Effect of a buckwheat extrudate addition on the quality of multicomponent albumin concentrates

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Abstract

Introduction. The aim of the research was to determine the influence of the moisture-binding plant ingredient addition on the quality of multicomponent albumin concentrates.

Materials and methods. Albumin mass was obtained from low-fat milk whey with an active acidity of pH 4.4-4.6 by thermoacidic coagulation: time of treatment 90±2 min at a temperature of 95±2 °C. Active acidity was determined potentiometrically; moisture content was measured using a thermogravimetric method; the moisture absorption capacity of milk-plant systems was estimated by the amount of adsorbed water; the effective viscosity of the test samples was determined on a rotary viscometer.

Results and discussion. Multicomponent albumin concentrates with buckwheat extrudate, similar in quality to modern milk protein products with fillers, were used in the present study. An optimal amount of buckwheat extrudate and a method of its preliminary preparation, which involves swelling of the plant ingredient in whey to form a milk-plant system, were proposed. The content of moisture in milk-plant systems with buckwheat extrudate increases from 70.84 to 82.27 % and is linear. Active acidity of a milk-plant system with buckwheat extrudate depends on the pH value of the ingredients. An increase in the heating temperature does not lead to a change in the active acidity of the milk-plant system. The average value of moisture absorption capacity of a milk-plant system is in the range of 58–63% and depends on the quantitative ratio of the components. For buckwheat extrudate, an increase in the water absorption capacity of the milk-plant system is observed with an increase in temperature from 35 to 65 °C, and at a temperature of 95 °C this indicator decreases by an average of 1.25 times. The optimal conditions for the swelling of the milk-plant system with buckwheat extrudate were determined, where the ratio of whey to buckwheat extrudate is 5:1 at a temperature of 63±2 °C and a holding time of 10±1 min. The optimal dose of buckwheat extrudate to albumin mass varies within 4±1%. Thus, the addition of buckwheat extrudate in larger quantities leads to a significant increase in effective viscosity and a decrease in active acidity. It is this amount of buckwheat extrudate, which has technological moisture-binding properties, that increases the moisture retention capacity of the milk-plant system. As a result, a multicomponent albumin concentrate with buckwheat extrudate with a normalized value of the mass fraction of moisture was obtained.

Conclusions. The optimal dose of buckwheat extrudate to the albuminous mass (ratio 1:5) and technological parameters of treatment (temperature (63±2 °C and the exposure time 10±1 min) to preserve the physicochemical and sensory characteristics of multicomponent milk-protein products were determined.

Introduction

The quality of raw materials and technological methods of their processing significantly affect the chemical composition and nutritional value of food products. (Picó et al., 2019). When assessing food diets, it is necessary to take into account their balance in many respects. Thus, the ratio of proteins, fats and carbohydrates in the normal diet of a healthy person should be 1:1.4:4.1 (Kelly et al., 2019).

Whey protein concentrates are biologically valuable food products that are used in the production of bakery and confectionery goods, ice cream and cheeses, cereal and nutrition bars, beverages and fortified functional foods for athletes looking to gain muscle mass (Early, 2012; Ivanov et al., 2021; Kochubei-Lytvynenko et al., 2022; Patel, 2015; Shevchenko et al., 2022).

In everyday life, a person uses a diet, which usually contains both animal and vegetable proteins. A person's daily need for protein depends on its quality: the more inferior the proteins consumed by a person are, the higher the daily rate should be, and vice versa, the closer the proteins are to the ideal in terms of amino acid composition, the lower this rate should be. Although plant proteins are incomplete, they play an important role in human nutrition (Fanzo et al., 2021; Franzoi et al., 2019). The following stages, which are presented in Figure 1.

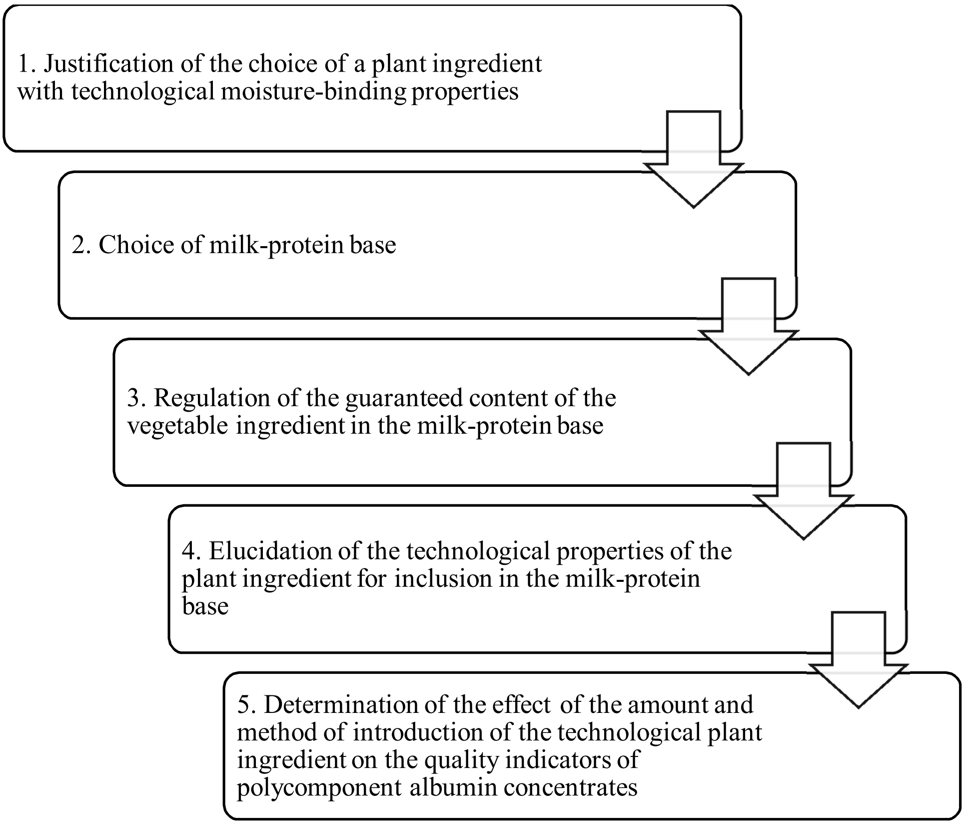

Figure 1. Stages of development of multicomponent albumin concentrates

Taking into account the principles of rational nutrition, for the enrichment of dairy products it is necessary to use ingredients that are in short supply, namely with an increased content of protein, essential amino acids, vitamins, macro- and microelements (Fanzo et al., 2021). The criteria for the selection of plant ingredients are presented in Figure 2.

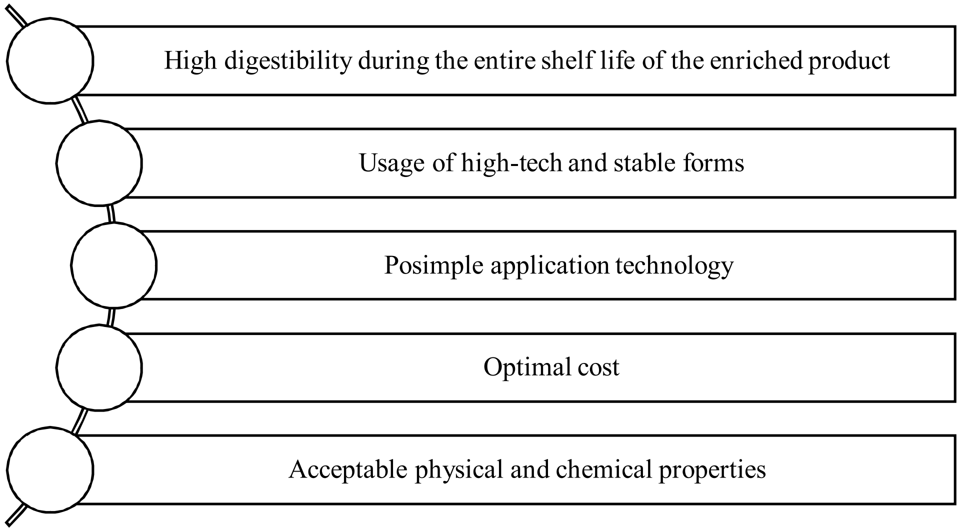

Figure 2. Criteria for selecting a plant ingredient

To expand the range of products and enrich them with nutrients, the dairy industry, along with the main raw materials, uses non-traditional fillers of plant origin, including grain ingredients processed in various ways (extrusion, infrared irradiation, and malting). In addition, they must meet the following requirements: sensory compatibility with the milk base, functional and technological properties, the method of preliminary processing of grain raw materials that increases the digestibility of all grain components, and the presence of dietary fibers.

The most promising are those that have technological moisture-binding properties with high efficiency of action in various food systems - milk and its processing products. From the spectrum of processed grain raw materials, extruded grain products deserve special attention (Grek et al., 2020a, 2020b).

Moist-thermal processing (extrusion) is one of the most common methods of converting native grain raw materials into a more edible form (Brennan et al., 2013). The cooking extrusion process is complex, since the processing of biopolymer compositions, in addition to physical ones, is accompanied by complex chemical transformations. They occur under the influence of various types of mechanical forces under the conditions of the presence of moisture and significant thermal effects in the screw extruder (Sule et al., 2024). Thus, the method of extrusion processing of grain raw materials improves its sensory indicators and increases the bioavailability of all constituent parts of the grain (Singh et al., 2019). In addition, it has a number of advantages: a high sterilization effect (destruction of almost all, even spore-forming, microflora); the possibility of enriching products with various components (protein, fibers, vitamins); low production cost (Ekielski et al., 2007).

As for the selection of products to be fortified, first of all, special attention should be paid to those that are widely consumed, available to all population groups, regularly used in food, which include protein dairy products - multicomponent albumin concentrates.

The aim of the present research was to study the effect of the technological moisture-binding plant ingredient addition on the quality indicators of multicomponent albumin concentrates.

Materials and methods

Materials

Taking into account the selected criteria, buckwheat extrudate (BE) with the composition shown in Table 1 was selected as a multifunctional technological and biologically complete ingredient (Garkina et al., 2021).

Table 1

Characteristics of the native and extruded buckwheat

Characteristics	Buckwheat	
	native	extruded
Chemical composition, % dry weight		
starch	61.50±0.1	52.70±0.1
dextrins	0.17±0.1	2.60±0.1
reducing sugars	0.20±0,1	1.76±0.1
protein	12.60±0.1	11.40±0.1
lipids	3.70±0.1	2.60±0.1
Functional and technological, %:		
moisture binding capacity	180±1	450±1
fat-binding capacity	125±1	230±1

An albuminous mass obtained from low-fat whey with an active acidity of pH 4.4–4.6 by thermoacidic coagulation during (90±2) min at a temperature of (95±2) °C. The protein base had a mass fraction of moisture – 77±2% and titrated acidity - (96±3) °T.

Low-fat milk whey had the following physicochemical parameters: content of fat, 0.2±0.1 %; dry substances, 6.30±0.02 %; titrated acidity, 18.0±0.1 ºC, pH, 5.32±0.02.

Methods

Content moisture was determined by the accelerated method on the QUARTZ-21M-33 moisture meter and by the thermogravimetric method on the laboratory electronic scales-moisture meter of the ADS series manufactured by the company «AXIS» (Poland).

Active acidity was measured potentiometrically on a Sartorius PB universal pH-meter.

Moisture absorption capacity *(MAC) of* milk-plant systems *(MPS)* was estimated by the amount of adsorbed water, respectively, in the process of infusion and centrifugation of the suspension. The process was carried out at different temperatures in low-fat milk whey.

The moisture absorption capacity was calculated according to the formula, in %:

$$MAC = (c - a) \cdot 100 / m \qquad (1)$$

where a is the mass of the supernatant liquid, g; c – mass of added liquid, g; m is the weight of the weight, g.

Effective viscosity of the test samples was determined on a rotary viscometer «Reotest II» (MLW, Germany) with a cylinder-cylinder measurement system by taking the deformation kinetics (flow) curves (Grek et al., 2019a, 2019b). Measurements were carried out in the "a" mode, which was established experimentally taking into account the structural and mechanical properties of the studied samples. Shear stress τ (Pa) was measured at twelve values of the gradient of the shear rate γ in the range from 0.33 to 145.8 s^{-1} during straight travel, for this, readings of the α value were taken at the maximum angle of deviation of the arrow on the instrument scale. Shear stress (Pa) was calculated using the formula:

$$\tau = Z \cdot \alpha \qquad (2)$$

where Z – is the constant of the cylinder, Pa·od. scales; α – readings of the measuring scale of the device.

The effective viscosity (Pa·s) was calculated according to the formula:

$$\eta = \frac{\tau}{\gamma}, \qquad (3)$$

where γ – shear rate gradient, s^{-1}.

Moisture-retaining capacity (MRC) of multicomponent albumin concentrates was determined by the Grau-Hamm modificated gravimetric method (Grek et al., 2019a). The filter was placed on a glass plate measuring 11×11×0.5. Weighed 0.3 g of the milk protein sample, with an accuracy of 0.5 mg, and transferred it to a polyethylene film with a diameter of 40 mm. From above, the film was covered with a glass plate of the same size, and a load weighing 0.5 kg was placed on it. The contents were pressed for 7 minutes. After that, the filter with the sample was released from the load and the plate. The multicomponent albumin concentrate together with the polyethylene film was removed from the filter paper and weighed. The difference in the mass of the product with the film before and after pressing indicates the mass of the separated serum. The amount of moisture retained by the sample was determined by the formula:

$$MRC = 100 (a - b) / a, \qquad (4)$$

where MRC – moisture-retention capacity of multicomponent albumin concentrate, %; a – the amount of moisture in the sample, mg; b - the amount of serum that was released from the test sample, mg.

$$a = 300 \, Wtv / 100, \qquad (5)$$

where 300 is the weight of the test sample, mg; Wtv is the content of moisture in multicomponent albumin concentrate, %.

Statistical analysis

Mathematical modeling methods (Box-Wilson cube method) were used to optimize the composition parameters of multicomponent albumin concentrates from buckwheat extrudate (BE). The determination of functional dependencies was carried out by the method of least squares.

Data were expressed as means ± standard deviations for triplicate determination. Statistical analysis was performed using Microsoft Excel 2007.

Results and discussion

Technological characteristics of milk-plant system with buckwheat extrudate

In order to obtain multicomponent albumin concentrates with buckwheat extrudate, approaching in terms of quality indicators to modern milk-protein products with fillers, the task was, first of all, to establish the optimal amount of buckwheat extrudate and the method of preliminary preparation, which involves the swelling of the vegetable ingredient in milk whey lasting 10±1 min with the formation of the milk-plant system. The main technological characteristics of milk-plant system with buckwheat extrudate are given in Table 2.

Table 2

Technological characteristics of milk-plant system with buckwheat extrudate

Ratio of components in milk-plant system (x_1)		Temperature, °C (x_2)	Content of moisture, % (Y_1)	Active acidity, pH (Y_2)	Moisture-retaining capacity, % (Y_3)
Milk whey	Buckwheat extrudate				
3	1	35	70.84±0.10	4.14±0.03	69.47±0.15
3	1	65	70.84±0.11	4.14±0.01	77.28±0.20
3	1	95	70.84±0.05	4.14±0.02	62.24±0.17
5	1	35	78.09±0.12	4.00±0.01	59.68±0.14
5	1	65	78.09±0.11	4.00±0.02	74.89±0.12
5	1	95	78.09±0.05	4.00±0.01	57.43±0.11
7	1	35	82.27±0.20	4.19±0.03	48.91±0.11
7	1	65	82.27±0.15	4.19±0.02	54.59±0.12
7	1	95	82.27±0.17	4.19±0.01	44.02±0.16

The content of moisture in milk-plant systems with buckwheat extrudate increases from 70.84 to 82.27 % and is linear. Active acidity of milk-plant system with buckwheat extrudate depends on the pH value of the ingredients. An increase in the heating temperature does not lead to a change in the active acidity of the milk-plant system. The average value moisture absorption capacity of milk-plant system is in the range of 58–63% and depends on the quantitative ratio of the components. For buckwheat extrudate, an increase in the water absorption capacity of the milk-plant system is observed with an increase in temperature from 35 to 65 °C, and at a temperature of 95 °C this indicator decreases by an average of 1.25 times.

The rheological parameters of milk-plant system with buckwheat extrudate were studied in the temperature range where the moisture-binding properties of the system increase. Changes of effective viscosity at different ratios of ingredients in milk-plant system and temperatures are shown in Figure 3.

The effective viscosity of the milk-plant system with buckwheat extrudate depends more significantly on the ratio of the ingredients. At temperatures of 35 and 65 ºC, the viscosity of the milk-plant system does not increase significantly, but when heated to a temperature of 95 ºC, this indicator decreases by an average of 1.8 times. This phenomenon can be explained by the fact that during repeated heat treatment, a deeper hydrolytic breakdown of plant proteins and carbohydrates occurs, which affects the reduction of the effective viscosity of the system (Yang et al., 2015).

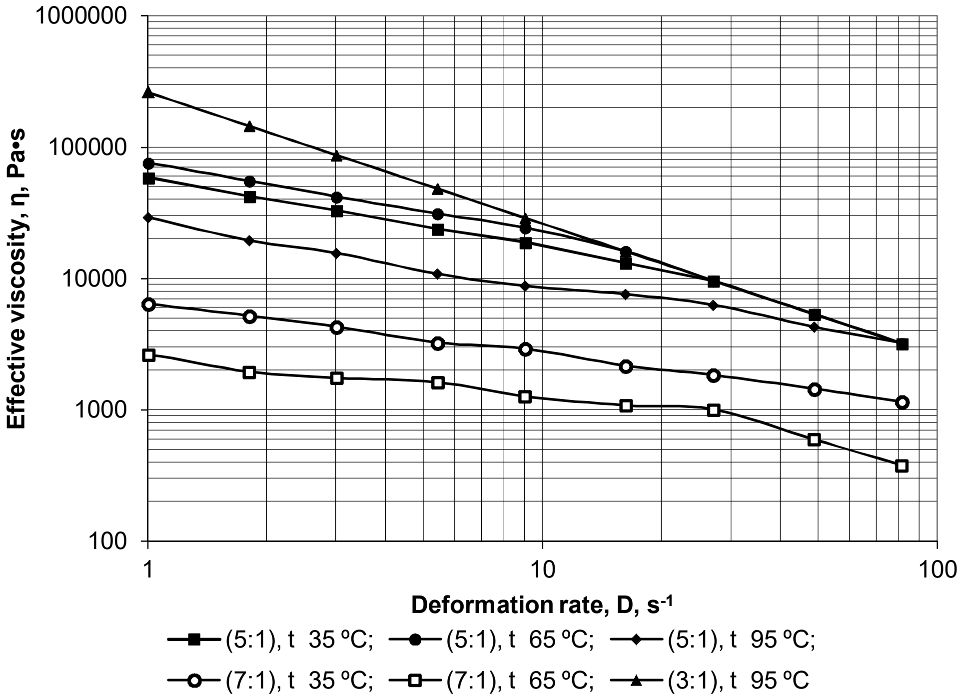

Figure 3. Dependence of effective viscosity of milk-plant system with buckwheat extrudate on the rate of deformation

So, the optimal conditions for the swelling of milk-plant system with buckwheat extrudate were determined, under which the quantitative ratio of milk serum to buckwheat extrudate is 5:1 at a temperature of 63±2 °C with a holding time of 10±1 min.

Optimization of the ratio of components in mixtures of albumin concentrates with buckwheat extrudate

In order to optimize the ratio of components in mixtures of albumin concentrates with buckwheat extrudate, the amount of grain filler was determined to obtain a product with appropriate sennsory, physicochemical, and rheological properties. The most objective characteristic of the consistency of multicomponent albumin concentrates is the effective viscosity.

The choice of the optimal dose of buckwheat extrudate was based on the principle of preservation of sensory properties, which are characteristic of modern milk-protein products with fillers and are 4±1% to the albumin mass. Its smaller amount does not affect the properties of the finished product, while its excess makes the structure inhomogeneous and too dense.

As part of the experiment, a full-factorial experiment was used to determine the optimal amount of milk-plant system with buckwheat extrudate, which must be added to the albumin mass in order to obtain a product with a normalized content of moisture. The physicochemical properties of polycomponent albumin concentrates with buckwheat extrudate were chosen as optimization parameters. In order to achieve the set goal, complex indicators were chosen that most characterize the effect of pre-prepared buckwheat extrudate on the quality of multicomponent albumin concentrates (Figure 4).

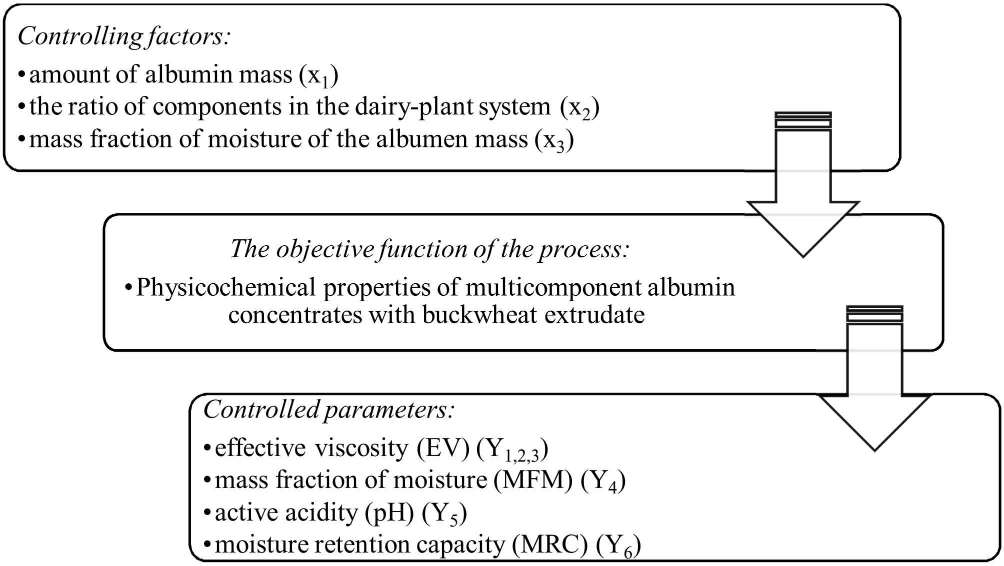

Figure 4. Scheme for optimizing the ratio of components in mixtures of albumin concentrates with buckwheat extrudate

With the help of mathematical and statistical processing of experimental data, regression equations were obtained and their graphical interpretation was given (Figs. 5, 6) for multicomponent albumin concentrates with buckwheat extrudate, which have the following form for:

– the effective viscosity of the test samples, respectively, at the rate of deformation 27, 81 and 243 s^{-1} (η_{ef}), Pa·s:

$$Y_{1(EV)} = 487.06 - 44.15x_1 - 254.14x_2 - 152.68x_3 + 76.33x_1x_2 + 34.13x_1x_3 + 119.12x_2x_3$$

$$Y_{2(EV)} = 291.75 - 31.38x_1 - 142.67x_2 - 87.55x_3 + 44.23x_1x_2 + 31.15x_1x_3 + 72.33x_2x_3$$

$$Y_{3(EV)} = 127.98 - 42.47x_2 - 33.42x_3 + 10.06x_1x_2 + 11.55x_2x_3$$

– mass fraction of moisture (MFM), W, %:

$$Y_{4(MFM)} = 74.01 - 3.10x_1 - 0.45x_2 + 5.19x_3 - 2.65x_1x_2 + 2.09x_1x_3 - 1.50x_2x_3$$

– active acidity (pH):

$$Y_{5(pH)} = 4.03 + 0.04x_1 - 0.07x_2 - 0.20x_3 + 0.04x_1x_3 + 0.02x_2x_3$$

– moisture-retaining capacity (MRC), %:

$$\mathrm{Y}_{6(MRC)} = 67.57 + 1.19x_1 - 3.16x_2 - 12.15x_3 - 0.41x_1x_2 - 0.54x_2x_3 - 4.34x_1x_3 .$$

For the equations given above, the condition $F_p < F_T$ is fulfilled, which makes it possible to draw a conclusion about the adequacy of the obtained equations to the actual state of the process.

According to the specified equations, it is possible to determine with high accuracy the flow of each ingredient in a multicomponent system to optimize the ratio of components in mixtures of albumin concentrates with buckwheat extrudate with normalized physicochemical parameters.

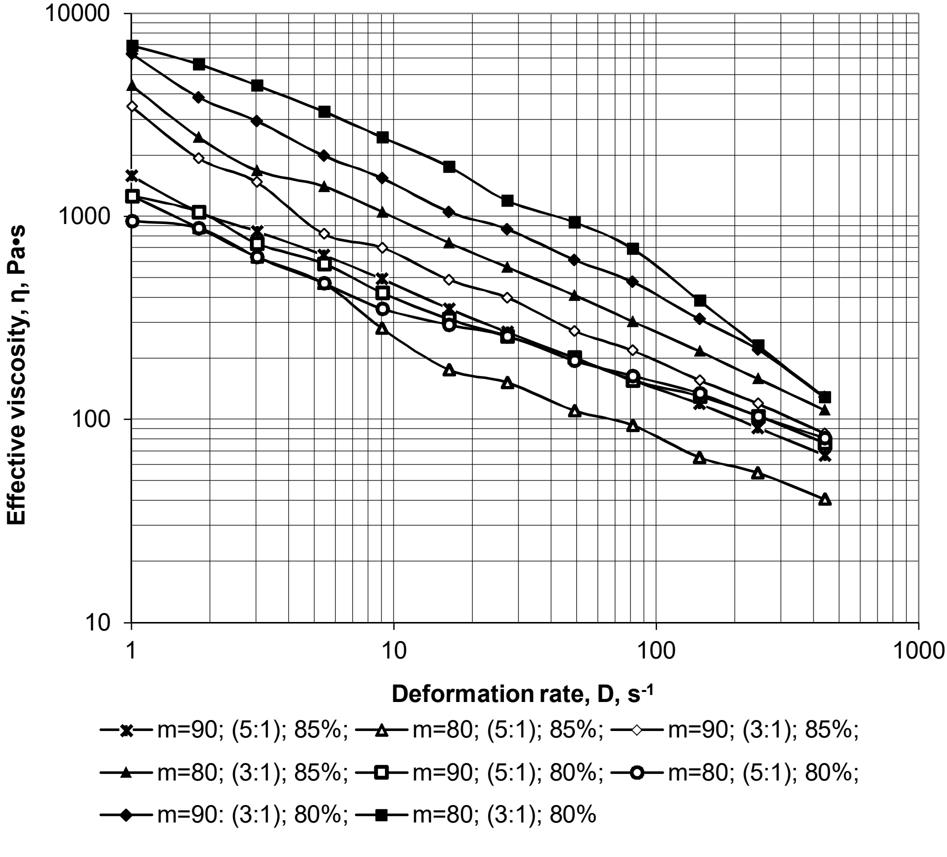

Figure 5. Dependence of the effective viscosity of albumin concentrates with buckwheat extrudate on the rate of deformation

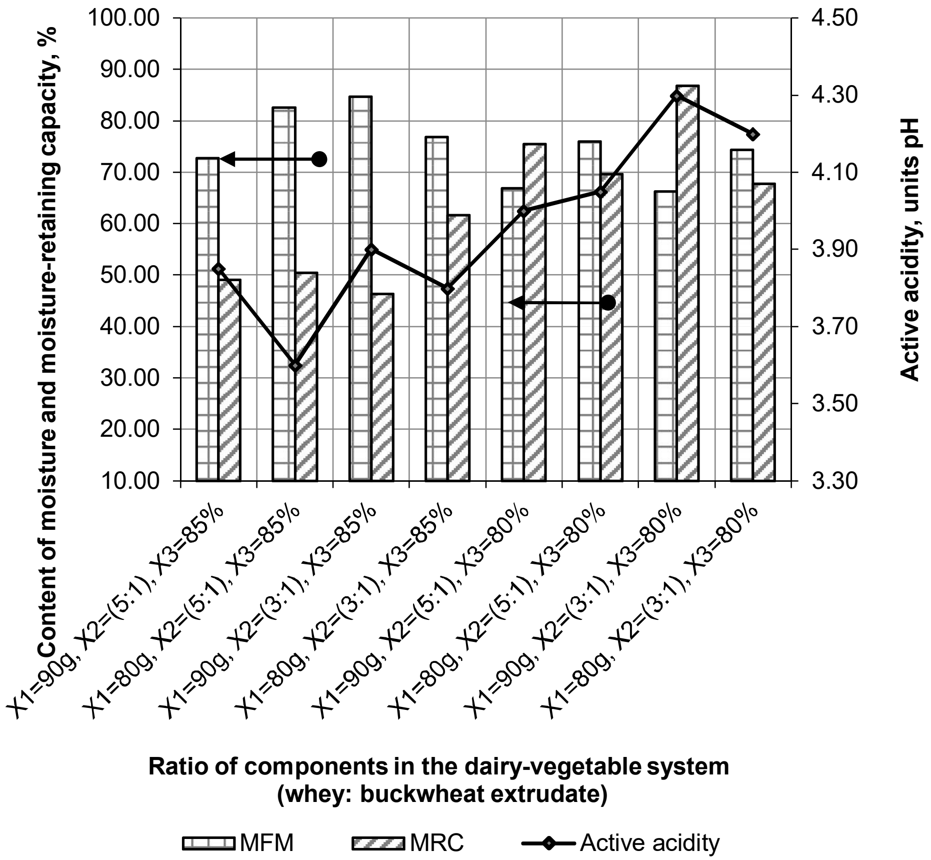

Figure 6. Dependence of quality indicators of multicomponent albumin concentrates with buckwheat extrudate on the ratio of components in milk-plant system

Thus, the optimal dose of buckwheat extrudate to albumin mass varies within 4±1%. The addition of buckwheat extrudate in larger quantities leads to a significant increase in effective viscosity and a decrease in active acidity. It is this amount of buckwheat extrudate, which has technological moisture-binding properties, that increases the moisture retention capacity of the milk-plant system. As a result, a multicomponent albumin concentrate with buckwheat extrudate with a normalized value of the mass fraction of moisture was obtained.

Conclusion

1. The possibility of applying a system approach to the development of the technology of polycomponent albumin concentrates with buckwheat extrudate has been confirmed. There is a positive economic effect due to a reduction in the cost of the product; the range of milk-protein products is expanding while maintaining a modern diet.

2. The optimal doses of adding buckwheat extrudate to the albumen mass to preserve the sensory indicators characteristic of modern milk-protein products with fillers have been established - 4±1% to the albumen mass. Their smaller amount does not have a significant effect on the quality indicators of mixtures, while an excess makes their structure heterogeneous and too dense.
3. A feature of the technology of multicomponent albumin concentrates with buckwheat extrudate is the introduction of an additional operation - the preparation of a milk-plant system: the quantitative ratio of whey to buckwheat extrudate is 5:1, the heat treatment temperature is (63±2) °C, the exposure time is 10±1 min. Empirical equations describing the functional-technological properties of milk-plant system depending on the ratio of ingredients and temperature were obtained.

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