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Research Article

Rheological properties of model systems of semi-finished products based on condensed low-lactose whey

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Abstract

The rheological properties of the model systems of semi-finished products, the components of which are fermented and condensed milk whey with low lactose content and pumpkin pulp puree, were investigated. The influence of the ratio of components on the formation of structure-forming indicators is established. The use of semi-finished products is justified as a basis for emulsion-type sauces.

Keywords: milk whey, fermented mashed pumpkin pulp with a high content of pectin, condensed *in vacuo* low lactose milk whey, the model of the system

Abbreviations:

BSL - boundary stress limit; CLLW - condensed *in vacuo* low lactose milk whey; ES - emulsion stability; FCW - fermented condensed whey; FFA - foam forming ability; FMPP – fermented mashed pumpkin pulp; FNCW - fermented non-condensed whey; FS – foam stability; LLW – low lactose milk whey; SFLLW – semi-finished based on low lactose whey;

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Introduction

The implementation of the strategic direction of development of the food industry for the rational use of raw materials is aimed at increasing in production volumes and expanding the range of products based on secondary dairy and vegetable raw materials. Such products can be used for mass and therapeutic and preventive nutrition.

For use in the diet of patients with lactose malabsorption, a technology of producing whey with a reduced lactose content (hereinafter – CLLW), thickened in vacuum is proposed (Gnitsevitch et al. 2018 (a)). The product we have got contains a significant amount of proteins that have foaming or emulsifying properties. It is envisaged to use CLLW as part of structured culinary products. As a system stabilizer it is proposed to use pumpkin puree, which was subjected to fermentalize enzymes to increase the content of pectin (hereinafter – FMPP) (Gnitsevitch et al. 2018 (b)).

An important problem of the food industry in modern conditions is the involvement in the economic turnover of local raw materials. The leading role in this is assigned to the dairy industry. Most traditional methods of milk processing involve the production of subsidiary-products that are not used in the future or are subjected to incomplete processing. Solving the problem of their rational use is possible through the creation of low-waste and waste-free technologies for processing and production of food products. Thus, the use of secondary dairy raw materials, in particular whey, in food production is one of the promising ways of complex processing of this valuable raw material.

One of the directions that expand the sphere of use of the whey is the production of low-lactose products as a result of the use of enzyme preparations of directed action, including *Propionobacterium freudenreichii genus* of *Propionibacterium ssp. shermanii*. In the process of fermentation, lactose hydrolysis occurs, and the whey is additionally enriched with vitamin B, organic acids, enzymes, immune bodies and other biologically active substances (Gnitsevitch et al. 2017 (a)).

Among the food products based on secondary dairy raw materials, a significant part is occupied by structured products (Rybak 2013). In particular, these are products with foam, emulsion and gel-like structure. The formation of the structure is possible in the presence of surface active substances. The role of structure-forming agents in traditional technologies is performed by egg and dairy products, as well as technological additives. The generalized experience of domestic and foreign scientists has determined that it is advisable to use a plant component as a stabilizer in the technologies of structured products. Vegetable purees, pastes, sauces serve as a stabilizer due to the content of pectin substances and other polysaccharides (Gnitsevitch et al. 2014).

We suggest the joint use of condensed low-lactose whey and pumpkin puree with a high content of pectin. Therefore, it is necessary to determine the rheological properties of such systems. In systems that contain milk proteins and low-esterified pectin, various interactions can occur. Depending on the temperature and duration of treatment, the pH of the medium, the ionic strength of the solution and the ratio of proteins and pectin in the systems, the formation of complexes (intramolecular, intermolecular, electroneutral, charged, coacervative) is possible (Aiqian 2008; Keren et al. 2005; Krzeminskia et al. 2014 (b)).

The use of fermentation processes for dairy and vegetable raw materials can lead to the formation of complexes between proteins and pectin to produce particles with different dimensional characteristics. That is, they can act as fat substitutes, imitating high-fat products (Krzeminskia et al. 2014 (a)). Such insoluble complexes can stabilize systems by the type of Pickering stabilization, or by soluble complexes by the type of steric stabilization. This will determine the texture of the finished product (Gnitsevich et al. 2017 (b); Goralchuk et al. 2017). These processes will determine the functional and technological properties of systems, in particular, their ability to form and stabilize foam, emulsion and other systems, to give them resistance to temperature, pH changes, the introduction of other components (Farrag 2008; Herceg et al 2007; Setiowati et al. 2017).

The nature of the interaction of casein and its fractions with polysaccharides and the properties of such systems are fully described in the literature (Corredig et al. 2011). As for the interaction of whey proteins and pectins, in particular low-esterified, the data are not systemic and limited. Therefore, it is necessary to conduct research to determine the rheological and functional-technological properties of model systems based on condensed low-lactose whey and pumpkin puree with a high content of pectin. Based on this, it is possible to develop recommendations for the use of such systems as the basis of structured products.

The aim of the work is to study the rheological and functional-technological properties of model systems based on condensed low-lactose milk and fermented pumpkin pulp puree.

To achieve this goal the following tasks were solved:

- to investigate rheological properties of CLLW and FMPP;

- to determine the effect of the ratio of components on the formation of structure-forming properties of food systems with their use;

- to provide recommendations for the further use of SFLLW, based on the rheological characteristics of the semi-finished product.

Materials and Methods

Materials and methods of research of influence of a ratio of components of a semi-finished product on emulsifying processes

The content of CLLW in model systems varied within from 40 to 90% in 10% increments. The components of the mixture at a temperature of 20 ± 1°C were stirred for 60 s until the homogeneity of the mixture was achieved using the homogenizer IKA Ultra-Turrax T18 basic with v=11 200 rpm.

The value of the surface tension of the prototypes with dilution up to from 0.1 to 1.0% was determined by stablemometric method at a temperature of + 23.3°C with a repetition rate of 5 times (Kafka et al. 1967).

Foam forming ability (FFA) samples CLLW was determined by the method of Lurie (Hrabovska et al. 2012). In the study of the foaming capacity of the model composition volume 0.5 dm^3 was knocked down on the machine for beating "Kuchenbach" for 10·60 s.

Calculation of FFA was carried out by the formula (1):

$$FFA = \frac{Vp}{Vc} \cdot 100 \qquad (1)$$

where: FFA-foaming capacity, %; VP-the volume of the system after whipping, m^3; VC-the volume of the system before whipping, m^3.

The foam resistance (FR) of the samples was determined by the Lurie method. Standing downed compositions were carried out for 15·60 s.

Calculation of foam stability was carried out by the formula (2):

$$FS = \frac{h_2}{h_1} \cdot 100 \qquad (2)$$

where: FS-foam stability, %; h_2 – foam height after proofing, m; h_1 – initial foam height, m.

The effective viscosity was determined on a rotary viscometer VPN-0.2 M. The limit of permissible error of viscosity measurement is ±6% of the value that is measured. The operating temperature in the thermostat was +23.3±1.5°C. For a fixed voltage value, up to five values of the rotation period were removed, excluding gross errors, the average value was calculated (Anonymous 1987).

The boundary stress limit (BSL) of the samples was determined by extrapolation of the linear section of the curve $\tau = f(\gamma)$, according to the shear rate of 100 s^{-1}, which corresponds to the value in the organoleptic evaluation at product consumption (Rensky et al. 2012).

The fat-absorbing capacity was determined by the amount of vegetable oil needed to reach the inversion point. The oil was emulsified on a laboratory top-drive agitator mechanical DLH with a nozzle for dissolution, for 25-35 min depending on the ratio of system components.

Determination of the phase inversion point to assess the emulsifying ability of model systems was carried out by the method of Gurov (Gurov et al. 1983). The type of emulsion was determined by dilution in water. The value of the phase inversion point corresponded to the mass content of the vegetable oil that was used in the process. Emulsion stability (ES) was determined according to a quality mark 31762-2012 (Anonymous 2013). Limits of absolute error of emulsion stability measurement results ± 3% (abs.). Stability was assessed by the amount of non-delaminated emulsion.

Results and Discussion

Foaming properties depend on the degree of thermal denaturation of CLLW proteins, residual lipid and phospholipid content, calcium content, pH value and degree of enzymatic hydrolysis of proteins, as well as the ratio of components. The ability of system formation of given structures is due to the content of surface active components (surfactants) and viscosity (Pivovarov 2000). The foaming capacity of CLLW was evaluated in comparison with FNCW and fermented whey concentrated by contact method at normal atmospheric pressure at a temperature of +50℃ (hereinafter – FCW). The results of the studies are shown in Fig.1.

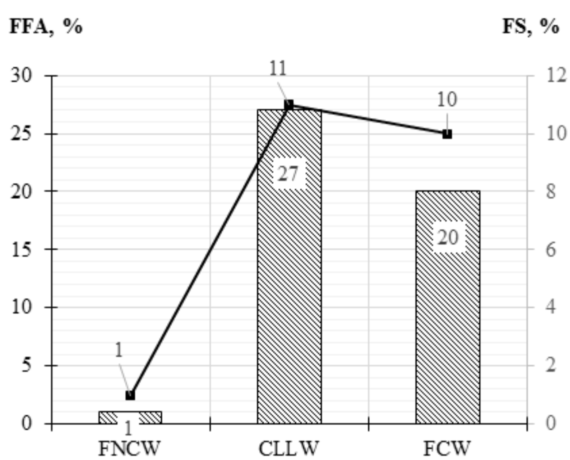

Figure 1. FFA and FS for FNCW, CLLW and FCW

Studies show that FCW has a foaming ability at the level of 20%. For the FNCW this figure was 1%. For CLLW, the value of FFA is 23%. This can be explained by the increase in the content of dry substances, in particular proteins, which are surfactants. Low foaming capacity of all samples can be explained by the fat content, which is about 5%. An additional factor that determines the low foaming capacity may be the high viscosity of the solution, which complicates the process of dispersing the air in the system. It is established that the stability of the foam formed by FCW is 10%, CLLW-11%, FNCW-1%, which is probably due to the high polydispersity and a high content of bubbles with low dispersion, which are destroyed by the process of disproportion (Zolotukhina 2006). The obtained values of FFA and FS for all the studied samples are insufficient for their further use as a foaming agent. Foaming and emulsifying processes differ in the amount of work required for dispersion. It is determined by the interfacial tension and density of dispersed phases. Further emulsifying properties of CLLW and model systems based on it were investigated. To evaluate the surface properties, the surface tension of CLLW was determined. The results are shown in Fig. 2.

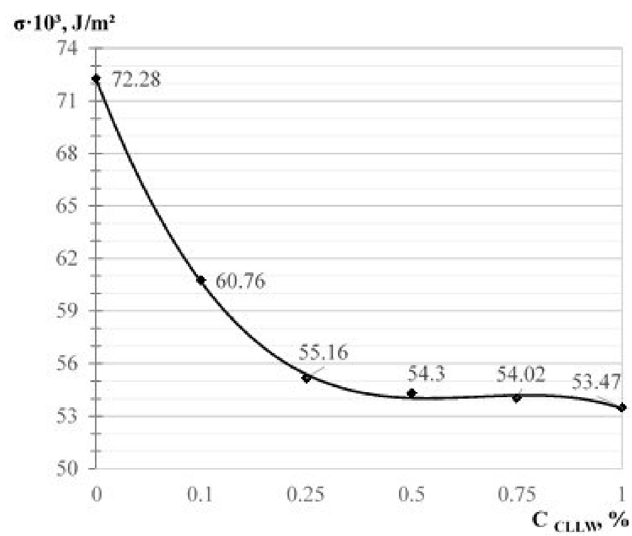

Figure 2. The surface tension isotherm of the CLLW

The decrease in the surface tension at the phase interface indicates an increase in the concentration of surfactants in monolayer. This is due to an increase in the content of whey proteins in the solution. However, it is necessary to determine what processes occur during the formation of emulsions and the possibility of regulating them in order to obtain stable systems.The ability of CLLW to reduce the surface tension during adsorption at the phase interface indicates a high surface activity, which confirms the effectiveness of its use in emulsions. However, such emulsions are potentially unstable systems. Therefore, it is advisable to study ways to stabilize it, for example, a plant component rich in pectin substances. It is known that pectins form intermolecular complexes with milk proteins, which can act as highly effective stabilizers of emulsions (Mishra et al. 2001). Therefore, it is advisable to investigate the nature of the interaction of pectin contains FMPP with proteins CLLW. Model compositions at different ratios of FMPP and CLLW are investigated. The interaction of serum proteins and pectin was evaluated by rheological methods. They can record abnormal changes in viscosity, shear stress limit systems, on the basis of which it can be argued about the interaction of substances or lack of it. In the model compositions, the content of FMPP was 10-60%. The results of studies of the effective viscosity of the model systems are shown in Fig. 3.

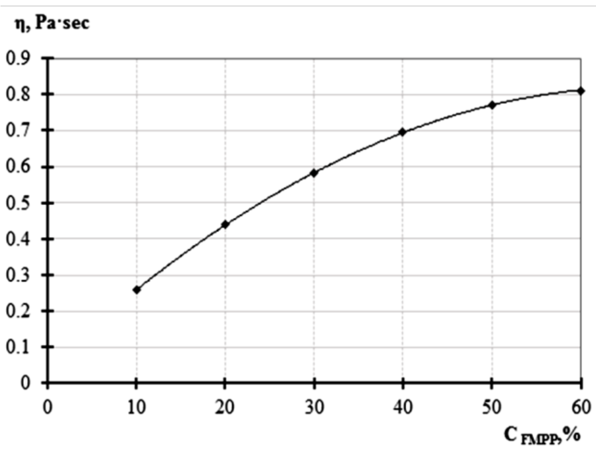

Figure 3. The effective viscosity of model systems FMPP (shear rate 100 sec^{-1})

It was found that with an increase in the proportion of FMPP from 10% to 60%, the effective viscosity increases by 3.1 times. That is, it can be argued that there is lack of coacervation of protein-pectin complexes and thermodynamic incompatibility of proteins with pectins. In such cases, the viscosity of the system should decrease. The obtained data indicate the interaction of serum proteins and pectins with the formation of interpenetrating polymer mesh structures in the process of micellization. At simultaneous or sequential formation of interpenetrating polymer mesh structures there is micro phase distribution of proteins and carbohydrates due to incompatibility. It arises from interstitial chains followed by oriented extrusion of polysaccharide molecules on the surface of proteins. An increase in the concentration of carbohydrates in micro volumes leads to an increase in their independent association, the formation of hydrogen bonds, combined sites of pyranose structures of pectin. This, in turn, leads to a faster increase in viscosity (Gnitsevich et al 2014). The process slows down the phase distribution of polysaccharides, which provides the necessary ordering of their supramolecular structures and stabilizes the structure of the system.

Determination of the magnitude and dependence of the BSL on the content of components allows to determine the possible type of interaction and to characterize the rheological behaviour of systems. It is established that with increasing content of FMPP the boundary intension increases. It should be noted that in the semi logarithmic coordinates of the BSL from the content of puree, the presence of a fracture point of the curve is observed at the content of 30% FMPP (Fig. 4).

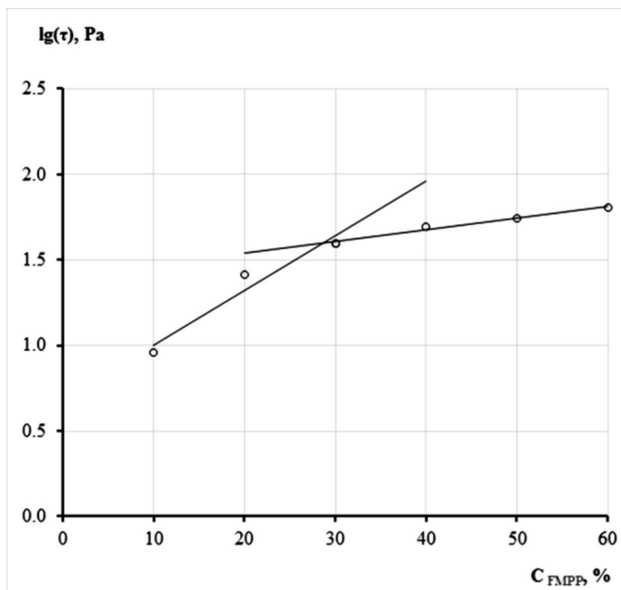

Figure 4. The dependence of the BSL on the content of the components

Probably, the type of interaction between proteins and pectins is changing. There is an increase in the structure-forming ability of 4.6 times to a concentration of 30%, compared to systems containing from 40 to 60% FMPP. Based on the obtained data, it can be stated that the maximum realization of structure-forming properties is achieved by the content of 30% FMPP, the systems are characterized as visco-plastic. The further increase in BSL is a consequence of changes in the interaction of serum proteins and pectin. This is evidenced by the rate of growth of the BSL, which is determined by the tangent of the angle of inclination of the curve, which decreases by 4.6 times. Probably, the solubility of complexes, molecular weight and diffusion coefficient change, which is consistent with studies (Krzeminskia et al. 2014), in which it is proved that with an increase in the content of pectin, the particle size of protein-pectin increases.

Thus, the given data indicates that the use of vegetable raw materials to achieve certain functional and technological properties has several advantages. First, it is an increase in nutritional and biological value, giving the product a therapeutic and preventive nature, radio protective and immunomodulatory effects. Secondly, plant tissue is able to retain liquid in the product structure, increasing storage stability, forming and increasing the viscosity of food systems. Thirdly, in this case, FMPP acts as a flavour filler and dye. But particular attention is drawn to FMPP as a source of pectins, which can save traditional structure-forming agents.

It can be stated that the introduction of different amounts of FMPP into the composition of model systems will allow to regulate viscosity as a factor of stability of systems. Since the counteracting factor of the oil emulsification process is the value of the effective viscosity, which leads to significant energy consumption in the emulsification process, it is necessary to assess the emulsifying capacity of the system.

The emulsifying ability of the model systems was estimated by the phase inversion point (Fig. 5).

It is established that the dependence of the inversion point on the ratio of components is extreme. In the range of FMPP content from 0 to 30% of the emulsifying capacity is increased. Further increase to from 40 to 60% leads to its decrease in 1.3 times. When the content of FMPP from 30 to 40% the inversion point of emulsion phase corresponds to fat

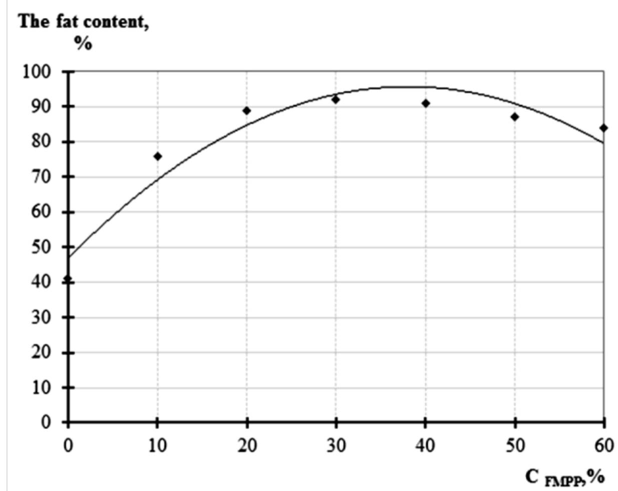

Figure 5. The dependence of the inversion point on the ratio of the components

content of from 91 to 92%. The analysis of the obtained data allows us to state the correlation of the FFA systems and the inversion point of the emulsion phases. This is probably due to the formation of complexes, the maximum hydrophobicity of which is formed in systems with a content of FMPP from 30 to 40%. According to the content of FMPP more than 40%, is likely to change the hydrophilic-lipophilic balance, the dimensional characteristics increases and, as a consequence, there is decrease in the diffusion coefficient.

This negatively affects the emulsifying container. However, it is possible to predict a positive effect on the stability of the emulsion.

Conducted studies of the stability of the emulsion due to the oil content of from 20 to 60% allow us to establish that with increasing content, the stability of the emulsion increases (Fig. 6). So for content FMPP from 40 to 60% and oil content of 60% achieves emulsion stability of 98±2% that meets the requirements of regulatory documentation for mayonnaise.

It should be noted that in systems with an oil content of from 40 to 60% at the content of FMPP from 40 to 60% the stability of the emulsion is practically unchanged, although the viscosity of the system increases in this range. On the basis of the analysis

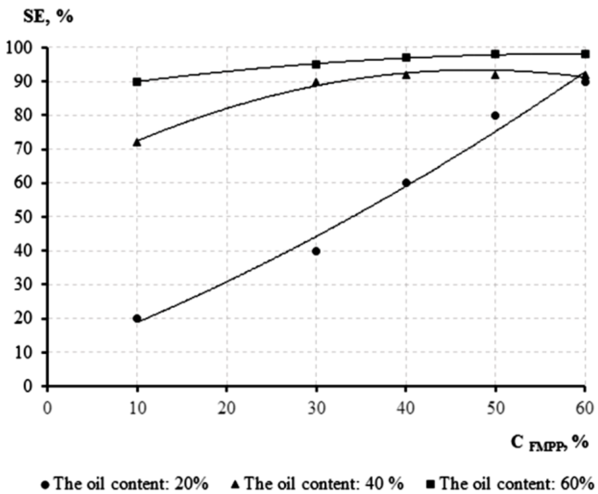

Figure 6. The dependence of the stability of the emulsion on the oil content

of capacity and stability of emulsions it is possible to recommend a rational ratio of components of model systems on the basis of CLLW for obtaining sauces of emulsion type.

Conclusions

The studies of rheological and functional-technological properties have substantiated the rational ratio of condensed low lactose whey and fermented pumpkin pulp puree with an increased content of pectin as (from 60 to 70) : (from 30 to 40). This ratio introduces high emulsifying and stabilizing properties, allowing to obtain emulsion systems with a stability of 98±2% with an oil content of 60%.

References

Aiqian Ye. Complexation between milk proteins and polysaccharides via electrostatic interaction: Principles and applications. *International Journal of Food Science & Technology*, 2008, 46: 406-415. https://doi.org/10.1111/j.1365-2621.2006.01454.x

Farrag A. Emulsifying and Foaming Properties of Whey Protein Concentrates in the Presence of Some Carbohydrates. *International Journal of Dairy Science*, 2008, 3(1): 20-28. https://doi.org/10.3923/ijds.2008.20.28 https://scialert.net/abstract/?doi=ijds.2008.20.28

Keren G., Marcela A., Milena C.. Interactions of High Methoxyl Pectin with Whey Proteins at Oil/Water Interfaces at Acid pH. *Journal Agric. Food Chem*., 2005, 53: 2236−2241. https://doi.org/10.1021/jf048683f

Gnitsevich V. (a), Chikun N., Honchar Y.. Kinetics of whey lactose fermentolysis. *Goods and markets*, KNUTE, 2017, 2(1): 97-104. UDC 637.142.2. Available at: http://tr.knteu.kiev.ua/index.php?option=com_content&view=article&id=1483&catid=123&lang=en

Gnitsevich V. (b), Daynichenko L., Goralchuk A.. The rheological properties of milk protein concentrates. Scientific works of NUFT, 2017, 23(2): 182-189. UDC 663/664. Available at: http://sw.nuft.edu.ua/Archiv/2017/swnuft_23_2.pdf

Gnitsevich V. (b), Honchar Y.. Investigation of the process of pumpkin pulp fermentation. Scientific works of NUFT, 2018, 24(2): 203–208. https://doi.org/10.24263/2225-2924-2018-24-2-24 Available at: http://sw.nuft.edu.ua/Archiv/2018/swnuft_24_2.pdf

Gnitsevich V. (a), Gonchar Y.. Method of production of condensed fermented whey with reduced lactose content. Proceedings of the International Scientific and Practical Conference «Development of Food Production, Restaurant and Hotel Facilities and Trade: Problems, Prospects, Efficiency», KNUFT, 2018, 1: 120-121. UDC 637.142.2. https://doi.org/10.31617/tr.knute.2018(28)10

Gnitsevich V., Nikiforov R., Fedotova N., Kravchenko N.. Food technology with specified properties based on secondary milk and vegetable raw materials: a monograph. Donetsk: DonNUET, 2014. Print ISBN: 978-617-683-284-3.

Goralchuk A. Gubsky S., Tereshkin O., Kotlyar O., Omelchenko S., Tovma L. Development of a theoretical model for the production of foam emulsions from a mixture of dry fat-containing and its experimental confirmation. Eastern European Journal of Advanced Technology, 2017, Vol. 2, 10(86): 12-19. https://doi.org/10.15587/1729-4061.2017.98322

Anonymous, GOST 31762-2012 Mayonnaises and mayonnaise sauces. Acceptance rules and test methods. M.: State Scientific Institution «All-Russian Research Institute of Fats», 2013. Available at: http://gostexpert.ru/data/files/31762-2012/70970.pdf

Gurov A., Lozinskaya N., Larichev N. et al. New methods for evaluating the emulsifying properties of proteins. Theses document All-Union Meeting «Physical chemistry of structured dietary proteins», Tallinn, 1983, pp. 57-58 [in Russian]

Hrabovska O., Miroshnykov O., Podobiy O., Volovyk L., Kovalevska Y., Serbova M., Bondarenko S.. Physical and Colloidal Chemistry: Method. Recommendations for students laboratories works, Kiev, NUFT, 2012, 91 pages. Available at: http://library.nuft.edu.ua/ebook/file/61.02.pdf

Kafka B., Lurie I. Technological control of confectionery production, Food industry, Moscow, 1967, 207 pages [in Russian]

Krzeminskia A. (a), Prella K.A., Busch-Stockfisch M., Weiss J., Hinrichsa J. Whey protein-pectin complexes as new texturising elements in fat-reduced yoghurt systems. *International Dairy Journal*, 2014, 36: 118-127. https://doi.org/10.1016/j.idairyj.2014.01.018

Krzeminskia A. (b), Prella K.A., Weiss J., Hinrichs J. Environmental response of pectin-stabilized whey protein aggregates. *Food Hydrocolloids*, 2014, 35: 332-340. https://doi.org/10.1016/j.foodhyd.2013.06.014

Corredig M., Sharafbafi N., Kristo E.. Polysaccharide-protein interactions in dairy matrices, control and design of structures. *Food Hydrocolloids*, 2011, 25: 1833-1841. https://doi.org/10.1016/j.foodhyd.2011.05.014

Mishra S., Mann B., Joshi V.K. Functional improvement of whey protein concentrate on interaction with pectin. *Food Hydrocolloids*, 2001, 15: 9-15. https://doi.org/10.1016/S0268-005X(00)00043-6

Pivovarov P. Theoretical technology of catering: a textbook. HDATOH, Kharkov, 2000,116 pages. Print ISBN: 5-7763-2202-2.

Rensky I., Ponomarev M., Berezhnyka O., Rudnitskaya G. Surface phenomena and dispersion systems: Method. Directions to windows. Laboratory work for students. Direction of preparation. 6.051301 «Chemical technology» of all forms of teaching. K.: National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», 2012, 84 pages [in Ukrainian]

Rybak O. Some aspects of the formation of emulsions and foams in food industry. Ukrainian Journal of Food Science, 2013, 1 (1): 41-49. Available at: http://nbuv.gov.ua/UJRN/ujfs_2013_1_1_5.

Setiowati A.D., Serveh S., Wahyu W., Van der Meeren P.. Improved heat stability of whey protein isolate stabilized emulsions via dry heat treatment of WPI and low methoxyl pectin: Effect of pectin concentration, pH, and ionic strength. *Food Hydrocolloids*, 2017, 63: 716-726.http://dx.doi.org/10.1016/j.foodhyd.2016.10.025

Anonymous, Technical description and instruction manual for VSN-0.2 M. Moscow, 1987, 50 pages [in Russian]

Zolotukhina I. The technology of semi-finished products based on buttermilk for the production of whipped dessert products: diss. cand. tech. sciences. Kharkiv, 2006, 157 pages. [in Ukrainian]

Zoran Herceg, Anet ReZek, Vesna Lelas, Greta Kresic, Mila Franetovic. Effect of carbohydrates on the emulsifying, foaming and freezing properties of whey protein suspensions. *Journal of Food Engineering*, 2007, 79: 279-286. https://doi.org/10.1016/j.jfoodeng.2006.01.055