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High Tech of Controlled Pumping into Whole Muscle Meat Food

Ivan Fiodorovich Gorlov[1,2], Andrey Georgievich Khramtsov[3], Sergey Aleksandrovich Titov[4], Irina Anatolievna Glotova[5], Valentin Ivanovich Shipulin[3], Marina Ivanovna Slozhenkina[1,2], Aleksandr Vasilievich Randelin[1], Elena Yurievna Zlobina[1] & Andrey Vladimirovich Kulikovskiy[1]

[1] The Volga region research institute of manufacture and processing of meat-and-milk production, Russia

[2] Volgograd State Technical Universities, Russia

[3] North Caucasus Federal University, Russia

[4] Voronezh State University of Engineering Technologies, Russia

[5] Voronezh State Agrarian University n.a. Emperor Peter I, Russia

Correspondence: Ivan F. Gorlov, The Volga region research institute of manufacture and processing of meat-and-milk production, 400131, Rokossovskogo street, 6, Volgograd, Russia. Tel: 7-84-4239-1101. Fax: 7-84-4239-1142. E-mail: niimmp@mail.ru

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Abstract

This work is aimed at the improving the processing methods of producing the injected whole muscle meat products through the use of whey as a universal bio-eco-material and rapeseed protein concentrate. To eliminate the existing adverse effect of the electro-flotational separation of the whey components, an apparatus for electro-flotational processing in which the current does not flow through the whey has been worked out. The sensory analysis helped to find out that the typical aromatic substances of the whey hardly contribute to the aroma of the roast chicken leg quarter samples injected with the brine of modified composition, as modifying of the whey volatiles occurs in the electro-flotation process. The proposed formulation of the injection brine allows not only to increase the biological value of the products, but also purposefully form the functional and technological properties of poultry meat, with no hydrocolloids to use without compromising the product quality. Improving the functional and technological properties of the chicken leg quarters after pumping with modified brine is influenced by three factors. Firstly, the removal of the hydrogen index of the float whey from the isoelectric point of the basic proteins of the raw meat; secondly, the maximum capacity of the rapeseed proteins to bind moisture at pH 6-8; thirdly, the additional effect of the calcium ions in the whey composition on the structuring in the protein systems.

Keywords: whey, ultrafiltration, electro-flotation, rapeseed, injection brine, whole-muscle products

1. Introduction

The whey because of its unique biological value and variety of applications can rightfully be called a universal bio-eco-material (Khramtsov, 1990, 2011; Ahmed & Misra, 2011; Khomenko & Merzlov, 2013; Ramos et al., 2013). The whey proteins have been used successfully in the meat industry to improve the taste of ready-prepared products, flavoring, texturing, as well as to improve the overall quality of products (Matsudomi, Rector & Kinslla, 1991; Kudryashov & Shalagina, 2011; Glotova, Pryanishnikov, Artemov & Pelevina, 2012; Rocha, Souza, Magalhães, Gonçalves & Andrade, 2014).

One of the promising directions in processing technology of whole muscle meat products is the use of protein-injection brines (Pryanishnikov, Iltyakov & Kasyanov, 2012). Due to the increasing the total mass of semi-finished products and the enhancement of the water binding and retention capacity of the integrated protein system, brine pumping reduces the cost of products. At the same time the biological value of the product may be increased due to the balance of amino acid composition and the use of the whey biopotential for the complex protein-mineral-vitamin enriching the meat products. The electro-flotational whey processing is usually used to isolate proteins therefrom (Ostermaier & Dolias, 1985; Rodionova & Schetilina, 2003), but may also be used to modify its structure in order to improve customer appeal of the products. A disadvantage of the electro-flotational separation of the whey components is a current flow through the whey while processing that may result in the accumulation of harmful electrolysis products (e.g., available chlorine) in the whey and its elektroflotated concentrate. Furthermore, during the operation the electrodes are contaminated rapidly with whey protein.

The purpose of the research is improving the processing methods of obtaining the pumped whole muscle meat products by the example of the chicken leg quarters through the use of whey as a universal bio-eco-material and of vegetable protein preparations.

2. Method

As a protein component of the injection brine we tested rapeseed protein concentrate. Advantages of rape as a raw object are determined by an acreage increase and a high proportion of protein in the composition of cattle cake and protein meal.

To obtain a protein concentrate from rapeseed meal, the cake was milled and mixed with water, the medium was acidified to pH 4.5-4.6, and the extraction of ballast substances with simultaneous treatment with the composition of the enzyme preparations Amilosubtilin G3x and Glyukavamorin G3x was carried out. The protein extraction from the liquid fraction was performed by the isoelectric precipitation method followed by the detachment of protein solid sediment performed by centrifugation. The injection brine was prepared on the basis of cottage cheese whey treated by electro-flotation. The whey was obtained in the production of cheese using traditional acid-rennet method.

The sensor evaluation of the samples of the native curd whey and of the one processed by electro-flotation as well as of the pumped chicken leg quarters was performed on the electron odor analyzer "MAG-8" using the "Electronic nose" procedures (Shogenov, Kuchmenko, Grazhulene & Red'kin, 2012).

The measuring array incorporates 8 sensors based on piezoelectric resonators with a base frequency of oscillation 10.0 MHz with diverse film sorbents on the electrodes. The coatings are selected in accordance with the test objectives (maximum adsorption on the sensor surface of the certain classes of organic compounds): 3 coatings are polar (sensitive to alcohols, aldehydes, esters, phenols, ketones, etc.); 2 coatings are polar, sensitive to highly volatile acids, water (18-C-6, Tween); 1 coating consists of carbon nanotubes (CNT), selective to ammonia, amines, alcohols, C_3-C_7; 1 coating is specific to phenols and other aromatic compounds, methyl esters of fatty acid-essential oil (trioctylphosphine oxide, PubChem CID: 65577); 1 nonpolar coating with sorption to the active sites is sensitive to the N-containing compounds, essential oils. All sensors are informative.

The sample preparation: the samples were thermostated at room temperature, an average sample of the same mass of 3.00 g was taken and placed in a sealed glass container with a soft polymer soft membrane. The samples were held at a constant temperature (20°C) for at least 30 minutes. The samples of 3 cm3 of equilibrium gas phase were selected with each individual syringe and put into a detection cell.

The water binding and water retention capacity of chicken leg quarters injected with brine of various composition was determined by Grau and Hamm method.

3. Results

To eliminate adverse effect of electro-flotational treatment of the whey, we proposed an apparatus, in which the current does not flow through the whey. This is achieved by placing the whey on a metal mesh serving as a cathode, with an electrolyte to be between an anode and a cathode, for example, sodium chloride (Figure 1).

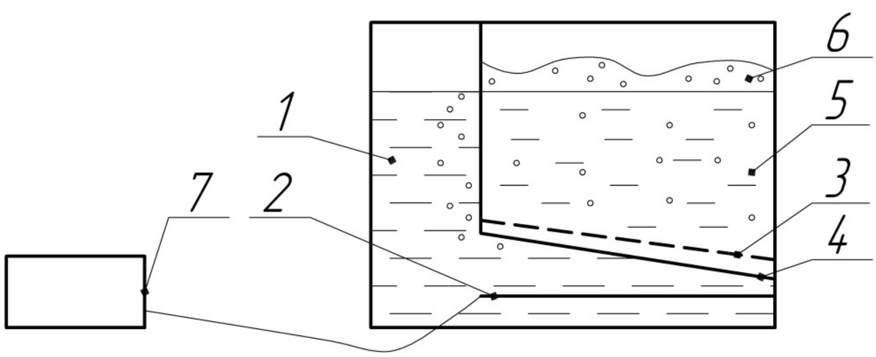

Figure 1. Installation for the membrane electro-flotation of the whey: 1 – electrolyte, 2 – anode, 3 - cathode (stainless steel mesh), 4 - a cellulose acetate membrane (pore diameter - 1 nm), 5 - milk whey, 6 – foam, 7 - constant voltage source

The whey and the electrolyte are separated by a cellulose acetate membrane having a pore diameter of 5 nm. After hydrogen bubbling, the bubbles break away from the cathode and come to the top. At the interface between the liquid - gas in the bubbles, the protein adsorption takes place. Simultaneously, the process of electrocoagulation of salts happens at the cathode, and the process is apparently caused by dehydration of cations when interacting with the electronegative metal cathode surface. After electro-flotation, the pH has been increased (Figure 2).

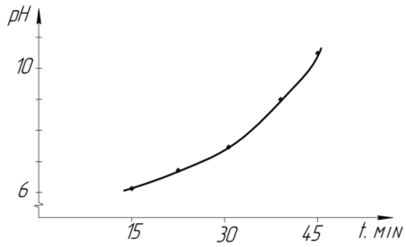

Figure 2. Change in the active whey acidity depending on the electro-flotation time

Some improved organoleptic qualities of the product have been noted, as well as the absence of the racy flavour and the smell of the whey. The change of the whey flavor was objectively confirmed by a system of "Electronic nose". This can be explained by the electroreduction of the whey volatiles on the cathode during the electro-flotation.

The float whey was used in the recipe of the injection brine for baked chicken leg quarters. The formulations for the injection brines are given in Table 1.

Table 1. Basic and modified formulations for the injection brines

	Component consumption in the brine formulation, kg / 100dm3	
Constituent	basic	modified
Table salt	7.0	7.0
Sugar or glucose	1.0	1.0
Sodium phosphate monobasic	0.3	0.3
Sodium pyrophosphate	0.3	0.3
Soy protein soluble	1.0	-
Corn or potato starch	1.0	-
Xanthan gum	0.1	-
Drinking water (ice)	88.3	-
Whey	-	91.4
Rape soluble protein	-	1.0

The experimental samples were characterized by a more juicy and tender texture (Table 2).

Table 2. Organoleptic indices of the samples of baked chicken quarters

	Product made with variants of injection brine formulation	
Indices	basic	modified
Appearance	The product of boneless chicken quarters The surface is clean, dry, with a decorative dusting or without it	
Taste and smell	Appropriate for high quality raw materials with aroma of spices	
Shape	Rectangular-oval, oval	
Sectional view	Characteristic of this type of product	
Consistency	Dense, elastic	Juicy, soft

It has been found that the test samples are characterized by a different qualitative and quantitative composition of the equilibrium gas phase (EGP) over the samples (Figure 3).

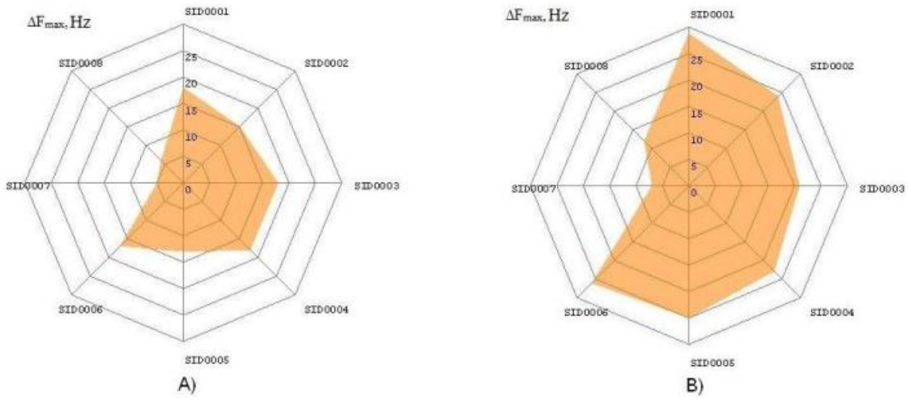

Figure 3. "Visual imprints" of the maximum sensor signals in the EGP over the injected chicken leg qurters. (A) Basic formulation, (B) modified formulation. Axes are indicated by sensors in the matrix

EGP over Sample 1 (a leg quarter injected with the brine, composed to the base formulation) contained less volatile substances than in Sample 2 in respect of their concentration and in respect of the qualitative composition, Sample 1 is simpler as compared with Sample 2 (a leg quarter injected with the brine to the modified formulation). The difference in flavor intensity of the samples was 66%. In Sample 2, the content of phenolic compounds, essential oils, amines, and other nitrogen- and sulfur-containing compounds is significantly increased; the content of aldehydes, ethers, ketones is slightly enhanced.

To work out the changes in detail and to establish fine differences in the composition of the EGP over the samples, more informative signals representing sorption kinetics are compared (Figure 4).

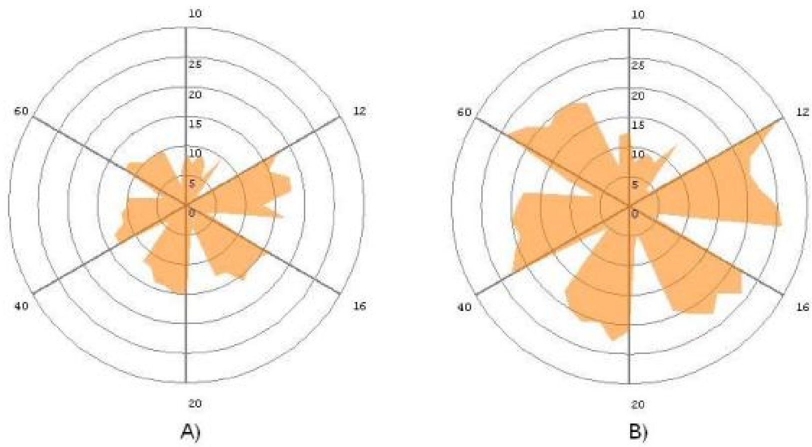

Figure 4. Kinetic "Visual imprints" of the injected leg qurters smell. (A) Basic formulation, (B) modified formulation. Around the circle, the measurement time is indicated, s; the vertical axis is a response magnitude of the 8-sensors array, Hz

The samples are characterized by the same type of "visual impressions" with decaying sorption and spontaneous desorption of the components with sorbent films. This processing history is typical for the selected sorbents during sorption of low concentrations of organic compounds interpolar (C3-C5 alcohols, alkyl acetates, ketones, amino acids, amines, essential oils, etc.). They are components of the additives (soybean, rape).

According to Korenman, Melnikova and Niftaliev (2005), the method of sensory analysis similar to the one used in the present study helped to find out that butyric acid (PubChem CID: 264) and acetaldehyde (PubChem CID: 177) make the most significant contribution to the formation of the specific whey smell, which correlates with the results of the gas chromatographic analysis.

Thus, the specific aroma-forming substances of the whey make virtually no contribution to the fragrance of the prototype sample that can be explained by modification of the volatile substances in the whey during the electro-flotation. Greater contents of the individual classes of organic compounds in the EGP over a sample (amines, heavy alcohols, oils) can be linked with some native rapeseed compounds.

The evaluating of the salting effectiveness was conducted in terms of the water binding (WBA) and water retention (WRA) capacities of the experimental and control samples of the chicken quarters according to the formulations of the injection brines given in Table 1.

The maximum values of WBA are shown when pumping with brine based on the whey with rape at 20% by the weight of the test sample.

To determine the rational duration of the salting in respect of the WBA and WRA formation as target values, we have investigated their dependence on the time of salting (Figure 5).

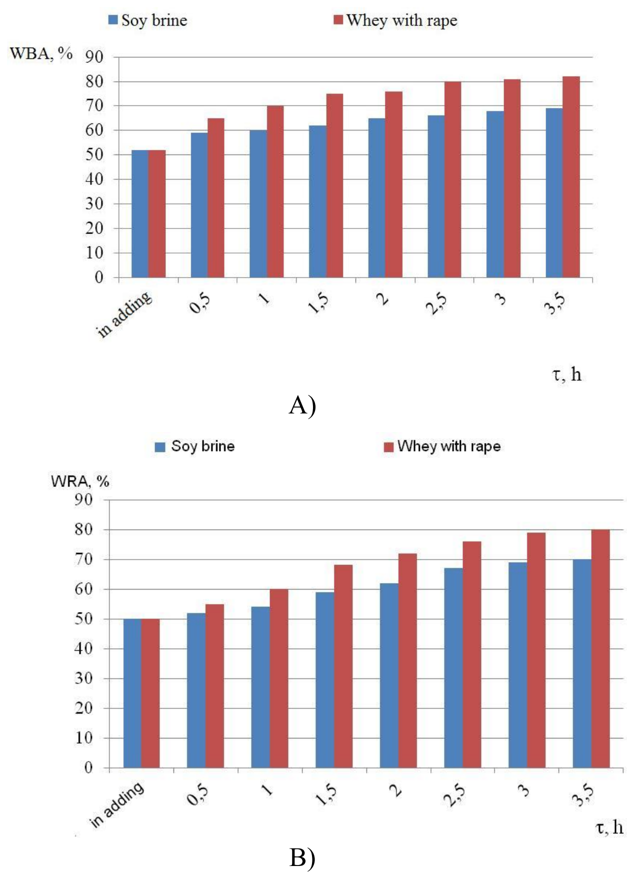

Figure 5. The water-binding (A) and water retention (B) capacities of the chicken leg qurters injected with brine to the basic and modified formulation

While the 3.5 hours salting there is a gradual increase in WBA that reaches its saturation at the 3 hours duration.

4. Discussion

The increased water binding and water retention capcity of the whole muscle raw meat injected with a solution of rapeseed protein in the float whey is, in our opinion, caused by three factors.

Firstly, the increase in the pH value of the medium when injected with the float whey of pH = 8 leads to the removal of the hydrogen index from the isoelectric point of the basic proteins of the raw meat and to the binding of additional amount of water by the charged polar groups.

Secondly, the use of isolates or concentrates of the rape protein instead of soy isolate creates certain benefits in terms of the increased water-binding capacity. In rapeseed the globulin fraction is represented primarily by proteins with a constant sedimentation of 11S, while in the bean seeds it contains more 7S-proteins (Shulvinskaya, Dolya, & Shirokoryadova, 2007). Rape contains albumins at 40-50% of the nitrogen-containing substance in the seed (soybean seeds have 10-20%) and the albumins have a higher isoelectric point at pH = 9 (strong basic properties of the protein are caused by the high content of amides of aspartic acid and glutamic acid). So, the rape protein solubility curve has two minima: one minimum at pH = 4-5, which corresponds to the minimum solubility of the globulin fraction and the other one at pH = 9-9.5 – the point where the albumin fraction is minimally soluble. In the range of pH = 7-8, the nitrogen solubility of the rapeseed flour is 65-70%. The characteristic of water binding capacity is closely correlated with solubility. The water binding capacity reaches the maximum at the nitrogen solubility index of 70%. So, the ability of the rapeseed proteins to bind moisture in the range of pH = 6-8 reaches the maximum. This explains the increasing importance of the water-binding capacity of the chicken quarters pumped with brine with rapeseed proteins addition. The increasing of the water-binding capacity of the rape isolates (and especially concentrates) compared with soy isolates was noted in.

The solubility curve of soy proteins at pH = 6-7 is a sharp rise. Therefore, the water binding capacity of the soy proteins will strongly depend on the pH of the medium that inconveniences when using brines with modified acidity.

The third determinant of the increased water binding capacity of the prototypes is the presence of calcium ions in the whey. There is some data on the calcium effect on the structure formation of different proteins.

So, the electron microscopy method revealed the addition of CaCl2 (PubChem CID: 5284359) to cause the increase in the diameter of the aggregate and the pores in the gels formed by the soy proteins (Maltais, Remondetto, Gonzaliez, & Subirade, 2005). When adding CaCl2 (PubChem CID: 5284359), the size of the emulsion droplets of soybean oil in the sodium caseinate solution increased (Ye, 2001), while the NaCl (PubChem CID: 5234) has no substantial effect on the size of the droplets of the emulsion, stabilized by the sodium caseinate (Srinivasan, Singh, & Munro, 2000). The Ca2+ ions affect the conformational changes of myosin and actin, causing unfolding of actin and myosin molecules, and also promotes the formation of intermolecular disulfide bonds. The conformational changes lead to the increase in the degree of hydrophobicity of myosin molecules, which together with the increase in the number of disulfide linkages creates conditions for the formation of the protein aggregates (Hemung and Yongsawatdigul, 2005). The overall rate of aggregation of the whey protein gels is higher when adding CaCl2 (PubChem CID: 5284359) than when adding NaCl (Marangoni, Barbut, McGauley, Marcone, & Narine, 2000).

It can be assumed that the rape protein molecules under the influence of calcium experience conformational changes leading to the formation of hydrophobic bonds with neighboring protein molecules. This can lead to the local formation of mixed gel structures. Moisture is immobilized in the cells of the structures.

5. Conclusion

The data in this study shows that the use of the float whey with rape protein isolate allows purposefully form the functional and technological properties (water binding, water holding capacities) of poultry, and omit the use of hydrocolloids - corn starch and xanthan gum - without compromising the quality of products. However, the present research studied only the basic functional and technological properties of the injected chicken leg quarters on the hypothesis that the rest of the whole-muscle meat products being injected show similar characteristics. Therefore, there emerges a necessity of researches like the one described, having other objects of investigation, such as ham meat products with meat from other farm animals to be used.

Since the viscosity of rape solutions in the whey differs from the one of traditional injection brines, there may be some changes in the injection technology. Therefore it is necessary to investigate the dependence of the functional and technological characteristics of the product from the processing parameters such as pressure and velocity of the fluid jet, followed by working out a quantitative physical-mathematical model. Intermolecular interactions of proteins in the muscle tissue and of the rape proteins are also of certain interest (Mahmoudi, Axelos, & Riaublanc, 2011; Ryan, Zhong, & Foegeding, 2013).

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References

Ahmed, L., & Misra, N. N. (2011). An overview of the biological activities of whey proteins and peptides. *Whey: Types, Composition and Health Implications*. New York: Nova Science Publishers, Inc., 197-210.

Glotova, I. A., Pryanishnikov, V. V., Artemov, E. S., & Pelevina, G. A. (2012). The use of whey in the recipe of sausage "Lyubitelskaya". *Proceedings of the universities. Food technology, 2*(3), 63-64.

Hemung, B. O., & Yongsawatdigul, J. (2005). Ca2+ effects physicochemical and conformational changes of threadfin bream myosin and actin in a setting model. *Journal of Food Science*, *70*(8), 455-460.

Khomenko, A., & Merzlov, S. (2013). The chemical composition of milk whey - component of the nutrient medium for Spirulina Platensis. *Технологія виробництва і переробки продукції тваринництва, 9*(103), 73-75.

Khramtsov, A. G. (1990). *Whey.* Moscow: Agropromizdat, 239 pp.

Khramtsov, A. G. (2011). *The phenomenon of whey*. St. Peteprburg: Profession, 804 pp.

Korenman, Ya. I., Melnikova, E. I., & Niftaliev, S. I. (2005). Applying modified piezoquarts sensors to the analysis of milk products. *Ecological Congres (USA)*, *8*(1), 13-15.

Kudryashov, L. S., & Shalagina, E. A. (2011). The use of milk-protein complexes in the manufacture of products from lamb. *Meat Industry, 1*, 35-38.

Mahmoudi, N., Axelos, M. A. V., & Riaublanc, A. (2011). Interfacial properties of fractal and spherical whey protein aggregates. *Soft Matter*, *7*(17), 7643-7654.

Maltais, A., Remondetto, G. E., Gonzaliez, R., & Subirade, M. (2005). Formation of soy protein isolate Gold-set gels: protein and salt effects. *Journal of Food Science, 70*(1), 67-74.

Marangoni, A. G., Barbut, S., McGauley, S. E., Marcone, M., & Narine, S. S. (2000). On the structure of particulate gels – the case of salt-induced cold gelation of heat-denaturated whey protein isolate. *Food Hydrocolloids, 14*, 61-74.

Matsudomi, N., Rector, D., & Kinslla, J. E. (1991). Gelation of bovine serum albumin and β-lactoglobulin: Effect of pH, salts and thiol reagents. *Food Chemistry, 40*, 55-69.

Ostermaier, R., & Dolias, B. (1985). The separation of proteins from their mixtures using flotation. *Colloids and Surfaces, 14*, 199-208.

Pryanishnikov, V. V., Iltyakov, A. V., & Kasyanov, G. I. (2012). *Innovative technologies in the production of meat products*. Germany, Saarbrueken: Lambert Academic Publishing, 308 pp.

Ramos, Ó. L., Reinas, I., Silva, S. I., Fernandes, J. C., Poças, M. F., Pintado, M. E., … Vicente, A. A. (2013). Effect of whey protein purity and glycerol content upon physical properties of edible films manufactured therefrom. *Food Hydrocolloids, 30*(1), 110-122.

Rocha, C. M. R., Souza, H. K. S., Magalhães, N. F., Gonçalves, M. P., & Andrade, C. T. (2014). Rheological and structural characterization of agar/whey proteins insoluble complexes. *Carbohydrate Polymers, 110*, 345-353.

Rodionova, N. S., & Schetilina, I. P. (2003). Efficiency of elektro-flotational allocation of whey protein. *Bulletin of the Russian Academy of Agricultural Sciences, 6*, 75-76.

Ryan, K. N., Zhong, Q., & Foegeding, E. A. (2013). Use of whey protein soluble aggregates for thermal stability – a hypothesis paper. *Journal of Food Science*, *78*(8), R1105-R1115.

Shogenov, Y. K., Kuchmenko, T. A., Grazhulene, S. S., & Red'kin, A. N. (2012). Quartz crystal microbalance determination of vapors of volatile organic compounds on carbon nanotubes under batch conditions. *Journal of Analytical Chemistry, 67*(1), 21-27.

Shulvinskaya, I. V., Dolya, O. A., & Shirokoryadova, O. V. (2007). Composite protein supplements from oilseeds and melon plants. *Proceedings of the universities. Food technology, 5*(6), 40-42.

Srinivasan, M., Singh, H., & Munro, P. A. (2000). The effect of sodium chloride on the formation and stability of sodium caseinate emulsions. *Food Hydrocolloids, 14*, 497-507.

Ye, A. (2001). Interfacial composition and stability of sodium caseinate emulsions as influenced by calcium ions. *Food Hydrocolloids, 15*, 195-207.

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