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INFLUENCE OF Se-LACTOALBUMIN ON FUNCTIONAL AND TECHNOLOGICAL PROPERTIES OF SELENIUM-PROTEIN DIETARY SUPPLEMENTS

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Abstract

One of the possible options for obtaining health products is the enrichment of food products with protein-selenium complexes, which form the basis of selenium-protein dietary supplements (SPDS). SPDS contain the organic Selenium compounds, which are the products of chemical interaction between Selenium salts and globular whey proteins. Such SPDS can be used not only as a source of the abovementioned nutrient, but also as an emulsifier of dispersed systems. Their introduction into the food recipes should not adversely effect on organoleptic characteristics of their quality, should increase the emulsion resistance, enhance the content of organic selenium, which determines the relevance of these studies. The aim of the article is to study the technological properties of selenium-protein dietary supplements to identify ways of their further use in food technology. The technological properties of selenium-protein dietary supplements are studied, the main factors providing their high values are determined. The water-holding capability of SPDS is obviously detected by increasing the temperature of their colloidal solutions to 90 °C. At SPDS «Neoselen» – 336.8 %, at SPDS «Syvoselen Plus» – 221.4 %. So long as significant part of the protein fraction of SPDS «Syvoselen Plus» is denatured during its production, it is natural that the values of the water holding capacity (WHC) of the additive is lower than SPDS «Neoselen» one. Hence, the smaller the number of proteins with natural technological properties in the additive, the smaller the WHC index value of it. Satisfactory values of fat-retaining (FRA) and fat-emulsifying (FEA) abilities of SPDS are determined, thanks to which they would show stabilizing and emulsifying properties in food systems. The complex of such technological characteristics is due to the modification of whey proteins during the SPDS production, namely: their interaction with serum enzymes (reductases, oxidases, etc.), Selenium salts, which are both reducing agents and oxidants, pH, temperature, etc. The abovementioned indicators of FRA and FEA can be explained by technological properties of hydrophobic functional groups of SPDS proteins that are presented on their contact surface (-CH_3, -C_2H_5 and so on). The study of moisture-absorbing capacity (MAC) and WHC of SPDS confirm the hypothesis. It became obvious that «Neoselen» in contrast to «Syvoselen Plus» has pronounced functional and technological properties as a result of SPDS experimental research. Thus, the WHC of this additive is 1.5 times higher than in SPDS «Syvoselen Plus» (336.8 ± 3.4 % and 221.4 ± 2.2 %, respectively), the rate of FEA – 11.5 times more (216.5 ± 2.1 % and 16.8 ± 0.9 %, respectively). The recommendations for the SPDS use in a wide range of foods with high nutritional value are developed based on the identified functional and technological properties. Based on the results of research on the functional and technological properties of SPDS, the additives have been recommended for use in dietary food technology as emulsifiers and stabilizers of food dispersed systems and sources of selenium as a functional carcinoprotective and immunomodulatory ingredient.

Keywords: dietary supplement; whey proteins; technological properties; Selenium; water; fat.

ВПЛИВ Se-ЛАКТОАЛЬБУМІНУ НА ФУНКЦІОНАЛЬНО-ТЕХНОЛОГІЧНІ ВЛАСТИВОСТІ ДОБАВОК ДІЄТИЧНИХ СЕЛЕН-БІЛКОВИХ

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Анотація

У статті досліджено технологічні властивості дієтичних добавок селен-білкових (ДДСБ), визначено основні чинники, що забезпечують їх високі показники. Виявлено вологоутримуючу, вологопоглинальну, жироутримуючу та жироемульгуючу здатності добавок «Сивоселен Плюс» та «Неоселен», обґрунтовано закономірності їх виникнення, проведено порівняльний аналіз їх значень. На основі виявлених функціонально-технологічних властивостей розроблено рекомендації з використання ДДСБ у складі широкого асортименту харчової продукції з підвищеною харчовою цінністю.

Ключові слова: добавка дієтична; сироваткові білки; технологічні властивості; селен; вода; жир.

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ВЛИЯНИЕ Se-ЛАКТОАЛЬБУМИНА НА ФУНКЦИОНАЛЬНО-ТЕХНОЛОГИЧЕСКИЕ СВОЙСТВА ДОБАВОК ДИЕТИЧЕСКИХ СЕЛЕН-БЕЛКОВЫХ

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Аннотация
В статье исследованы технологические свойства диетических добавок селен-белковых (ДДСБ), определены основные факторы, обеспечивающие их высокие показатели. Выявлены влагоудерживающая, влагопоглощающая, жироудерживающая и жироэмульгирующая способности добавок «Сивоселен Плюс» и «Неоселен», обоснованы закономерности их возникновения, проведен сравнительный анализ их значений. Основываясь на выявленных функционально-технологических свойствах, разработаны рекомендации по использованию ДДСБ в составе широкого ассортимента пищевой продукции с повышенной пищевой ценностью.
Ключевые слова: добавка диетическая; сывороточные белки; технологические свойства; селен; вода; жир.

Introduction

The enrichment of food products with protein-selenium complexes, which form the basis of selenium-protein dietary supplements (SPDS), is one of the possible ways for obtaining health-improving products. SPDS contain organic compounds of selenium that are the products of chemical interaction between selenium salts and globular proteins of whey. Such SPDS can be used not only as a source of the above-mentioned nutrient, but also as an emulsifier of dispersed systems. Their introduction into food recipes should not adversely affect the organoleptic characteristics of systems' quality, should increase their emulsion resistance and the content of organic selenium determining the relevance of these studies [18; 23].

Analysis of recent research and publications. Deficiency of macro and microelements causes a number of metabolic disorders in the human organism. A special place among them is occupied by Se-deficient. Their elimination (or correlation) can be a decisive factor in overcoming a number of cardiovascular, oncological diseases, etc. [1].

Reduction of the detrimental effect of regional hyposelenosis on human health is possible with dietary supplements or Se introduction in high demand foods [2]. They are not drugs and are over-the-counter prophylactics that can saturate the body with deficient food elements and thus promote good health [3].

It is advisable for a human to eat products containing non-toxic organic forms of Se: cereals and products of their processing, nuts, livestock products, etc. [4]. Nevertheless, it is undeniable that the situation of world Se-deficit (including in Ukraine) tends to worsen due to the reduction of the amount of trace elements in soils and, consequently, in crop and livestock products [5]. Therefore, the issue of developing of dietary supplements' technologies enriched with selenium is becoming relevant.

Most scientists prefer to use compounds as close as possible in biosynthesis to Se-cysteine (Se-methionine) in order to avoid unwanted side reactions, which are inevitable in multistage syntheses (originating from selenates and selenites) and threaten the accumulative effects [6–10].

Technologies for obtaining selenium-protein additives «Syvoselen Plus» and «Neoselen» [11; 12] are developed based on whey proteins of milk and selenium salts. Regulatory documentation for additives was developed and approved in accordance with the established procedure: TU U 10.8-01566330-329: 2018 «Mineral-organic food additives. Technical conditions».

The obligatory stage of their design and development is the study of technological properties of raw materials, semi-finished or finished products as shown by the analysis of recent research and publications [13–15, 19–21].

Water-holding (WHC), moisture-absorbing (MAC), fat-retaining (FRA) and fat-emulsifying (FEA) abilities were selected from the indicators of functional and technological properties for the characteristics of SPDS «Neoselen» and «Syvoselen Plus».

The determination of such properties should give a comprehensive idea of the nature of the interaction of SPDS with the most common solvents (water, sunflower oil) [22; 24; 25], disperse systems (in particular, an emulsion of the type «water in fat») [16; 17], and the possibility of using the above additives in food technology enriched with Se, in general.

The aim of the article is to study the technological properties of selenium-protein dietary supplements to identify ways of their further use in food technology.

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Statement of the main research material. Determination of WHC of SPDS was performed according to the method shown in DSTU 4595:2006 and according to the data given in table 1.

Table 1

Baseline data and indicators water-holding capacity SPDS «Syvoselen Plus» and «Neoselen»

Indicator	SPDS	
	«Syvoselen Plus»	«Neoselen»
The mass of the sample *m*, g	1 ± 0.01	1 ± 0.01
The mass of the test tube with a dry sample m_1, g	65.2 ± 0.7	71.9 ± 0.7
The weight of the test tube with a wet sample m_2, g	65. 3 ± 0.7	71. 6 ± 0.7
Water-holding capacity *WHC*,%	109. 0 ± 1.1	35. 0 ± 0.4

Water-holding capability of SPDS «Neoselen» is 35%, whereas the same one of SPDS «Syvoselen Plus» – 109%. The technological features can explain such a cardinal difference between their values.

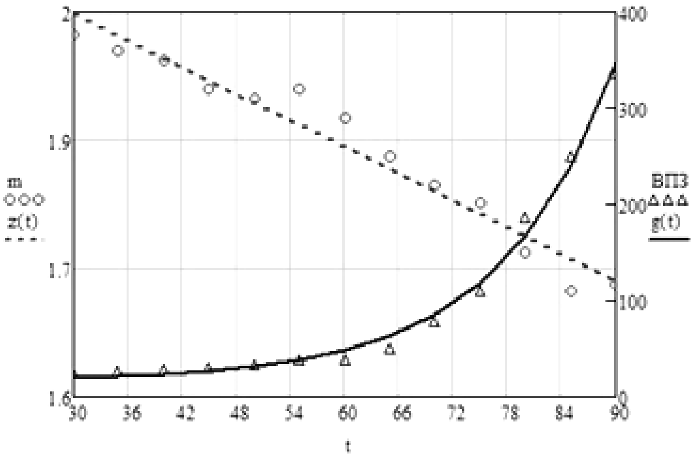
The determination of the MAC SPDS indicator was carried out in accordance with the methodology shown in GOST ISO 17718-2015 and according to the data given in table 2.

Table 2

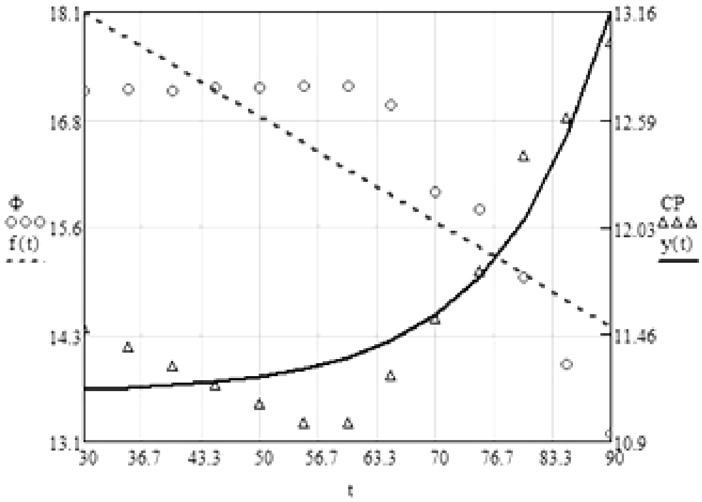
Moisture-absorbing **capacity characteristics of SPDS «Syvoselen Plus» and «Neoselen» (n = 5, p ≤0.05)**

Indicator according the temperature	SPDS					
	«Syvoselen Plus»			«Neoselen»		
	30 °C	60 °C	90 °C	30 °C	60 °C	90 °C
The mass of the liquid phase *F*, g	16.3 ± 0.2	16.5 ± 0.2	14.5 ± 0.1	17.2 ± 0.2	17.3 ± 0.2	13.2 ± 0.1
The solids content of SR^f,%	9.5 ± 0.1	10.0 ± 0.1	12.0 ± 0.1	11.5 ± 0.1	11.7 ± 0.1	13.0 ± 0.1
The amount of solids in the liquid phase, g	1.55 ± 0.02	1.65 ± 0.02	1.74 ± 0.02	1.98 ± 0.02	1.89 ± 0.02	1.72 ± 0.02
Moisture-absorbing capacity MAC,%	17.4 ± 0.2	16.7 ± 0.2	221.4 ± 2.2	25.6 ± 0.3	39.1 ± 0.4	336.8 ± 3.4

The dependence of the mass of the liquid phase and the dry matter in it on the thermostating temperature was determined based on research data in the MAC study (fig. 1).



a)



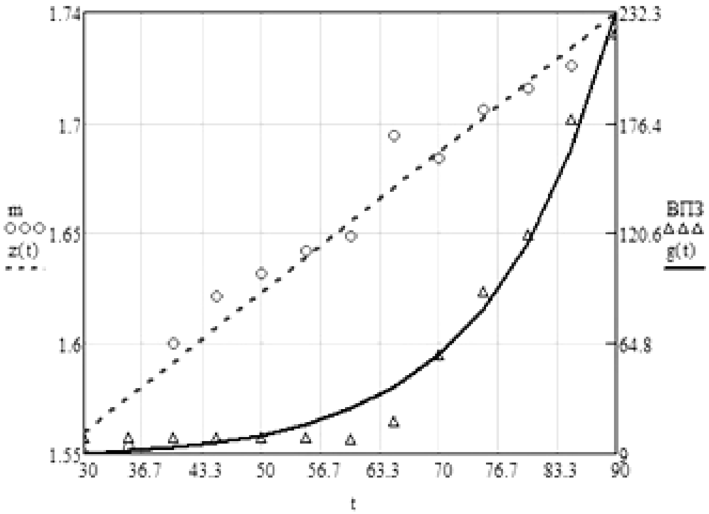
b)

Fig. 1. Variation of the mass of the liquid phase and the dry matter in it on the thermostating temperature in the study of MAC:
***a* – SPDS «Syvoselen Plus»; *b* – SPDS «Neoselen»**

Fig. 2. Samples of liquid phase of SPDS «Syvoselen Plus» (upper row) and SPDS «Neoselen» (bottom row) at a thermostating temperature:
***a* – 30 °C; *b* – 60 °C; *c* – 90 °C**

Fig. 2 shows the samples of the liquid phases of SPDS «Syvoselen Plus» and «Neoselen».

As shown in fig. 2, the transparency of liquid phases obtained from dissolving and heating of SPDS «Syvoselen Plus» and «Neoselen» were improving with temperature increasing. Obviously, the following phenomenon is associated with coagulation processes in SPDS colloidal solutions: at temperatures above 60 °C SPDS proteins were denatured (coagulated), fall into the sediment and deposited by centrifugal force on the walls of the test tube during centrifugation (fig. 2. *b*).



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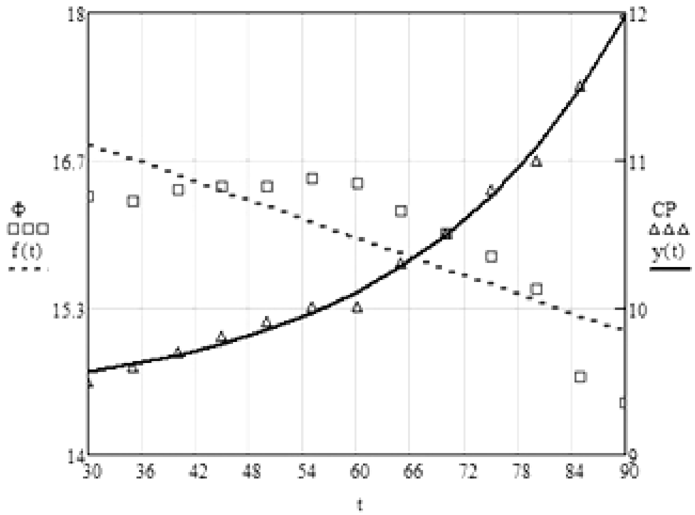

b)

Fig. 3. Variation of the rate of MRC and the amount of solids in a liquid phase from the temperature of thermostating: *a* – SPDS «Syvoselen Plus»; *b* – SPDS «Neoselen».

Comparison of the transparency of the liquid phases obtained from SPDS was performed with the newly prepared benchmark liquids (I, II, III and IV) in accordance with the methodology shown in DSTU ISO 7027:2003. According to the results of comparisons, the liquid phases, obtained from SPDS «Neoselen» (orange-red color liquid) and «Syvoselen Plus» (dark-brown color liquid), at a temperature of 30 °C are characterized as turbid – their transparencies corresponded to standard IV. With increasing temperature up to 60 °C, opalescence of liquids decreased. This phenomenon could be especially observed in the SPDS «Neoselen»: the transparency approached the standard II. At 90 °C this liquid phase sample had a coefficient of transparency corresponding to the standard I that is, the solution became almost transparent. This was not observed in studies of the «Syvoselen Plus» liquid phase neither at 60 ℃ nor at 90 °C: the turbidity of the solution at 60 ℃ corresponded to the IV standard value, and at 90 °C – to the III one.

Moisture-absorbing properties of SPDS were clearly detected by increasing the temperature of their colloidal solutions to 90 °C: in SPDS «Neoselen» – 336.8 ± 2.2 % and SPDS «Syvoselen Plus» – 221.4 ± 2.2 %. Since a significant part of the SPDS «Syvoselen Plus» protein fraction denature during its manufacture, MAC lower value of this additive is natural compared with SPDS «Neoselen». In other words, the smaller the number of proteins with natural technological properties in the additive, the lower the value of its MAC parameter.

The determination of the FRA indicator of SPDS was carried out in accordance with the methodology shown in DSTU 4595:2006 and according to the data given in table 3.

Table 3

Initial data and indicators of fat retention capacity of SPDS «Syvoselen Plus» and «Neoselen» (n = 5, p ≤0,05)

Indicator	SPDS	
	«Syvoselen Plus»	«Neoselen»
The mass of the sample *m*, g	5 ± 0.05	5 ± 0.05
The mass of the test tube with a dry sample m_1, g	70.2 ± 0.7	75.9 ± 0.8
The mass of the tube with the sample and the oil retained by it m_2, g	74.2 ± 0.7	79, 7 ± 0.8
Fat retention capacity *FRA*, %	80.2 ± 0.8	75.4 ± 0.7

FRA indicator of SPDS «Neoselen» is 80.2 %. Such a value of this indicator testifies to that this SPDS will exhibit stabilization properties in food-dispersed systems, for example, «fat-in-water» emulsions. It should be noted, the set of such technological characteristics is caused by the modification of whey proteins while the production of SPDS: by whey enzymes action on them (reductases, oxidases, etc.), temperature conditions, pH-value and Selenium salts. The last act as reducing agents and oxidants.

In accordance with the procedure shown in DSTU 4595:2006 and the data presented in table 4 the FEA determination of SPDS was carried out.

Table 4

Initial data and indicators of fat emulsifying ability of SPDS «Syvoselen Plus» and «Neoselen» (n = 5, p ≤0.05)

Indicator	SPDS	
	«Syvoselen Plus»	«Neoselen»
The volume of the emulsified layer V_e, cm^3	4.8 ± 0.5	52.5 ± 0.5
The total volume of the mixture V_c, cm^3	25.3 ± 0.3	24.3 ± 0.2
Fat emulsifying ability *FEA,* %	16.8 ± 0.9	216.5 ± 2.1

The emulsified layer, which was formed by emulsifying of SPDS «Neoselen» with water and oil (fig. 4, *a),* characterized as a thick jelly emulsion unlike the dispersed system, formed by water, oil and SPDS «Syvoselen Plus» – liquid, almost non-emulsified layer (fig. 4, *b)*.

a) b)

Fig. 4. Appearance of the emulsified layers: *a* – SPDS «Neoselen»; *b* – SPDS «Syvoselen Plus»

The production technology of SPDS «Neoselen» includes whey degreasing in order to obtain an additive with extended shelf life. Instead, low-temperature drying of this additive allows receiving a protein-selenium semi-finished product, in which whey proteins retain their main functional and technological properties (in particular, gel and jelly formation, swell ability, dissolve in water, etc.).

Results and discussion

Water-holding capability of SPDS «Neoselen» is 35%, whereas SPDS «Syvoselen Plus» – 109 %. The following technological features can explain such a cardinal difference in their values. Firstly, by the presence in SPDS «Neoselen» water-soluble globular proteins (lactoalbumins, lactoglobulins) with preserved functional and technological properties (e.g., the ability to dissolve in water at room temperature). When obtaining SPDS «Syvoselen Plus», an accelerated method of drying the additive at high temperatures (t° = 100…120 °C) is used. Therefore, the water-soluble part of the protein component of the additive is reduced and passed through the filter paper together with water.

Secondly, it appears that drying of SPDS «Neoselen» at low temperature (50 ± 2 °C) creates the conditions for «sintering» of the dry matter, which consists of a whole system of protein residues. In this way, it promotes the layering of globulin layers on whey albumin during the SPDS production. In contrast to the SPDS «Syvoselen Plus», during the preparation of which the drying accelerated method is used at high temperatures (t° = 100...120 °C). Therefore, part of the water-soluble protein component of the additive is reduced and passes through the filter paper along with water.

Obviously, with increasing temperature the improving of transparency of the liquid phase obtained by dissolving and heating the SPDS «Syvoselen Plus» and «Neoselen» is associated with coagulation processes in colloidal solutions of additives. Under the action of temperatures above 60 °C, SPDS proteins were denatured (coagulated), precipitated and deposited by

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centrifugal force on the walls of the test tube during centrifugation. Based on these studies it was determined the dependence between the MAC and the amount of dry matter in the liquid phase from the thermostating temperature (fig. 3).

In the study of MAC of SPDS «Neoselen», the significant difference between values of this index at different temperatures can be explained as follows. At temperature, the structures of the protein molecule are denatured in stages, starting from the quaternary. Moreover, the destruction can take place until all its structures will destroyed. Each structure has certain types of chemical bonds. As the structure of the molecule changes, hydrophilic groups that bind water may appear outward, causing MAC of the additive.

FRA index of SPDS «Neoselen» is 80.2%. The abovementioned FRA indicator can be explained by the technological properties of the hydrophobic functional groups of the SPDS proteins that are on their contact surface (- CH_3, - C_2H_5, etc.). The hypothesis is confirmed by previous studies of WHC and MAC.

With regard to FEA, it can be stated that Se-lactalbumin of SPDS «Neoselen» most likely contribute to formation of a jelly, rather than an emulsion, which is confirmed by the characteristics of the organoleptic indexes of the emulsified layer in the FEA study. Unlike a layer of water and oil, formed after emulsification of SPDS «Syvoselen Plus». There was a weak and liquid emulsion. This may indicate the denaturation of the protein residues during the production of SPDS «Syvoselen Plus», and as a result, the loss of the additive's ability to emulsify or stabilize dispersed systems.

Conclusions

Because of the conducted experimental researches of SPDS, it became obvious that SPDS «Neoselen» in contrast to SPDS «Syvoselen Plus» has pronounced functional and technological properties. It was found that the MAC of SPDS «Neoselen» is 1.5 times higher than such one of SPDS «Syvoselen Plus» (336.8 ± 3.4% and 221.4 ± 2.2 %, respectively). It has been experimentally confirmed that the rate of FEA of SPDS «Neoselen» is 11.5 times higher than in SPDS «Syvoselen Plus» (216.5 ± 2.1 % and 16.8 ± 0.9 %, respectively). Thus, the use of SPDS «Neoselen» would be appropriate in food systems that will not be affected by high temperatures during cooking and industrial production: sauces, toppings, dairy products, sweet and cheese dishes, and the like. It is also possible to use SPDS «Neoselen» as an emulsifier in food technology.

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