FOOD PRODUCTION TECHNOLOGY

THE SCIENTIFIC AND PRACTICAL PRINCIPLES OF CREATING PRODUCTS WITH INCREASED PROTEIN CONTENT

A. V. Bannikova[a,*], I. A. Evdokimov[b]

[a] Saratov State Agrarian University named after N.I. Vavilov,
Teatralnaia square 1, Saratov, 141012 Russian Federation

[b] North-Caucasus Federal University,
Pushkin Str. 1, Stavropol, 355009 Russian Federation

* e-mail: annbannikova@gmail.com

Received April 28, 2015; Accepted in revised form June 18, 2015; Published October 20, 2015

Abstract: The studies show that there is an increased interest in the market for the production of protein-fortified products due to the clearly observed trend of general decline in the protein intake by the population. The purpose of this work is to develop the new types of dairy products with increased protein content using the principle of products gradation for protein content, and to assess their functional and textural characteristics. The applied methods included an assessment of the rheological and textural characteristics, an optical microscopy, and the characteristic of color parameters of the products developed. It has been shown that the protein performs various functions in dairy products, such as changes in structural properties of the dairy products, reduction of fat level, and fortification of the products with the rich source of the branched-chain essential amino acids. The assessment of the textural properties of the developed products, which includes the measurements of the viscosity versus shear rate relationship, of the functional and technological properties of foam (fold and stability), and of the texture parameters (hardness and adhesion), has showed the acceptability of the developed technological solutions. The inclusion of the desired level of protein into the dairy products has not significantly affected their textural characteristics. An analysis of the viscosity-shear rate relationship has demonstrated the similar trends in the rheological properties for all the products studied. The texture of the new products was analyzed instrumentally pointing to their similarity with the commercial versions of the products containing half as much of the complete protein. The results of the study indicate the similar values of the color attributes of the developed products. The studies of the biological value of the new products has showed an increased content of the essential amino acids to an average of up to 76.9%, 80%, and 80.7% in cream, drinks, and desserts, respectively, as compared to their commercial counterparts. The amount of leucine, which is an amino acid that plays a fundamental role in the muscle protein synthesis, increased up to 61.9%, as compared to the commercial variants. This study can lay the foundation for the further development of a wide range of the structured food products with increased protein content.

Keywords: Dairy products, protein, viscosity, foam properties, texture, adhesion, biological value

DOI 10.12737/13114 *Foods and Raw Materials*, 2015, vol. 3, no. 2, pp. 3–12.

INTRODUCTION

The protein is one of the major cell components, and therefore plays an important role in functioning of a human organism. The protein, as a macronutrient, is built from the smaller units called amino acids that can be synthesized in a human organism or must be supplied from the external sources. In general, the increase in the protein intake up to 25–30 grams per meal is one of the requirements for obtaining the required amount of essential amino acids necessary to maintain or improve the health of the adult population [1, 2].

Thus, in early 2010, according to the Russian Federal State Statistics Service, nearly one in eight Russians, i.e. 12.9% of the country population, was aged 65 years or over. In the long run, the scale of aging of the Russian population will demonstrate increasing growth. Thus, according to the official demographic projection, in 2030, the share of the population aged 65 and over will increase up to 18% (according to the most optimistic scenario of growth of the total population of Russia), and up to 19.4% (according to the pessimistic scenario). This is a challenge for the changing demand for the access to the affordable services of good quality within the sphere of pension provision, health care, and social services,

as well as for the support of food industry. People aged over 65 experience decrease in the metabolism and changes in the physiology that significantly affects their nutritional needs. The wise choice of food products and a balanced diet are important for the people aged over 65 in order to maintain their health and quality of life.

Despite the growing worldwide consumer awareness about the importance of healthy eating, nearly fifty percent of people living in the developed countries suffer from a lack of essential nutrients [3]. With age and differences in the availability of nutrients, the changes in food consumption habits resulted in an imbalance between the essential nutritional ingredients contained in diet and the actual presence thereof in the consumable food products. Thus, it would be beneficial to review the criteria for food in order to prevent and treat the inadequate intake of protein in the diet of adults. Consequently, there is an increased interest in the market for the production of the protein-fortified products [4].

The quality and quantity of protein are the key considerations, since by consuming the "right" type of protein in the "right" time it is possible to achieve the consistency of the physiological responses and to optimize the protein intake. Among the amino acids that are important for the protein synthesis, the scientists distinguish the branched-chain amino acids (leucine, isoleucine, and valine), which possess the ability to stimulate protein synthesis. To improve the muscle protein synthesis, the scientists proposed to additionally include the diet with leucine, an amino acid that plays a core role in protein synthesis in cells [5].

The growing consumer interest in the easily accessible food products, which meet the nutritional needs required, led to the production of various products with specific nutritional purposes. In particular, the industry uses whey proteins (isolates and concentrates) and caseinates to produce the protein-fortified food products [6]. It is known that the texture and sensory properties of dairy products are largely dependent on the type of protein in the system. However, a market analysis has shown that the protein-fortified products are not always easily accessible for the consumers and, furthermore, do not completely satisfy the content of the desired amount of protein.

The casein is a conjugated protein, which is formed during milk fermentation. The coagulation of casein in milk occurs under the action of the proteolytic enzymes of rennet juice (cheese), the acids generated by lactic acid bacteria (cottage cheese), or by direct adding of acids (technical casein). The casein is one of the basic proteins of milk, cheese, yogurt, and other dairy products along with the whey proteins (albumin, etc.). The casein contains all the essential amino acids and is therefore an important food protein. The dried casein is a white powder with no taste and odor. In the human digestive tract, under the action of gastric enzymes (rennin, etc.), the caseinogen of milk is transformed into the casein (the enzymatic fermentation of milk). Wherein, the casein in the form of clots precipitates together with the milk fat. This precipitate is longer retained in stomach, slowly ingested, and split by the pepsin. The milk and milk products have a high nutritional value largely owing to the casein. The casein is a rich source of available calcium and phosphorus. The casein preparations are widely used in medicine, especially, in parenteral nutrition. Due to the balanced amino acid composition and high digestibility, the milk-derived casein often acts as a basis of the athletes' diet. However, because of the relatively slow process of splitting in stomach, its intake is appropriate during the long periods of rest between the workouts, for example, at night [7, 8].

The whey proteins (albumins and globulins) contain the optimal set of essential amino acids and, in terms of nutritional physiology, approach the amino acid scale of "perfect protein", wherein the ratio of amino acid corresponds to the needs of the organism, and according to the content of essential amino acids and branched-chain amino acids (valine, leucine, and isoleucine), surpass all other proteins of animal or vegetable origin [9, 10]. The whey proteins stimulate the immune system, increase the level of insulin-like growth factor, and reduce the cholesterol content better than the casein and soy protein. Moreover, the whey proteins have a low glycemic index, which optimizes the insulin secretion by regulating the blood glucose level and, thereby, prevents the occurrence of the type II diabetes. The use of the whey proteins for the fortification of dairy products is a physiologically sound and priority direction. A whey protein isolate, which is produced through micro- and ultrafiltration of whey and has a mass fraction of protein over 90%, is almost free of fat, cholesterol, and carbohydrates (lactose). A whey protein isolate is very rapidly ingested by an organism and contains a high concentration of amino acids with branched side chains, which prevail in the metabolism of muscle tissues. A whey protein concentrate is the most advantageous and common form of the whey protein containing a certain amount of fats, cholesterol, and carbohydrates (lactose) – 20% of the product weight and above.

The purpose of this work is to develop the new types of dairy products with increased protein content, and to assess the functional and textural characteristics of the products developed. The new technologies involve the application of whey protein and caseinates with the justification of the methodological principles for producing dairy products using the principle of products gradation according to the content of protein. The use of this concept will allow producing the products, the proteins in which act as a structure-forming agent and replace a part of the fat component and a source of the branched-chain amino acids, which will ultimately lead to the production of products with a full range of biological properties.

OBJECTS AND METHODS OF STUDY

The commercially available milk ingredients were used to prepare test samples: cream with 51.5% of fat, skim milk with 0.12% of fat, whole milk (with 3.8% of fat and 3.2% of protein), and low-fat milk (with 2% of fat and 4.2% of protein).

In order to prepare the samples of cream with increased protein content, the following ingredients were used: low-esterified pectin (LEP) and sodium alginate (CP Kelco, USA), λ-carrageenan (Swift and Company Limited, Australia), guar gum (Lotus Foods Pty Ltd., Australia), ι-carrageenan (SBI, the Netherlands), xanthan (Langdon, Australia), agar (RYP Foods PTY Ltd., Australia), gelatin (Bloom 225, Gelita, Germany), and whey protein isolate with a mass content of protein - 90 g, fat - 1.5 g, carbohydrates - 0.5 g, and sodium - 0.7 mg per 100 g of product (Asceno Sport, Australia).

The concentration of fat content in cream was reduced by adding an appropriate proportion of skim milk. The confirmation of the final fat content of 35% in the modified cream was carried out using the method of Babcock. In order to prepare the final samples of cream with increased content of protein, the aqueous solution of the whey protein isolate with the specified stabilizers were added to the cream with 35% of fat content, which reduced the fat content from 35% down to 20%.

To prepare the samples of drinks, the following ingredients were used: Alanate 180 sodium caseinate (Fonterra, New Zealand), carrageenan (FMC, USA), Cetrolex G lecithin (Langdon, Australia), inuline (Orafti, Belgium), cocoa powder (Maltra Foods, Australia), food coloring agents - chocolate brown (Hanson, Australia), cherry pink (Queen Food Colouring Company, Australia), and natural vanilla flavoring agent (Queens Fine food, Australia).

To prepare the samples of milk drinks, the dry ingredients and the skim/whole milk were separately weighted, and then stirred for 20 minutes at room temperature. In order to ensure the proper dissolution of the ingredients, the system temperature was increased up to 50°C followed by a four-step homogenization (FT9, Armfild, UK). The heat treatment of drinks was carried out at 85°C during 5 minutes using a pasteurizer, as well as through the ultra-high temperature treatment (UHT) with the plate heat exchanger system (FT74X, Armfild, UK) at 140°C during 2 to 5 seconds. The drinks were filled into the sterilized glass containers (250 ml) in aseptic conditions and stored at 4°C for 24.0 ± 1.0 hours prior to the physical and chemical analysis.

To prepare the samples of desserts, the following ingredients were used: Lacprodan DI-7017 whey protein concentrate (WPC) (Arla Foods Ingredient Group, Denmark), Alanate 385 calcium caseinate, Alanate 180 sodium caseinate, whey protein isolate (WPI) (Fonterra, New Zealand), Peptiplus XB hydrolyzed gelatin (Gelita, Germany), Gelcarin GP379 carrageenan (FMC, USA), xanthan (CP Kelco, USA), hydroxypropyl distarch phosphate (National starch, USA), High Bloom 25 gelatin (Gelita, Germany), Cegepal TG 186 vegetable fat (BASF, Australia).

To prepare the samples of the commercially frozen desserts (4 kg), the dry ingredients and the skim/whole milk were separately weighted, and then stirred for 20 minutes at room temperature. In order to ensure the proper dissolution of the ingredients, the system temperature was increased up to 50°C followed by a four-step homogenization at 70 bars. The heat treatment of desserts included heating up to 85°C and holding at this temperature for 5 minutes. The samples were cooled to 55°C, filled into plastic containers (120 ml), and stored at –20°C, which is a commercial product storage temperature. For conducting the physico-chemical and sensory tests, the dairy desserts were thawed at 4°C for 24.0 ± 1.0 hours prior to testing.

The relationship of the system's viscosity versus shear rate of the yoghurt samples was determined by a AR-G2 rheometer (TA Instruments, USA) using a parallel geometry of 40 mm in diameter at 4 and 22°C.

The functional properties of the cream foam were determined through measuring the fold and stability of foam. The fold was determined as the percentage of the foam volume increase to the volume of initial mixture due to the inclusion of air [11]. The foam fold was determined by whipping the cream on a low (first) speed (by a Breville Wizz Mix mixer). The foam fold was measured every 30 seconds when whipping, which lasted until the maximum fold was achieved (about 3 min). However, the whipping continued until the clearly separated phases of fat and liquid were obtained. In order to determine the foam fold percentage, the following formula was used [12]:

$$\text{Fold (\%)} = [(\text{fixed volume after whipping} / \text{fixed initial volume}) - 1] \times 100. \quad (1)$$

After achieving the maximum foam fold, its stability was assessed during 7 hours. According to the data obtained, there were built the relationships of the foam fold percentage versus the time of whipping and the foam stability within the time specified. The experiments were performed in a three-fold repetition.

The light microscopy of cream and its whipped texture with full and reduced fat content was carried out using a Leica DM 2500 microscope (Wetzlar, Germany) with an attached Leica DFC400 digital camera with a 100× lens. The samples were prepared for a microscopic examination by spreading the cream on a slide in a not too thick and not too thin layer ensuring that the structure of the product was not destroyed. A cover glass was used to obtain a flat surface of images.

The hardness and adhesiveness of the samples were determined using a TA.XT2 texture analyzer (Stable Micro Systems, England) with a cell load of 5 kg. The measurements were carried out using an aluminum cylindrical probe (25 mm in diameter) submersible into a ring with a diameter of 40 mm for sample compression. The tests were conducted at a speed of 1 mm/s with a pressing force of 10 g until the sample compressive deformation of 80% of the original height was obtained. The mechanical properties (hardness) were assessed by interpreting the experimental data into stress (kPa) depending on the strain. After a compression cycle, the aluminum probe returned back to its original position. Since the dairy desserts are adhesive, the monitor displays a negative area taken as a measure of the sample's adhesiveness. This parameter has no units of measurement and is expressed in the internal units of the computer program. Each experiment was repeated three times. An average value of the hardness

and adhesiveness was accepted. All experiments were conducted at room temperature (22 ± 1°C).

The assessment of the milk drinks color was carried out by a Minolta colorimeter (CR-100, Japan). Various color gamut are given in scales L*, +a*, -a*, +b*, -b* representing the degree of white, red, green, yellow and blue colors, respectively [13]. Initially, the device was calibrated with the following values of color gamut: Y = 93.13, x = 0.3138, y = 0.3199. 40 ml of the drink sample were poured into the small plastic containers with the subsequent measurement of the color attributes in three repetitions. The color of the new milk drink compositions, as compared to a commercial sample, was determined by calculating the degree of luminance, color value (C^*), color hue angle (h_{ab}), and general characteristic of color ΔE using the following equations [14]:

$$\Delta E^*_{ab} = ((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)^{1/2}, \quad (2)$$

$$\% \text{ of } \Delta E^*_{max} = (\Delta E^* \times 100) / \Delta E_{max}, \quad (3)$$

where ΔE_{max} is the standard value (ΔE_{max} = 196.98).

$$C^*_{ab} = ((a^*)^2 + (b^*)^2, \quad (4)$$

$$h_{ab} = \tan^{-1} (b^*/a^*), \quad (5)$$

$$\Delta H = ((\Delta E^*_{ab})^2 - (\Delta L^*)^2 - (\Delta C^*)^2)^{1/2}. \quad (6)$$

Usually, the ΔE value indicates the general difference between the two products without specifying the direction of the changes (due to *L*, *a*, *b* or their combinations). Thus, by detecting a color hue angle (h_{ab}), it is possible to claim the absolute difference in color, while ΔH describes the Euclidean color difference between the two samples.

RESULTS AND DISCUSSION

The functional and technological properties of cream with a protein content of about 4%

Many studies in Russia have found that there is not enough complete protein in the diet of Russians. Quite often this fact causes decrease in immunity, heart muscle disorders, hormonal disorders, digestive system disorders, etc. The protein is an organic compound comprising 22 amino acids that are the basic building material for a human organism. The proteins are involved in many biological processes and perform many diverse functions. In order to investigate the potential of protein, the principle of protein gradation was chosen as a basis for producing structured dairy products. This principle is based on the production of dairy products comprising about 4% (whipped products), 6% (milk drinks), and 12% (dairy desserts) of protein. The choice is substantiated by an analysis of structural characteristics of various systems comprising an increased amount of protein as well as by the assessment of texture formation of the structured dairy products depending on the protein content.

A commercial sample containing gelatin was taken as a basis for developing whipping cream with increased protein content. The increase in the protein content and the decrease in the content of a part of fat component in the products under study were carried out by adding a whey protein isolate possessing a high content of essential amino acids. In order to determine the textural properties of the developed products, their viscosity-shear rate relationship was measured (Fig. 1). The rheological characteristic of behavior of the samples with reduced fat content and with increased protein content indicates the imitation of textural properties of the cream with gelatin and full fat content, which confirms the appropriateness of applying the advanced technologies of cream production according to the nutrition concept.

It is confirmed that the whipping cream with reduced fat content and with increased protein content produced the texture similar to that of the cream with full fat content and with gelatin. Since whipping is the designated purpose of the products, the functional and technological properties of foam of the developed cream samples were assessed as compared to the samples of the cream with full fat content and with gelatin. The foam fold of the cream with increased protein content was similar to the foam fold of the cream with full fat content (Fig. 2). This indicator is

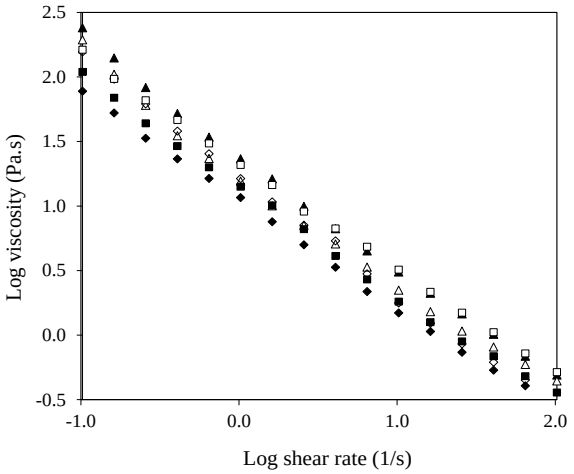


Fig. 1. The viscosity-shear rate relationship for the samples of whipping creams with full fat content with gelatin (▲); and reduced fat content with whey protein isolate and agar, LEP, and guar gum (Δ); ι-carrageenan, λ-carrageenan, and guar gum (♦); sodium alginate, λ-carrageenan, and guar gum (■); ι-carrageenan, LEP, and guar gum (◊) at 5°C.

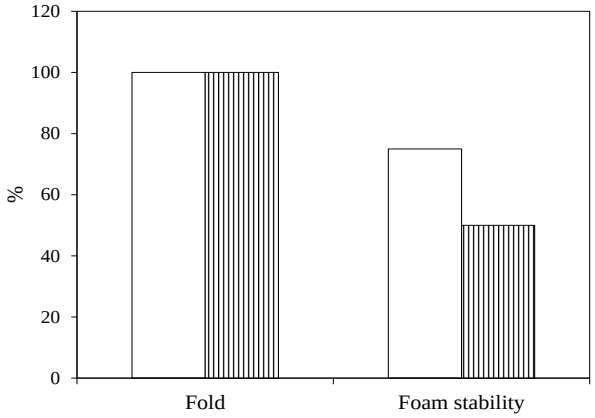
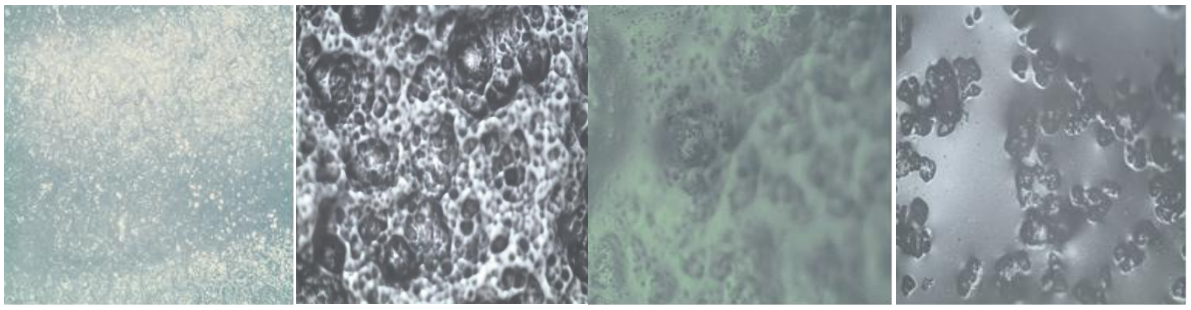


Fig. 2. The fold and stability of foam during 7 hours of the samples of whipping creams with full fat content and gelatin (left), and with full fat content with whey protein isolate, ι-carrageenan, LEP, and guar gum (right).



(a) (b) (c) (d)

Fig. 3. The photomicrographs of the gelatin-stabilized cream with full fat content, and of the polysaccharide-stabilized cream with reduced fat content with whey protein isolate (formulation of ι-carrageenan, λ-carrageenan , and guar gum) (a and b, respectively), and of the whipped cream of these systems (c and d, respectively). The photomicrographs are obtained with a 100×lens.

desirable since it is known that the currently existing cream with reduced fat content do not produce the foam fold similar to that of the cream with full fat content. The foam stability of the cream with reduced fat content was 30% lower than of the cream with full fat content and with gelatin. This indicator is expectable since in the cream with full fat content, the fat is the primary foam-forming and foam-stabilizing agent, which allows obtaining systems with high content of dry substances. After storage, the whey separation was not observed in all samples.

Four photomicrographs of the cream before and after whipping are presented in Fig. 3. These photomicrographs are shown for identifying the difference in the microstructure of the cream with full fat content and with gelatin, and of the cream with reduced fat content and with increased protein content stabilized by ι-carrageenan, λ-carrageenan, and guar gum. The cream with gelatin before and after whipping demonstrated a significant share of fat phase in their content (Fig. 3a, 3c). This product is homogeneous and single-phase with uniformly dispersed air bubbles. Unlike this system, the polysaccharide-stabilized cream with reduced fat content and with increased protein content demonstrated a three-phase system on a microscopic level. This behavior is related to the term of "thermodynamic incompatibility", which leads to the formation of a homogeneous system with a delicate, pliable, and air structure (Fig. 3b, 3d).

Thus, this study allows us to assess the functional and technological properties of the products with a reduced fat content and a protein content of about 4% additionally stabilized by the dietary fibers. The present results have shown the appropriateness of applying a whey protein isolate as a substitute for a part of the fat component, which, in turn, corresponds to the modern trends in food production.

The assessment of the rheological and color parameters of drinks with a protein content of 6%

The casein contains all the essential amino acids, and is therefore an important dietary protein. Unlike the whey, which is soluble and therefore rather quickly digestible and absorbable, the casein takes the form of tiny micelles or globules, which are almost insoluble and form clots in the stomach. The recent studies have shown that the slow digestibility of casein stops the process of catabolism (cleavage) of the muscle protein, thereby contributing to the intensification of the muscle growth. In addition, the scientific studies of the Texas University Medical Branch have recently shown that the casein is nearly as effective in stimulating the muscle protein synthesis as the whey protein.

Besides the caseinate usage in the technology of milk drinks production, the purpose of this study is to include the natural inuline prebiotic. The inuline promotes the

growth of the beneficial intestinal microflora, and thus has a positive effect on the digestive process. Moreover, the inuline helps our organism to better ingest calcium and magnesium, contributes to improvement of the human immune system and to the enhancement of the lipid metabolism (cholesterol reduction). In addition to its healing properties, the inuline has other useful properties. Thus, it is capable of providing the products with a creamy saturation and texture, but also increases the feeling of satiety, which is especially important for the people who take care of their diet.

During the course of study, the various technological solutions on the protein and prebiotic inclusion into the new milk drinks were generated. In particular, the authors stated the technological solutions on the inclusion of sodium caseinate, lecithin, carrageenan, and inuline into the technology of the milk drinks production, which allows obtaining a product that contains about 6% of protein and 2% of prebiotic, as compared to a prebiotic-free commercial product that contains only 3.3% of protein. The rheological properties of the new milk drinks produced in two ways, as compared to a commercial sample, indicated the reproduction of the trend in the change of viscosity depending on the sear rate, as shown in Fig. 4. The curves of the viscosity versus shear rate relationship for all tested samples were similar and indicated the identical values of viscosity, for example, η~66 mPa·s (0.1 s^{-1}) and η~27 mPa·s (100 s^{-1}).

The UHT treatment makes it possible to process a product at a very high temperature (140°C) with holding for a short period of time (2–5 sec.) in the heating section of the plate heat exchanger system followed by the immediate cooling of a product to the room temperature in the cooling section. The pasteurization, which was also applied in the production of drinks during the course of study, also allowed processing the products at 85°C with holding for 5 minutes without the immediate process of cooling. It is shown that the UHT treatment is preferable for developing the food products of long-term storage, which was additionally analyzed by studying the physical changes in a product, and in particular, the variations in color.

In order to assess the color of the new products, as compared to the commercial ones, we applied the CIE modified in 1976 colorimetric systems with the new standardized color spaces called as the CIE 1976 *L*a*b** color space. A CIELAB color model is currently the main color space for the analysis and description of the physical colors. The formulas for calculating the *L*a*b** and their obtained polar coordinates *L*C*h** were defined in 1990 with the new version of the DIN 5033-3 standard. The *L*a*b** are the color gradations in a color space, which are defined as follows: *L** for the luminance, *a** for the gradation of the red-green hues, *b** for the gradation of the yellow-blue hues, *C** describes saturation, and *h** describes the color hue in the CIELAB circle [4, 5]. For many years, it was recognized that the values of *L**, *a**, *b** showed the most appropriate changes in color in the dark area, which is of especial importance for the chocolate drinks. Usually, the "*L*" values are used to denote the difference in the whiteness of a sample, while the "*a*" and "*b*" values characterize the redness and yellowness of the tested materials, respectively [15].

The color differences between the commercial and developed samples in Table 1 show that the milk drinks fortified with protein and prebiotic are lighter than a commercial sample, i.e. the *L** value of the new drinks is higher. However, the difference of 5 units in the *L** value between the commercial product and our developed product cannot be determined visually. Such color parameters as *a** and *b** possess positive values for both products, though it should be noted that the values of redness and yellowness are higher in the test sample, as compared to the commercial product. For the determination of whiteness, the differences of 1 or 2 units in the values of *a** and *b** are not significant and cannot be determined visually.

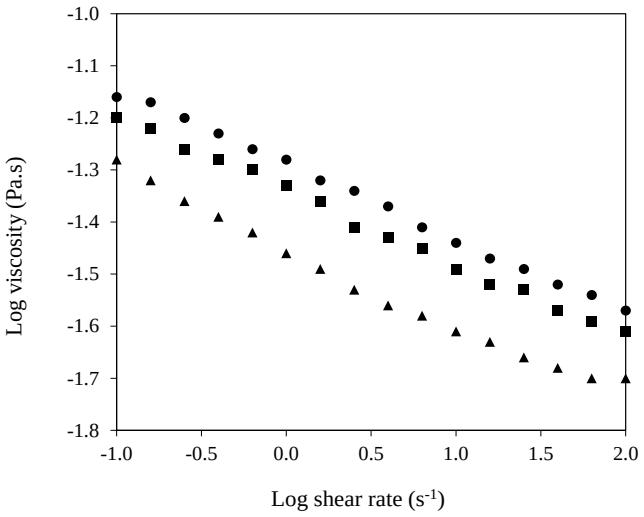


Fig. 4. The viscosity-shear rate relationship for a commercial sample of the milk drink containing 3.3% of protein (▲), and of the developed milk drinks with more than 6% of protein and 2% of prebiotic obtained through the UHT treatment (■) and pasteurization (●) at 4°C.

In general, the color distinctiveness (E^*_{ab}) between a commercial product and a protein/prebiotic-fortified drink was 5.43 ± 0.53, while the maximum possible color distinctiveness (E^*_{max}) between the two materials was 2.75%, which is in the area between the low (<0.5%) and high (5%) distinction in color. The color values in Table 1 for a commercial product and an experimental sample were determined as 13.49 ± 0.16 and 15.56 ± 0.04, respectively. This means that the product produced in this work is 15.34% more luminous than the commercial milk drink [(15.56–13.49)/13.49]. The actual color of the milk drinks was shown in the measurement of the color hue angle (h_{ab}) in Table 1 in order to demonstrate a small difference in the measured values of a^* and b^*. Thus, the milk drink fortified with protein and prebiotic was closer to the pale red color with yellow hue (h_{ab} = 57.66 ± 0.06), while the commercial product (h_{ab} = 55.58 ± 0.04) had a slight yellow hue. The difference between the hues of the tow milk drinks was rather small (ΔH = 0.53 + 0.03).

The results of this study indicate that both milk drinks (a commercial product and a test sample) showed the similar values of color attributes and the flux behavior, as shown in Fig. 1 and Table 1, which is very promising from the standpoint of developing the new functional technological solutions. The further development of these products should include the output of a larger batch of the product, the assessment of its general consumer acceptability, and the characteristic of some sensory properties using the human sense organs.

The rheological and textural characteristics of the developed desserts with a protein content of about 12%

In order to determine whether the technological parameters of the desserts production are approximated to the production parameters applied in this study, a prototype of a commercial dessert was reproduced, which was subjected to the tests on the viscosity versus shear rate relationship within the study concept and comparison of the textural properties of the produced counterpart and the commercial sample. The work was carried out using the parameters described in the "Objects and Methods of the Study" section.

Fig. 5 shows the rheological properties of the commercial sample and the counterpart of the commercial sample with the increase in the shear rate from 0.1 up to 100 s^{-1}. The trend of the steady decline in the viscosity values at shear demonstrates the linear descending profile of the textural properties indicating the dilution. The results show that our attempts to reproduce the textural characteristics of the commercial product were quite successful with the viscosity values for the two systems within the range of 100 to 1 Pa·s at the beginning and at the end of the experiment, respectively.

A texture analysis complements the above-mentioned small shear strains focusing on the instrumental properties of hardness and adhesion. The results indicate that the dairy desserts produced in a production workshop have similar values of hardness and adhesiveness indicating that these materials possess a "rich" texture (Fig. 6, 7).

The experimental work on the study of textural properties of the commercial dessert sample and its prototype developed in the laboratory allowed suggesting the new technological solutions on the protein fortification of desserts using a whey protein isolate (WPI) and a whey protein concentrate (WPC, Alacen 392 and Lacprodan). The data of the technological solution are based on the improvement of the product's nutritional characteristics along with preserving the pleasant organoleptic profile typical of dairy desserts. As noted earlier, it is known that the leucine is one of the most important amino acid for people over 60 years due to its specific action on the production of ribosomes, which are the place for the protein production in cells. Thus, it was noted that the additional fortification of food products with leucine improves the muscle protein synthesis in the adult population [16]. In this context, the dairy ingredients are an excellent source of protein with the high levels of branched-chain amino acids including the leucine; they are available in flexible formats, easily digested and can be included in a diet [17].

It should be noted that in this work, in order to increase the content of protein in desserts, about 150 formulations were developed, which were exposed to the thorough sensory and textural control. Some of these were inappropriate in terms of texture, as compared to the commercial sample. Therefore, only those samples of desserts, the properties of which were similar to the commercial product, were selected for the further study and included into the work. Thus, four samples with the content level of about 12% of protein and 1.2% of leucine were developed and compared according to the textural and nutritional properties to the commercial sample containing only 6.7% of protein and less than 0.5% of leucine.

Table 1. The color parameters for the commercial and test samples of milk drinks

Sample	Visual assessment of color	L^*	a^*	b^*	C	h_{ab}	ΔE^*_{ab}	ΔH
A commercial sample	Chocolate brown color	54.36 ± 0.40	7.63 ± 0.09	11.14 ± 0.12	13.49 ± 0.16	55.58 ± 0.04	5.43 ± 0.53	0.53 ± 0.03
A test sample fortified with protein and prebiotic	Chocolate brown color	59.35 ± 0.13	8.33 ± 0.03	13.15 ± 0.03	15.56 ± 0.04	57.66 ± 0.06		

Note. N = 3; L^* = axis of luminance (0 – black, 100 – while); a^* = red-green axis ("+"– value of red, "-" – value of green, 0 is neutral); b^* = blue-yellow axis ("+"– value of yellow, "-" – value of blue, 0 is neutral); C = color value; h_{ab} = color hue angle; E^*_{ab} = total difference in color; ΔH = difference between hues.

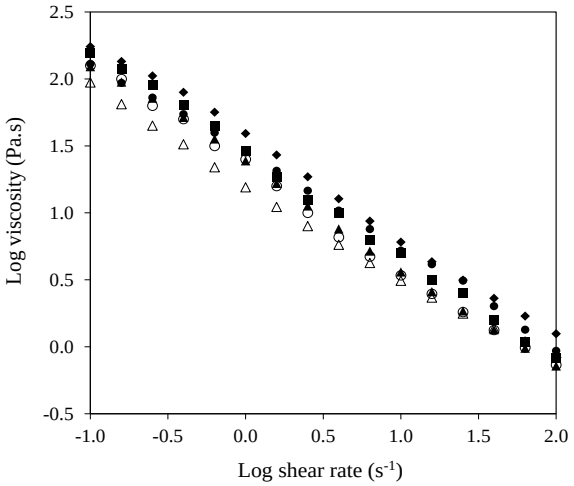


Fig. 5. The viscosity-shear rate relationship for a commercial sample of a dessert (Δ), a counterpart of a commercial sample prepared in the laboratory (●), and of the desserts fortified with protein with 2.6% of WPI and 7.8% of Lacprodan (♦), 3.2% of WPI and 7.5% of Lacprodan (○), 3% of WPI and 7.1% of Alacen 392 (■), and with 3% of WPI and 7% of Alacen 392 (▲) at 22°C.

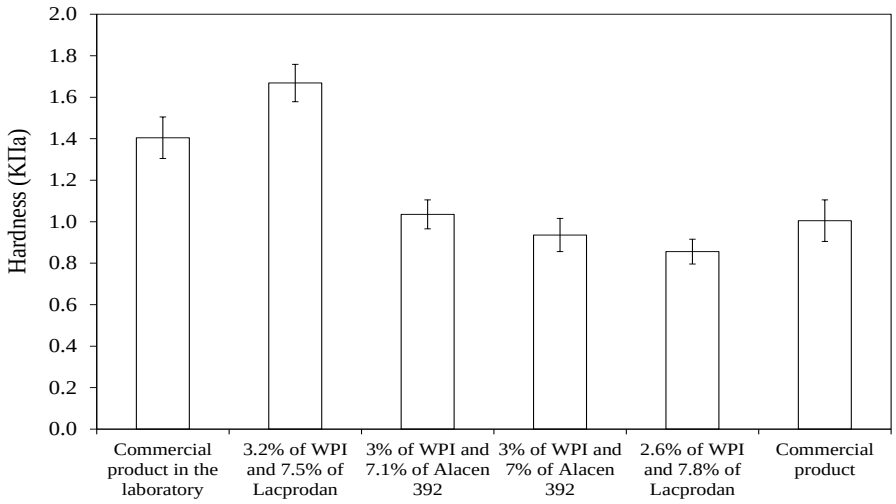


Fig. 6. The hardness of a commercial sample of a dessert, a counterpart of a commercial sample prepared in the laboratory, and of the desserts fortified with protein with 2.6% of WPI and 7.8% of Lacprodan, 3.2% of WPI and 7.5% of Lacprodan, 3% of WPI and 7.1% of Alacen 392, and with 3% of WPI and 7% of Alacen 392 at 22°C.

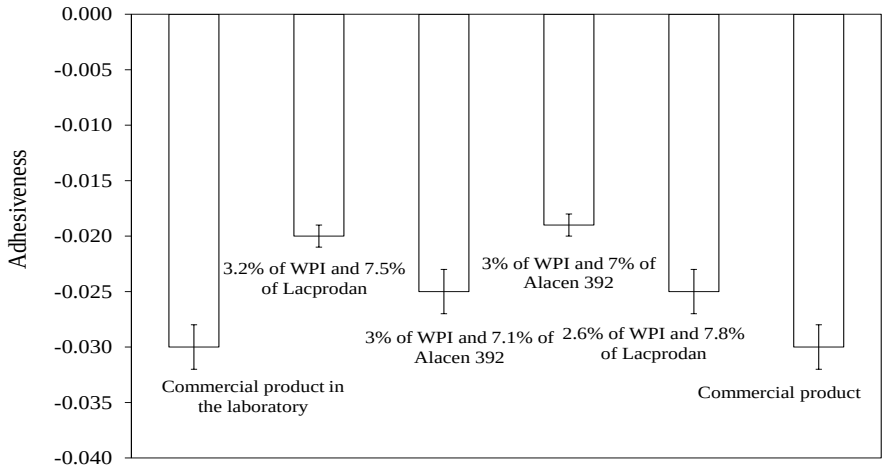


Fig. 7. The adhesiveness of a commercial sample of a dessert, a counterpart of a commercial sample prepared in the laboratory, and of the desserts fortified with protein with 2.6% of WPI and 7.8% of Lacprodan, 3.2% of WPI and 7.5% of Lacprodan, 3% of WPI and 7.1% of Alacen 392, and with 3% of WPI and 7% of Alacen 392 at 22°C.

Fig. 5 shows that the commercial prototype of the dessert and the four developed products with the high protein content demonstrated similar behavior of dilution at the increase in shear indicating the structure of a soft gel for the studied dairy desserts. Three developed desserts containing from 2.6 to 3% of WPI and from 7 to 7.8% of WPC (Lacprodan or Alasen 392) demonstrated the similar values of hardness (about 0.9 kPa), shown in Fig. 6. The figure also shows that the gel-like structure of these samples is relatively weaker than of the developed dessert with 3.2% of WPI and 7.5% of WPC of the Lacprodan type with the hardness values of about 1.7 kPa. The obtained data on the increase in the hardness of the test samples, as compared to the commercial sample, are associated with the higher protein content forming a three-dimensional lattice in the product structure, which affects the gel strength. The change in adhesiveness under compression of the developed samples is shown in Fig. 7. It is shown that the experimental samples of desserts demonstrate the comparable adhesion values within the range of –0.02 to –0.03, which is indicative of the creamy and "rich" texture of the dairy desserts with a protein content of about 12%.

The biological value of the developed food products with the increased content of protein

As noted, one of the main directions of the government policy concept in the field of healthy eating involves the development of the mass-consumption products, the technologies of the functional purpose products differentiated for the prevention of diseases and improvement of the protective functions of an organism, and reduction in the risk of exposure to the harmful substances. Considering the fact that at present, the natural products demonstrate a reduced amount of nutrients, including the protein, it is necessary, when developing the new products, to purposefully achieve the enhancement of their biological value by fortifying these products with the functional ingredients, which contain the substantial amounts of vitamins, minerals, amino- and fatty acids.

Table 2 presents the amino acid composition of the developed cream, drinks, and desserts with the increased protein content. The table shows that the sum of the essential, non-essential, and conditionally essential amino acids in the developed samples exceeds the values of the reference samples with the full fat content. Thus, the amount of the essential amino acids in the new cream increased by 76.9%, in the drinks – by 80%, and in the desserts – by 80.7%, which ultimately increases the total content of amino acids in the cream by 82.2%, in the drinks – by 82.9%, and in the desserts – by 65.7%, as compared to the reference samples.

As already noted, the leucine refers to the group of branched-chain amino acids, which play a core role in the protein synthesis in a cell. Its increase averaged 61.9%, while the increase in another branched-chain amino acid – the isoleucine, which is necessary for

Table 2. The amino acid composition of the developed products with an increased content of protein as compared to the commercial products (g/100 g of product)

Amino acid	Cream (protein content – 4%)		Drinks (protein content – 6%)		Desserts (protein content – 12%)	
	Commercial sample	Developed cream	Commercial sample	Developed drink	Commercial sample	Developed desserts
EAA	1.0706	1.8934	1.2462	2.2793	2.6934	4.4622
Lysine	0.1986	0.3485	0.2294	0.4196	0.4958	0.8214
Methionine	0.0624	0.1178	0.0775	0.1418	0.1675	0.2775
Phenylalanine	0.1219	0.2120	0.1395	0.2552	0.3015	0.4995
Valine	0.1625	0.3062	0.2015	0.3686	0.4355	0.7215
Isoleucine	0.1385	0.2591	0.1705	0.3119	0.3685	0.6105
Leucine	0.2415	0.3909	0.2573	0.4706	0.5561	0.9213
Threonine	0.1094	0.2072	0.1364	0.2495	0.2948	0.4884
Tryptophan	0.0358	0.0518	0.0341	0.0624	0.0737	0.1221
CEAA	0.296	0.5888	0.3875	0.7088	0.8375	1.3875
Arginine	0.0871	0.1743	0.1147	0.2098	0.2479	0.4107
Histidine	0.0676	0.1319	0.0868	0.1588	0.1876	0.3108
Cystine	0.0202	0.0202	0.0093	0.0170	0.0201	0.0333
Tyrosine	0.1211	0.2685	0.1767	0.3232	0.3819	0.6327
NAA	1.233	2.2420	1.4756	2.6989	3.1892	5.2836
Alanine	0.0813	0.1272	0.0837	0.1531	0.1809	0.2997
Glycine	0.0473	0.1130	0.0744	0.1361	0.1608	0.2664
Proline	0.2496	0.4804	0.3162	0.5783	0.6834	1.1322
Serin	0.1365	0.2685	0.1767	0.3232	0.3819	0.6327
Aspartic acid	0.1807	0.3014	0.1984	0.3629	0.4288	0.7104
Glutamic acid	0.5376	0.9514	0.6262	1.1453	1.3534	2.2422
All amino acids	2.5996	4.7241	3.1093	5.6870	6.7201	11.1333

Note. EAA – essential amino acids; CEAA – conditionally essential amino acid; NAA – non-essential amino acids.

for the hemoglobin synthesis, amounted to 87%. Such an increase in the amount of the essential amino acids, especially of the branched-chain amino acids, is beneficial for the use of these products by all groups of population, since the developed structured products have the entire spectrum of biological properties required for the protein synthesis. Besides, the principle of protein gradation successively increased the concentration of the essential amino acids with preservation of the acceptable texture of the structured products.

CONCLUSION

This work is devoted to a detailed justification of the use of protein preparations rich in essential amino acids within the technology of the dairy products production. The new technological concepts in protein fortification enabled obtaining a range of products with the high nutritional and consumer characteristics. The optimal technical functionality in combination with the recommended nutritional value in the developed products has been instrumentally confirmed by assessing the functional and rheological characteristics of the structured products, which demonstrate similarity to the commercial counterparts containing less amount of the total protein. Using the whey protein and caseinates, this study on the fortification of the dairy products with the high-quality protein allows developing compositions comprising up to 12% of protein and 1.2% of leucine.

The inclusion of such products into the diet of the adult population will provide real benefits substantiated by the high level of leucine, an amino acid needed for the efficient muscle protein synthesis. In addition to the nutritional properties, the new types of the structured products possess a "rich" texture and pleasant sensory characteristics, which makes it possible to consider the developed technological concepts as the acceptable for the future implementation.

REFERENCES

1. Valeriol A., Antona G. and Nisoli E. Branched-chain amino acids, mitochondrial biogenesis, and health span: an evolutionary perspective. *Aging*, 2011, vol. 3, no. 5, pp. 464–478.
2. Burton L.A. and Sumukadas D. Optimal management of sarcopenia. *Clinical Interventions in Aging*, 2010, no. 5, pp. 217–228.
3. Loenneke J.P. and Pujol T.J. Sarcopenia: an emphasis on occlusion training and dietary protein. *Hippokratia*, 2010, vol. 15, no. 2, pp. 132–137.
4. Bannikova A.V. and Evdokimov I.A. Dairy products fortified with whey proteins. Technological aspects of production. *Dairy Industry*, 2015, no. 1, pp. 46–48. (In Russian).
5. Rom O., Kaisari S., Aizenbud D. and Reznick A.Z. Lifestyle and sarcopenia – etiology, prevention, and treatment. *Rambam Maimonides Medical Journal*, 2012. vol. 3, no. 4, pp. 1–12.
6. Katsanos C. S., Kobayashi H., Sheffield-Moore M., Aarsland A. and Wolfe R. R. A high proportion of leucine is required for optimal stimulation of the rate of muscle protein synthesis by essential amino acids in the elderly. *American Journal of Physiology Endocrinology and Metabolism*, 2006, vol. 291, no. 2, pp. 381–387.
7. Abou-Samra R. and Keersmaekers L. Effect of different protein sources on satiation and short-term satiety when consumed as a starter. *Nutrition Journal*, 2011, vol. 10, pp. 139–145.
8. Aguilera J.M. and Rademacher B. Protein gels. *In: Proteins in food processing* (R. Yada (Ed.)). Cambridge: Woodhead Publication, 2004, pp. 468–482.
9. Remeuf F., Mohammed S., Sodini I. and Tissier J.P. Preliminary observations on the effects of milk fortification and heating on microstructure and physical properties of stirred yogurt. *International Dairy Journal*, 2003, vol. 13, no. 9, pp. 773–782.
10. Fujita S. and Volpi E. Amino acids and muscle loss with aging. *The Journal of Nutrition*, 2006, vol. 136, no. 1, pp. 277–280.
11. Ostroumova T.L. and Prosekov A.Yu. The effect of protein substances on the foaming properties of milk. *Transactions of Higher Educational Institutions, Food Technology*, 2007, no. 2, pp. 43–46. (In Russian).
12. Balerin C., Aymard P., Ducept F., Vaslin S. and Cuvelier G. Effect of formulation and processing factors on the properties of liquid food foams. *Journal of Food Engineering*, 2007, vol. 78, no. 3, pp. 802–809.
13. Jafarpour A., Sherkat F., Leonard B. and Gorczyca E.M. Colour improvement of common carp (cyprinus carpio) fillets by hydrogen peroxide for surimi production. *International Journal of Food Science and Technology*, 2008, vol. 43, no. 9, pp. 1602–1609.
14. Iserliyska D., Chinnan M.S. and Resurreccion A.V.A. Physicochemical and sensory properties of a peanut drink. *Agricultural Engineering International: CIGR Journal*, 2012, vol. 14, no. 2, pp. 49–56.
15. Bayoumi H.M., Mohamed A.G., Sheikh M.M.E., Farrag A.F. and Eissa H.A. Effect of ultrafiltration permeates on the quality of chocolate milk. *Journal of American Science*, 2011, vol. 7, no. 7, pp. 609–615.
16. Newton J.P., Yemm R., Abel R.W. and Menhinick S. Changes in human jaw muscles with age and dental state. *Gerodontology*, 1993, vol. 10, no. 1, pp. 16–22.
17. Bannikova A.V. and Evdokimov I.A. *An Innovative Approach to the Production of Fortified Dairy Products with Increased Content of Protein*. Moscow: DeLi Plyus Publ., 2015. 136 p. (In Russian).

Please cite this article in press as: Bannikova A.V. and Evdokimov I.A. The scientific and practical principles of creating products with increased protein content. *Foods and Raw Materials*, 2015, vol. 3, no. 2, pp. 3–12. doi: 10.12737/13114.