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# CORRECTION OF TECHNOLOGICAL CHARACTERISTICS OF PROTEIN-FAT MIXTURE BY EXPANDING THE COMPONENT COMPOSITION

*Об'єктом дослідження є технологічні характеристики білково-жирової суміші підвищеної харчової цінності в залежності від додавання рослинної олії як компоненту. Білково-жирова суміш являє собою суміш підсушеного подрібненого насіння льону – 60,00±3,00 %, насіння кунжуту – 25,00±1,25 % і обрушеного насіння соняшнику – 15,00±0,75 % від маси суміші насіння. Одним з найбільш проблемних місць в технології виробництва даного продукту є тонкий помел сировини, а також видалення суміші з камери подрібнювача з причини високої в'язкості маси. В ході дослідження обґрунтовано розширення компонентного складу білково-жирової суміші підвищеної харчової цінності за рахунок додавання рослинної олії на основі моделювання та раціоналізації технологічних характеристик продукту.*

*В ході дослідження визначено такі технологічні показники продукту, як ефективна в'язкість та ступінь розшарування суміші в залежності від масової частки рослинної олії, що додавалася. Обґрунтовано раціональну кількість рослинної олії в рецептурі білково-жирової суміші підвищеної харчової цінності. У порівнянні з виробництвом білково-жирової суміші без внесення даного компоненту запропоноване технологічне рішення забезпечує можливість подолання труднощів щодо тонкого помелу насіння, а також видалення отриманої пасти з камери подрібнювача. Доведено необхідність застосування 15 % рослинної олії для отримання білково-жирової суміші з ефективною в'язкістю і стійкістю до розшарування у відповідності до вимог виробництва. Відповідно вміст насіння льону в білково-жировій суміші склав 51,00±2,50 %, насіння кунжуту – 21,25±1,00 %, насіння соняшнику – 12,75±0,60 %. Ефективна в'язкість отриманої білково-жирової суміші склала 16,0±1,5 Па·с, а ступінь розшарування продукту – 0,20±0,01 %. Рослинна олія як компонент білково-жирової суміші покращує її технологічні характеристики, що, в свою чергу, спрощує процес дозування та пакування отриманого продукту.*

**Ключові слова:** *олійне насіння, рослинна олія, ефективна в'язкість, ступінь розшарування суміші.*

## 1. Introduction

Currently, the development of protein-fat mixtures with specified characteristics (composition, structure, organoleptic characteristics) is conducted in accordance with the principles of food combinatorics [1]. Work on the enrichment of food mixtures with essential substances to improve their quality, carried out in many countries around the world, involves balancing the fatty acid composition of lipids, the amino acid composition of proteins, and also enriching them with minor nutrients [2–4]. However, all these works include, as a rule, the use of raw materials of animal origin – meat, meat products, casein, whey proteins, etc. It should be noted that animal proteins are more biologically valuable than vegetable proteins, but their cost is much higher.

In the production of food products, plant protein mixtures are beginning to be widely used. Their use is due to their technological properties, which imply the behavior of proteins in food systems: the ability to absorb and retain water, fat, form emulsions, foam, gels, play the role of binding agents, etc. [5]. These semi-finished products can improve technological indicators of quality, replace scarce, animal raw materials, and enrich food products with irreplaceable nutrients.

For consumers, it is advisable to supply products based on traditional plant materials. Practical human nutrition is due to optimal standards and real possibilities. Modern foods should best fit the natural processes of human nutrient absorption, formed in the course of history. As a result of research [6, 7], a protein-fat mixture of increased nutritional value has been developed, enriched with essential amino acids and polyunsaturated fatty acids of the ω-3 group in accordance with the physiological needs of athletes, heavy physical workers, and military personnel. This protein-fat mixture contains the following components: dried, ground sunflower seeds, sesame and flax in reasonable proportions. It should be emphasized that in the process of grinding the selected oilseeds and mixtures based on it in a continuous type impact mill revealed difficulties in fine grinding of seeds. In addition, it is complicated to remove it from the chopper chamber due to the high viscosity of the resulting mass. Thus, the study and justification of ways to reduce viscosity and increase the fluidity of the mass of the protein-fat mixture of high nutritional value from oilseeds is relevant. The developed technological solution has important theoretical and applied importance for increasing the efficiency of processing oilseeds.

## 2. The object of research and its technological audit

*The object of research* is the technological characteristics of the protein-fat mixture of increased nutritional value, depending on the addition of vegetable oil as a component.

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To identify such dependence, a technological audit is carried out, the purpose of which is determination of the change in the effective viscosity and the separation degree of the protein-fat mixture from the amount of added vegetable oil.

In the process of grinding, the selected oilseeds and mixtures based on it on the knife-type vertical shredders of the Glasser model (rotational speed of about 7.000...10.000 rpm/min.) Difficulties are identified in the actual grinding of seeds, as well as its removal from the chopper chamber due to high mass viscosity. Therefore, the main direction of improving the production technology of the protein-fat mixture is determination of rational conditions for reducing viscosity and increasing the fluidity of the mass, which, in turn, simplifies the process of dosing and packing of the product. This will improve its technological characteristics.

## 3. The aim and objectives of research

*The aim of research* is substantiation of the expansion of the component composition of the protein-fat mixture of increased nutritional value due to vegetable oil on the basis of modeling and rationalization of its technological characteristics. To achieve this aim it is necessary to solve the following tasks:

1. To investigate the dependence of the effective viscosity and the separation degree of the protein-fat mixture on the content of refined vegetable oil in it.

2. To determine the component composition of the protein-fat mixture with acceptable technological characteristics.

## 4. Research of existing solutions of the problem

Among the main areas for solving the problem of improving the technological characteristics of protein-fat mixtures identified in the resources of the world scientific periodicals, can be highlighted [8, 9], which deals with a method of obtaining protein-fat mixtures by the method of dry mixing. This method of mixing does not lead to the formation of «dead zones» and the heating of the product. In [10], the advantages and disadvantages of dry mixing of the components of protein-fat mixtures using drum mixers are presented. It is shown that the advantages of this equipment with respect to other devices are simplicity of design and reliability in operation, the ability to mix materials without destroying particles, a wide range of working volume, and a minimum of negative effects of centrifugal force. However, the physicochemical parameters of the raw materials of the developed protein-fat mixture of increased nutritional value for nutrition of athletes [6, 7] make this method of obtaining a product impractical due to the high content of fat in the oily seeds. When fine grinding of raw materials, a pasty mass of high viscosity is formed, it can't be classified as a dry mixture.

The works [11, 12] are devoted to the consideration of the preparation of protein-fat complexes by emulsifying the components and their further application. The authors of the work show that the prepared emulsions of protein and fat supplements are stable for a long time and have a different consistency depending on the intensity of whipping and the diameter of the formed fat globules. Therefore, the effect of their use may differ significantly in different protein-fat mixtures for special purposes [13]. From the analysis of these works, the question remains of emulsifying mixtures in which intense processes of hydrolysis of the lipid phase in the presence of water are observed. For example, developed protein-fat mixture of increased nutritional value [6, 7] contains in its composition natural surfactants (phospholipids). But the process of emulsification in the product does not occur and is impractical, therefore the water content is normalized in the range from 4.5 to 6.5 %.

It is of interest to consider a solution to the problem described in [14, 15], which implies the encapsulation of lipid components of protein-fat mixtures. At the same time particles with a size from several microns to several millimeters are formed. In particular, microcapsulation allows separate encapsulated material from the environment until it is released. The material properties of the walls of the capsules can be selected in such a way as to protect the contents of the capsules and to ensure the release of substances under certain conditions. In addition, encapsulation makes it possible to achieve substantial inhibition of the processes of oxidative damage to the lipid component in the product [16, 17]. But technological solutions are described that are resource intensive and expensive, in particular for complex multicomponent mixtures, in which, in addition to the protein and lipid components, dietary fiber, vitamins and minerals are also present.

Thus, the results of the analysis of the resources of world scientific periodicals allow to conclude that there is no consensus on the possibility of improving the technological characteristics of protein-fat mixtures. The choice of the most appropriate technical solution for each individual object can be based on the results obtained on investigated model systems.

## 5. Methods of research

The following materials are used for research:
– flax seeds according to DSTU 4967:2008;
– sesame seeds according to DSTU 7012:2009;
– sunflower seeds according to DSTU 7011:2009;
– sunflower oil according to DSTU 4492:2005.

The protein-fat mixture is a mixture of dried, crushed flax seeds – 60.00±3.00 % by weight, sesame – 25.00±1.25 % by weight and sunflower –15.00±0.75 % by weight of seed mixture. Model samples of protein-fat mixture with different concentrations of sunflower oil obtained by grinding in a continuous shock mill.

The effective viscosity of the model samples of the protein-fat mixture with the selected concentration of vegetable oil is determined on a rotational viscometer «Rheotest 2» (Germany). This device is designed to measure the rheological properties of non-Newtonian fluids, for example, thickener solutions (gums, pectins) in a system of coaxial cylinders. Before determining the samples of suspensions of protein-fat mixture with a selected concentration of vegetable oil were kept for 2 hours at a temperature of 20 °C.

Separation degree of the protein-fat mixture with refined vegetable oil is determined by centrifugation in «800-D» centrifuge (China) for 5 minutes at a rotation speed of 1500 rpm/min.

Mathematical methods are used for experiment planning and data processing using the software packages of Misrosoft Office Excel 2003 (USA) and Stat Soft Statistica v 6.0 (USA). Studies are conducted in triplicate.

For a given degree of probability $P$=95 %, the relative error doesn't exceed:

– when determining the effective viscosity of model samples of protein-fat mixture with sunflower oil – 3 %;

– when determining the separation degree of model samples of protein-fat mixture with sunflower oil – 2 %.

## 6. Research results

Research of the effective viscosity and the separation degree of the model samples of the protein-fat mixture with refined sunflower oil is carried out at room temperature. The concentration of refined sunflower oil in the mixture is taken as a factor; the response function is the effective viscosity of the samples. The research results are shown in Fig. 1.

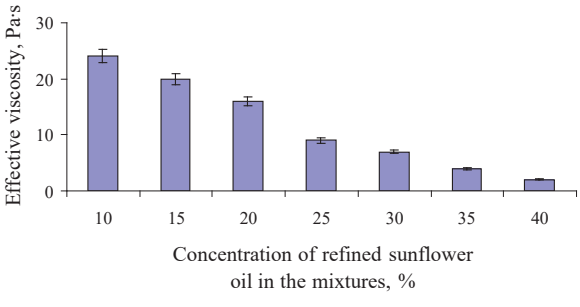


**Fig. 1.** Dependence of the effective viscosity of model samples of protein-fat mixture with sunflower oil on the mass fraction of oil

The regression equation for calculating the response function is:

$$V_e(c_{oil}) = 0.2976 \cdot c_{oil}^2 - 6.2024 \cdot c_{oil} + 30.571$$

$$\text{(in the interval } c_{oil} = 10...40\ \%), \quad (1)$$

where $V_e$ – the effective viscosity of the protein-fat mixture, Pa·s; $c_{oil}$ – mass fraction of sunflower oil in the protein-fat mixture, %.

As can be seen from the diagram in Fig. 1, with an increase in the concentration of oil in the protein-fat mixture from 10 to 40 %, there is a decrease in the effective viscosity from 24 to 2 Pa·s.

The study of the separation degree of model samples of protein-fat mixture with refined sunflower oil in the formulation held at room temperature. The concentration of sunflower oil introduced into the model samples of the protein-fat mixture is taken as a factor; the response function is the stability of the mixture samples. The research results are shown in Fig. 2.

As can be seen from the diagram in Fig. 2, when the oil concentration in the protein-fat mixture increases from 10 to 40 %, the separation degree of the mixture increases from 0.1 to 2.5 %. The increase in the separation degree of the resulting mass to 1.00...2.5 % is unacceptable from the point of view of consumer properties of the product.

The regression equation for calculating the response function is:

$$DS(c_{oil}) = 0.0988 \cdot c_{oil}^2 - 0.3869 \cdot c_{oil} + 0.4429$$

$$\text{(in the interval } c_{oil} = 10...40\ \%), \quad (2)$$

where $DS$ – separation degree of the protein-fat mixture, %; $C_{oil}$ – mass fraction of sunflower oil in the protein-fat mixture, %.

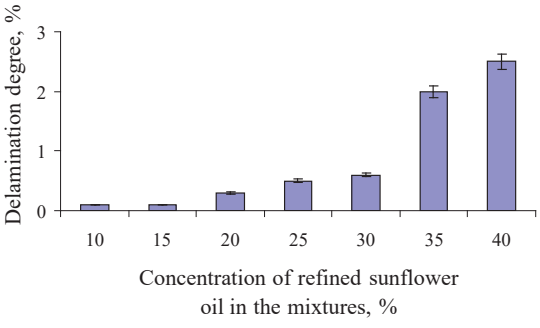


**Fig. 2.** Dependence of the separation degree of model samples of a protein-fat mixture with sunflower oil on the mass fraction of oil

The given regression equations (1), (2) are obtained by data approximation. The adequacy of the regression models is tested using the Fisher criterion. The value of the coefficient of determination of nonlinear regression is $R^2 > 0.98$ and $R^2 > 0.95$, respectively. The equations of the regression models describe the real process adequately in the range of concentrations of refined oil in the protein-fat mixture from 10 to 40 %. Analysis of the obtained data shows that sunflower oil added to reduce viscosity and increase the fluidity of the mass, simplifies the process of dosing and packaging of the product. The effective concentration of oil is 15.00±0.75 % by weight of the finished product as one that improves the technological characteristics and does not impair the consumer properties of the product. According to the content of flax seeds is 51.00±2.50 %, sesame seeds – 21.25±1.00 %, sunflower seeds – 12.75±0.60 %. The effective viscosity of the resulting protein-fat mixture is 16.0±1.5 Pa·s, and the degree of product separation is 0.20±0.01 %.

Thus, the necessity of using vegetable oil to obtain a protein-fat mixture with optimal technological characteristics, in particular viscosity, and resistance to separation in accordance with the requirements of production has been substantiated and experimentally confirmed.

## 7. SWOT analysis of research results

*Strengths.* Among the strengths of this research, it is necessary to note the results obtained to substantiate the rational content of sunflower oil in the protein-fat mixture of increased nutritional value to improve its technological characteristics. According to the analysis of modern scientific literature today, such results are absent. Using the data obtained allows to solve the problem of choosing the method of fine grinding of the protein-fat mixture with obtaining a mass of acceptable viscosity and increased flowability. It is worth noting the economic attractiveness of the selected method of obtaining protein-fat mixture for food production. The use of such a mixture in food technology, in particular confectionery, industry, opens up broad opportunities for expanding the range of specialized products based on oilseeds for athletes, heavy physical workers, military personnel, because at present this type is almost absent.

*Weaknesses.* The weak side of this development can be considered the choice for a protein-fat mixture of such a component as refined sunflower oil. This component of the mixture can be replaced by vegetable oil, it has high biological value in such indicators as the content of polyunsaturated fatty acids ω-3 groups and antioxidants. In addition, the obtained dependences of the technological

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characteristics of the protein-fat mixture on the oil content require the standardization of a number of physico-chemical parameters of oilseeds.

*Opportunities*. In the future, it would be advisable to conduct research on indicators of biological activity and stability in the oxidative deterioration of protein-fat mixture with other refined oils that are represented on the Ukrainian market.

*Threats*. Difficulties in the implementation of the research results may be associated with such factors as the management of food industry enterprises. Investing additional funds, even insignificant, in the purchase of necessary equipment and the lack of tangible results affects the position of decision-makers. This risk is well founded, since the obtained mathematical models of the process, as mentioned above, require the standardization of a number of indicators of oilseeds.

Thus, the SWOT-analysis of the research results allows to determine the main directions for achieving the research aim, namely:

– development of scientifically based recommendations on the standardization of indicators of oilseeds for the production of protein-fat mixture of high nutritional value;
– evaluation of the effectiveness of fine grinding of oilseeds with the addition of vegetable oil of reasonable concentration in industrial conditions;
– development of technological solutions for the production of protein-fat mixture of high biological value.

## 8. Conclusions

1. The dependences of the effective viscosity and the separation degree of the protein-fat mixture on the content of refined vegetable oil in it are investigated. These dependences are quadratic functions that predict a decrease in the effective viscosity during production and an increase in the separation degree of the protein-fat mixture during storage with an increase in the content of refined sunflower oil.

2. The component composition of the protein-fat mixture with acceptable technological characteristics is determined. The effective concentration of refined sunflower oil is 15.00±0.75 % by weight of the finished product. According to the content of flax seeds is 51.00±2.50 %, sesame seeds – 21.25±1.00 %, sunflower seeds – 12.75±0.60 %. Thus, the effective viscosity of the resulting protein-fat mixture is 16.0±1.5 Pa·s, and the degree of product separation is 0.20±0.01 %.

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