in the centrifuge for centrifugation over 5 minutes at a speed of 1,500 min⁻¹. This tube is then placed above a boiling water bath for 3 min and again centrifuged for 5 minutes.

The stability of the emulsion by volume, % of undestroyed emulsion, is calculated from the following formula:

$$C = (V/H) \cdot 100 \%,$$

where V is the volume of undestroyed emulsion, cm³; H is the volume of the investigated sample, cm³.

The accepted result of the determination is the arithmetic mean of two parallel measurements, with a permissible difference between them not exceeding 2.0 %.

The calculation is carried out to the first tenth character, followed by rounding to an integer [32].

In the fourth stage, we studied the establishment of interdependence between the indicator of the moisture-retaining capacity of a milk-containing curds-based sour milk product on the percentage of the introduced moisture in the emulsion composition. To solve this goal, we determined the mass fraction of moisture in a milk-containing curds-based product after introducing emulsion by an express method using a Chizhova moisture meter. Under a given procedure, drying is performed in packets, whose manufacturing implies the diagonal folding of a sheet of filtration or newsprint paper, the size of 150×150 mm, bending the corners, and then the ends, by about 1.5 cm. To prevent the release of a product, a paper bag is inserted inside a larger sheet of parchment bent diagonally, the ends of which are also bent.

Prepared packets are dried between the plates of the device for 3 minutes at a temperature of 150...152 °C, they are cooled and stored in an exicator for not more than 2 hours. A packet is weighed with an error not exceeding 0.01 g; 5 g of the product is introduced, distributing it evenly over the surface of the packet. The packet is closed, placed between the plates of the device, and dried at a temperature of 150...152 °C for 5 minutes. Packets with dried samples are cooled in an exicator over 3...5 min and weighed.

The mass fraction of moisture as a percentage is calculated from the following formula:

$$B = \frac{M_1 - M_2}{M} \times 100,$$

where M is a product batch, g; M_1 , M_2 is the weight of a packet with a batch before and after drying, respectively, g.

Next, moisture-retaining capacity (MRC) was determined by a gravimetric method by Grau-Hamm, modified by Alekseev, which is based on determining the amount of moisture released from a product at easy pressing. To this end, a batch of weight 0.3 g, weighed up to 0.001 g, was placed on a soft waterproof plate with a diameter of 40 mm, covered with a slowly absorbing ash-free filter with a diameter of 40 mm. The top plate was covered with another glass plate with a diameter of 100 mm; a weight of 500 g was placed on it. After 7 minutes, the plate was removed and the plate

with a batch was weighed. Moisture-retaining capacity was determined from the following formula:

$$MRC=(100 \cdot (a-b))/a,$$

where MRC is the moisture-retaining capacity, %; *a* is the amount of moisture in a batch, g; *b* is the amount of moisture released from the batch of curds, g;

$$a=0.3 B/100,$$

where 0.3 is the batch of curds, g; *B* is the mass fraction of moisture, % [33].

5. Results of studying the possibility and appropriateness of using egg products as natural emulsifiers

Data on the experimental study into determining the FRC of emulsifiers are shown in Fig. 1.

Based on the results shown in Fig. 1, it was established that the highest FRC indicator, 5 cm³/g, is achieved at a 3 % introduction of a natural emulsifier in the experimental samples with egg yolk powder and the emulsifying mixture “Prottekt 01”. Consequently, the emulsifiers that are made using them could be equally effective in technologies of milk-containing products with the combined composition of raw materials, provided that these emulsifiers are introduced starting from the minimum amount of 3 %.

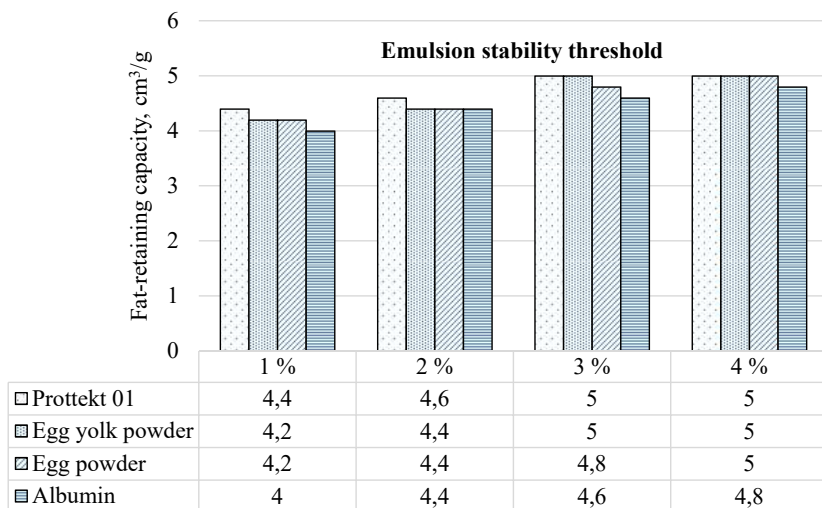


Fig. 1. Comparative evaluation of FRC of the investigated emulsifiers

5.1. Results of determining the efficiency of using egg products to ensure the stability of the fat phase in a milk-containing curds-based sour milk product

In order to detect the threshold of the emulsifying capacity of the investigated emulsifiers, we produced emulsions according to the above procedure under which the ratio of the water to fat phases did not change (70:30). The investigated

emulsifier was added in the amount of 1, 2, 3, and 4 % (of the introduced vegetable fat mass). Next, we determined the stability of the model samples of emulsion based on the selected emulsifiers of natural origin. Based on the acquired data, a columnar diagram of emulsion stability «o/w» was built (Fig. 2). This diagram shows the ratio of the volumetric particles (in %) of the stable emulsion and the phases separated after centrifugation at a speed of 1,500 min⁻¹ for 5 min.

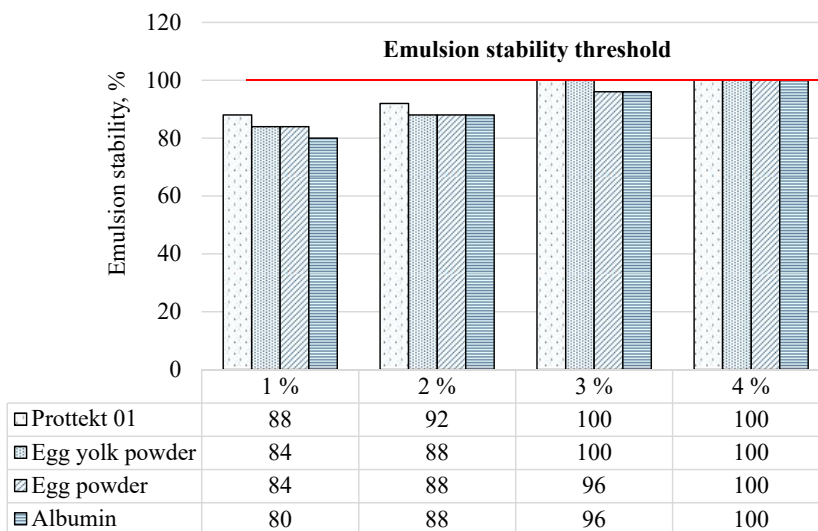


Fig. 2. Comparison of the «o/w» emulsion stability when using the investigated emulsifiers

An analysis of Fig. 2 reveals that the emulsion stability reaches 100 % if one introduces 3 % of the emulsifier “Prottekt 01” or egg yolk powder, and does not change at their increase. Thus, when manufacturing direct emulsions, it is advisable to introduce these emulsifiers in the amount of at least 3 %.

5.2. Results of studying the technological parameters for introducing egg products to the composition of a milk-containing curds-based sour milk product

In order to prevent the excessive amount of moisture, introduced to a milk-containing curds-based sour milk product, we made the model samples of products at various water phase content (whey) and stable amount of an emulsifier, 3 % (egg yolk powder). The samples of experimental emulsions were prepared according to data in Table 1.

Next, we studied FRC while varying the system’s moisture content. According to the results of experimental study, the highest FRC indicator, 5 cm³/g, as well as the emulsion stability, are kept at the maximum decrease in the percentage of using whey from curds down to the ratio of 21:76:3. At the next stage of our research, it was necessary to determine the dependence of MRC of the developed milk-containing product with a 50 % replacement of milk fat with a blend of vegetable oils on moisture content, added in the composition of emulsion. After all, an important factor

affecting the moisture content in curds-based products is its amount in the starting raw materials, which is indirectly associated with the fat content.

Table 1

Composition of the examined samples of emulsions

Emulsion component	Experimental sample, No.			
	1	2	3	4
Water phase (whey from curds)	50	35	21	7
Fat phase (blend of vegetable oils)	47	62	76	90
Emulsifier (egg yolk powder)	3	3	3	3

The samples of emulsions were prepared according to the formulation data given in Table 1. The samples of a milk-containing curds-based sour milk product were made with a fat mass fraction of 9 % in a separate way. The prepared emulsion was introduced to the calculated amount of cream with a fat mass of 50...55 % during the normalization, calculated for 4.5 g per 100 g of product, which ensures a 50 % replacement of milk fat. After that, the mixture was exposed to thermal processing at the temperature $t=85\pm 2$ °C with aging over 60 s, and then cooled to $t=20\pm 2$ °C. The control used was curds with a fat mass fraction of 9 %, made in a separate way.

The results of studying the moisture content and the MRC in a milk-containing curds-based sour milk product with the experimental samples of emulsions are shown in Fig. 3.

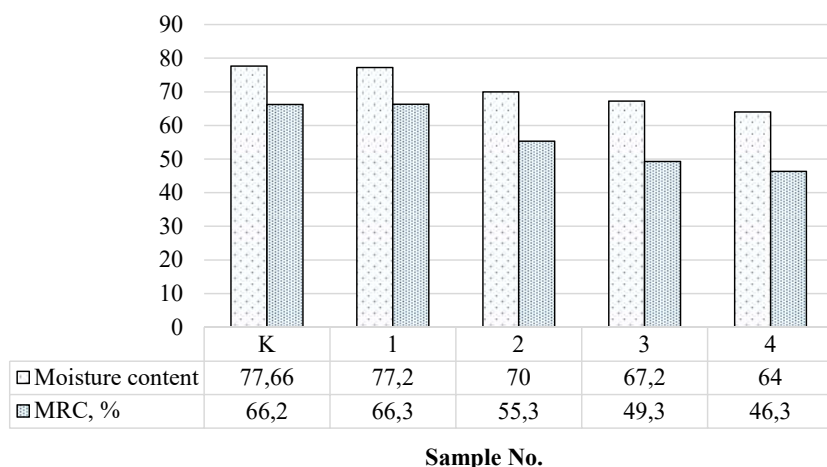


Fig. 3. Comparative characteristics of the MRC indicator for the examined samples of milk-containing curds-based sour milk products with different moisture content (added with emulsion)

Fig. 3 shows that the indicator of moisture content is dependent on the MRC indicator: the moisture-retaining capacity of the product is higher for those samples containing more moisture.

5.3. Results of establishing the dependence of the number of functional substances (lecithin) in the composition of an emulsifier on its emulsifying properties

The final stage of the series of experimental studies was the comparative characterization of the selected natural emulsifiers according to the effect exerted by the amount of functional substance (lecithin) in their composition on emulsifying properties (the percentage of FRC and DE). Conversion to lecithin content in the applied emulsifiers involved a mathematical method based on the lowest emulsifier efficiency index (egg yolk powder), 3 %. The obtained results are shown in Fig. 4.

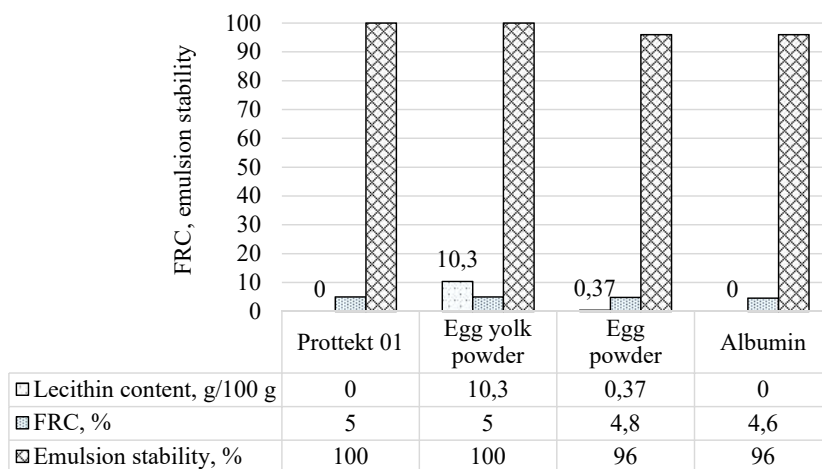


Fig. 4. Comparing the dependence of FRC and emulsion stability indicators on the number of functional substances in the applied emulsifiers (at 3 %)

According to the data shown in Fig. 4, there is a dependence between the quantitative content of lecithin and the percentages of FRC and DE in such egg products as egg yolk powder and egg powder. In this case, the absence of phosphatidylcholine (lecithin) in emulsifiers – “Prottekt 01” and albumin (from chicken eggs) – does not affect the above indicators.

6. Discussion of results of studying the efficiency of using egg products to stabilize emulsions

The main reasons for the lack of emulsion stability are associated with layering. That is why, in order to provide the emulsions with stability, emulsifiers are used. Due to the diphilic structure of the molecule, they are able to partially dissolve in oil and in water, while linking these components to one another [34]. In order to obtain the “oil in water” (o/w) emulsions, under industrial conditions, the hydrophilic emulsifiers are applied that have a higher degree of solubility in water than in oil.

It was established that at a 50 % replacement of the fat mass fraction in a milk-containing curds-based sour milk

product with a blend of vegetable oils it is necessary to use an emulsifier in the case when the fat content in the product exceeds 9 %. This can be explained by binding the introduced fat with milk proteins (casein and albumin) in a curds-based sour milk product and by the existing essential phospholipids in the composition of blended oils, which together act as a stabilizer of such a system.

By analyzing the FRC indicators of the selected natural emulsifiers (Fig. 1), it was found that the lowest FRC is demonstrated by albumin – 4...4.8 cm³/g provided it is added in the amount from 1 to 4 %, respectively. It should be noted that the average value of FRC, which is observed for 1 % of the albumin introduced to the emulsion, is 0.2 cm³/g, while the maximum value of FRC cannot be achieved even at a 4 % albumin introduction. In contrast to it, the largest value of FRC at 1 % of the introduction is demonstrated by egg yolk powder, 0.26 cm³/g. Already at 3 % of the introduction of egg yolk powder to the emulsion, one reaches the maximum FRC of 5 cm³/g of vegetable fat similar to the emulsifying mixture “Prottekt 01”, 5 cm³/g. However, the magnitude of an FRC value, when introducing 1 % of egg yolk powder, compared to the mixture “Prottekt 01”, is larger by 0.06 cm³/g, and has a spasmodic character when it is introduced in the amount from 2 % to 3 %.

Our research into the variation of percentage of the water phase content in the model samples of emulsions at the stable amount of an emulsifier (egg yolk powder) of 3 % has determined the smallest acceptable dosage of whey. In accordance with the data obtained, the highest FRC indicator (5 cm³/g), at the ratio “water phase:fat phase:emulsifier”, is observed in samples No. 2 – 35:62:3; and No. 3 – 21:76:3. That is, the minimum permissible percentage of the introduction of whey to model emulsions varies from 35 to 21 %. We argue that it is more expedient, in the technology of making a milk-containing curds-based sour milk product, to use the ratio of the components contained in model sample No. 3. After all, the mass fraction of moisture is a mandatory normative technological indicator in the production of curds; its excessive amount leads to a deterioration in the quality of the product.

The higher level of an egg yolk powder FRC is due to the content of the set of surfactants, phospholipids, which form the adsorption film, which covers the oil drops and prevents their separation, the layering of phases, and predetermines the formation of a stable direct type emulsion.

Our study has established that the preservation of the aggregate stability of a milk-containing curds-based sour milk product with a 50 % replacement of the mass fraction of fat with the developed blend of vegetable oils depends on the amount of emulsifier in model emulsions. If the minimum amount of an emulsifier is introduced, 1 %, the highest indicator of emulsion stability is observed in the samples containing the emulsifier “Prottekt 01”, 88 %, and the lowest one – containing albumin, 80 %. With an increase in the amount of an emulsifier to 3 %, the emulsifier stability of 100 % is reached when using “Prottekt 01” and egg yolk powder. It should be noted that the limit of stability at a given percentage of introduction for the emulsifiers of egg powder and albumin is the same, 96 %. Thus, if the emulsifier quantity is minimized, and in order to achieve a 100 % efficiency in the production of direct emulsions «o/w», it is

recommended to use egg yolk powder in the amount of 3 % of the mass of the introduced blend (fat).

The results obtained when using egg yolk powder in the emulsion composition can be explained by the content of phospholipids of egg products, which ensure the formation of a water-fat emulsion. Due to the diphilic structure of the molecule, they are able to partially dissolve in oil and in water, while linking these components to one another [34]. In order to obtain the “oil in water” (o/w) emulsions, under industrial conditions, the hydrophilic emulsifiers are applied that have a higher degree of solubility in water than in oil.

The emulsion stability at the smallest concentration of egg yolk powder is explained by the hydrophilic properties of phospholipids in its composition. Such a hydrophilic emulsifier, under the condition of obtaining the “oil in water” (o/w) emulsion, has a relatively higher degree of solubility (due to the diphilic structure of the molecule) in water than in oil, linking these phases to each other. The mechanism of this emulsion formation (using phosphatidylcholine) is associated with the “theory of reducing the interphase surface tension”, whose provisions are described by PA Rehbinder.

Thus, when adding lecithin to dispersed systems, the surface tension between the water and fat phases (due to the adsorption of the emulsifier) is reduced, thus contributing to dispersing (improvement of the process of interphase distribution in heterogeneous systems). In this case, emulsion stability would depend on a strong energy barrier, which prevents the coalescence (the merging of the droplets of dispersive substance and the emulsifier in a solid layer) and coagulation of individual droplets. This energy barrier is created by the presence of an emulsion film, which is formed at the surface of the drops. This film is the main factor for stabilizing the emulsion and may consist of one or more molecular layers of the emulsifier (mono- or poly-molecular films) [27].

The formation process of the emulsion described above is shown in Fig. 5.

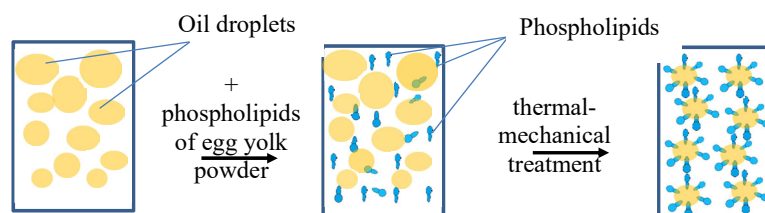


Fig. 5. Schematic representation of the formation of an o/w type emulsion based on vegetable oils and phospholipids of dry egg yolk

The results of studying the experimental samples of a milk-containing product have established that for the emulsion based on whey and blended oil, the maximum value of an MRC indicator, 66.3 %, is observed at a moisture content of 77.2 %. The derived dependence of MRC on the available percentage of moisture in the emulsion is in good agreement with the known phenomenon of reducing the moisture-retaining capacity of a food product while increasing its content of fat. Thus, the maximum fat content is 90 % in emulsion No. 4 (at 64 % moisture), which is marked by the lowest value of MRC, 46.3 %, among all examined samples. In this case, we observed, in a product manufactured using the sample of emulsion No. 4, a phase breakdown and subsequent release of plant fat drops on the surface of the product (due to the lack of emulsion stability). The maximum values of moisture content and MRC are seen in the sample of emul-

sion No. 1 (MRC, 66.3 %, at 77.2 % moisture), which is only 0.4 % (MRC) and 0.1 % (moisture mass fraction) lower than the control indicators. An overall tendency to decrease (a reduction step of 14...15 %) in the water phase content in the samples of emulsions is accompanied by the averaged decrease in the MRC indicators, by 4.3 %, and the mass fraction of moisture in the product, by 6.6 %. This effect is due to the lower moisture-retaining capacity of the fat phase compared with protein.

According to the data obtained (using an estimation method), which are shown in Fig. 4, there is a direct dependence of an FRC indicator and emulsion stability on the quantitative content of lecithin in the composition of such experimental samples of emulsifiers as egg yolk powder, egg powder, and albumin. The highest FRC indicators, 5 cm³/g, and the formation of a 100 % stable emulsion, are observed when using egg yolk powder with a lecithin content of 10.3 g (per 100 g of the product). These results are explained by a significant amount of lecithin and its high fat-retaining capacity; the emulsion stability is due to the presence of hydrophilic and lipophilic phosphatidylcholine groups.

The comparatively lower FRC indicator, 4.8 cm³/g, and the lack of emulsion stability when using egg powder, are due to the minimum amount of lecithin in its composition, 0.37 g, and the lack of a capacity of available protein components to the formation of a high-quality and stable emulsion. These causes also predetermine our findings in the case of using albumin. However, the high enough FRC indicator, 4.6 cm³/g, in the total absence of lecithin in its composition is explained by the increased concentration of protein components. It should be noted that the absence of lecithin in the emulsifier "Prottekt 01" is due to its synthetic origin and does not affect the FRC indicators and emulsion stability due to the presence of other active substances in its composition.

Since the milk-containing curds-based sour milk product with blends of natural vegetable oils is characterized by the quite high moisture content (up to 75 %), there is an issue of the product microbiological stability during storage.

Strict adherence to the technological regimes of pre-pasteurizing an egg yolk mass (in order to reduce the degree of microbial seeding of the raw materials) and its subsequent drying by a spraying method ($t=140...180$ °C) lead to the destruction of cells of vegetative forms and much of spore. The influence of temperature inactivates spores (they are reborn) that are not killed; their ability to be germinated is significantly weakened. The microbiological characteristics of the applied egg yolk powder (QMAFAnM<10,000/g, *Enterobacteriaceae*<10, *Salmonella* – absent in 25 g, *S. Aureus* – absent in 0.01 g) are within admissible limits under the current standard (DSTU 5028:2008. Microbiological indicators and safety indicators of eggs). Under appropriate conditions of its storage, the further development of microorganisms is not possible (due to the low percentage of moisture – 3...9 %), however, some thermostable microflora and spore forms of bacteria are able to maintain life (bacteria genera: *Staphylococcus*, *Streptococcus*, *E. coli*, and even separate *Salmonella* species).

The existing acidic environment of the developed milk-containing curds-based sour milk product (pH 4.5...4.7) would create unfavorable conditions for the development of neutrophilic and alkalophilic microorganisms. In addition, lactic acid bacteria (represented by mesophilic lactic acid lactococcal) in its composition would manifest antagonistic

activity with respect to the Gram-negative enterobacteria of different species (*Pseudomonas*, *Micrococcus*, *Bacillus*), including opportunistic pathogens. And the subsequent rational selection of sealed packaging and adherence to temperature regimes of storing could make it possible to restrain to a certain degree the growth of pathogenic microflora until the expired storage date of the developed product.

However, all the above-mentioned aspects cannot warrant the 100 % absence of foreign microflora in the finished milk-containing curds-based sour milk product (introduced due to the use of animal-origin products – egg yolk powder). Consequently, in addition to the implementation of microbiological control over the indicators of the resulting curds-based products (according to DSTU 4503:2005. Curds-based products. General Technical Requirements), additional classic, alternative, and fast methods of microbiological research are needed in accordance with the acting standard on egg products (DSTU 5028:2008). Specifically:

- determining QMAFAnM (not more than $5 \cdot 10^5$ CFU/g), with the bacteria of the *Escherichia coli* group titer not below 0.1;
- determining bacteria of the *Escherichia coli* group (coliform bacteria) (not allowed in 0.1 g of the product);
- revealing the bacteria of genus *Salmonella* (absent in 25 g of the product);
- revealing the bacteria of genus *Proteus* (absent in 1 g of the product);
- revealing the bacteria *Staphylococcus aureus* (absent in 1 g of the product).

Considering the above arguments, it is promising to undertake a further microbiological study of both the finished milk-containing curds-based sour milk product and when storing it, including a microbiological analysis at the expiration of shelf life.

Certain limitations of our research include:

- a narrow range of the examined emulsifiers of natural origin (only from animal sources), which could prove effective in the technology of a milk-containing curds-based sour milk product;
- the results of the current scientific study could be used only for the developed milk-containing curds-based sour milk product. Their application in technologies of other dairy products with the combined composition of raw materials is limited, first of all by the difference in the fat mass fraction of such products and their inherent specific physical and chemical properties;
- the absence in the tasks of our study the examination of functional substances (phospholipids) from each selected emulsifier and proving the dependence of their moisture-retaining capacity in the emulsion composition on the amount of an active component (lecithin).

Areas of further research include:

- studying the efficiency of plant sources of lecithin in the technology of a milk-containing curds-based sour milk product;
- examining the potential of using egg yolk powder as an emulsifier in other technologies of dairy products with a combined composition of raw materials (sour cream product, spread, etc.);
- investigating the effect exerted by the amount of functional substances in the emulsifier composition on its emulsifying properties (specifically, MRC indicators);
- conducting a microbiological study of the finished milk-containing curds-based sour milk product with a 50 %

replacement of the fat mass fraction with a blend of vegetable oils using egg yolk powder as an emulsifier (3 % of the blend introduced).

The data reported here could be used for the development of technological schemes for making milk-containing products (with a 50 % replacement of the fat mass fraction with a blend of vegetable oils). In this case, small, effective doses of the emulsifier (egg yolk powder) would be absolutely acceptable for a manufacturer. The creation and introduction of such products for mass consumption could be economically beneficial (due to the use of natural raw materials only) for enterprises in the dairy industry. That would also possess a social effect due to their functional properties.

7. Conclusions

1. We have substantiated the expediency of using phospholipids and phosphatidylcholine from egg products as effective emulsifiers of natural origin (the emulsifying mixture "Prottekt 01" was used as control). The rational amount of

the introduction of egg yolk powder, 3 %, egg powder, and albumin, 4 %, has been determined, which ensures a 100 % FRC value and does not affect the organoleptic parameters of the emulsifying mixture product.

2. It is established that the 100 % stability of direct emulsions «o/w» is achieved when using: egg yolk powder – 3 % of the fat mass, egg powder, or albumin – 4 %.

3. We have established the rational correlation among the formulation components of the emulsion, provided that the minimum amount of the water phase is introduced: a blend of vegetable oils: whey: egg yolk powder – 21:76:3, which would ensure the stability of the fat phase of the product with its use.

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