UDC 637.142.2:542.816

MILK WHEY PROCESSING: PROSPECTS IN UKRAINE

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DOI: https://doi.org/10.15673/fst.v13i4.1557

Article history

Received 07.07.2019
Reviewed 10.09.2019
Revised 24.09.2019
Approved 03.12.2019

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Cite as Vancouver style citation

Sychevskyi M, Romanchuk I, Minorova A. Milk whey processing: prospects in Ukraine. Food science and technology. 2019;13(4):58-68. DOI: https://doi.org/10.15673/fst.v13i4.1557

Цитування згідно ДСТУ 8302:2015

Sychevskyi M., Romanchuk I., Minorova A. Milk whey processing: prospects in Ukraine // Food science and technology. 2019. Vol. 13, Issue 4. P. 58-68 DOI: https://doi.org/10.15673/fst.v13i4.1557

Abstract. Milk processing not only provides people with traditional dairy foods, but also results in the formation of by-products. They are not fully utilised, and their effluents worsen the environment. The modern technical and technological level of milk processing allows the full use of by-products, which are a source of whey proteins, lactose, and other potentially useful ingredients. As milk production has been decreasing in recent years, an urgent problem is to increase the level of milk processing in order to obtain products with high added value. The article presents the results of analytical studies of the situation about whey processing in Ukraine, and describes modern conceptual approaches to processing various types of whey, which is formed as a by-product in the manufacture of cheeses, sour milk cheese, casein. It is shown that new products and ingredients obtained from whey have a wide range of functional and technological properties and prove useful in the manufacture of other foods. The development trends of the new technologies for a wide range of whey-based products and ingredients are analysed, and new research data on their importance for human health are presented. The article is a review that proves how practical it is to introduce modern membrane technologies of whey processing at domestic milk processing enterprises. These technologies will allow using raw milk resources rationally, reducing damage to the environment, and increasing production profitability. The article presents the results of scientific and applied research of using membrane methods and enzymatic hydrolysis of lactose in the technologies of dry demineralised whey and condensed low-lactose whey. The use of existing industrial equipment allows, due to changes in the protein-mineral composition of whey, obtaining products with a wide range of functional and technological properties and increased nutritional values.

Keywords: milk whey, membrane technologies, electrodialysis, whey proteins, lactose, food value.

Introduction and problem statement

The dairy industry plays an important part in the effective functioning of the agricultural and food market in Ukraine. In the total sale of food products, the dairy industry accounts for about 11% [1]. In general, the domestic food industry has every possibility to integrate into global trade. Ukraine has great potential to develop its dairy industry, in particular now that there is an increase in the global demand for food [2,3]. Milk and dairy products are extremely important for Ukrainian consumers. Due to processing milk industrially, we can have traditional dairy food, such as products from whole milk, cheeses, butter, preserved milk products, and the like. However, until recently, by-products of milk processing, which are a source of whey proteins, lactose, and other potentially useful ingredients, have not been processed to the full extent. In countries with a developed dairy industry, milk is normally highly processed in order to obtain products with high added value. For Ukraine, it is especially necessary to develop in this direction, since in recent years, there has been a tendency for a decrease in its milk production [4]. The modern level of technologies and equipment can ensure the full use of all milk components to manufacture high-quality products, or the further processing of by-products in order to extract their valuable components [5,6]. Now dairy products are viewed not only as a traditional source of macronutrients, but also as a natural source of such functional ingredients as calcium, riboflavin (vitamin B_2), beneficial microorganisms, peptides, linoleic acid [7]. That is why processing secondary dairy raw materials, in particular whey, is a topical problem for the dairy industry.

The purpose of the work is to analyse how whey is processed in Ukraine, and to identify the current tendencies in the development of milk processing

technologies and in the use of the resulting products for nutrition.

The objectives of the study are to prove how prospective it is to use the membrane methods of desalination and enzymatic hydrolysis of lactose for whey processing, and to find out what are the results of introduction of such technologies at dairy enterprises in Ukraine.

Analysis of recent research and publications

The problem of full and rational use of whey is characteristic of the countries with traditionally high cheese consumption. According to the official data from the EWPA (European Whey Processors Association), in the European Union, over the past decade, production of whey powder has increased from 1.95 MMt to 2.20 MMt [8]. To solve the problem of the disposal of the whey formed as a by-product during cheese production, EWPA has adopted a special programme [9].

In Ukraine, annual whey resources of all types total about 2 MMt. More than half of its volume (59%) is sold to agricultural enterprises as livestock feed, more than 20% is discharged into sewer systems, and only about 25% is processed to make export products [10]. According to the State Statistics Committee, in 2016–2017, there was a surplus in the export of such dairy products as cream, condensed whey and milk, dried cream, and whey powder. In 2017, whey powder export ranked sixth among various product groups [11,12]. After the Russian market was lost, Ukrainian processors faced the necessity to diversify sales markets, and discover new countries with different cultures of consumption and business methods. As a result, large milk processing enterprises of Ukraine concentrated the bulk of their exports on the markets of the East (Egypt, Morocco, the United Arab Emirates, Tunisia, Libya, Algeria, Bangladesh, Vietnam), post-Soviet countries (Kazakhstan, Moldova, Georgia), and began exploring new markets – the EU and China. In particular, 13.0% and 16.5% of all exported whey were sent, respectively, to China and Vietnam [13,14].

Based on the balance of the produce manufactured in 2018, the data have been calculated, which indicate that the production of hard cheese and sour milk cheese can alone yield 2.11 MMt of whey, including 1.58 MMt of cheese whey and about 524.8 KMt of acid whey (and setting aside casein whey). Of these amounts, only 1.02 MMt of whey is processed in the traditional way to produce powdered whey, which is only 48.3% of the total amount of whey. Thus, of 4.18 MMt of milk purchased for industrial processing, about 1.09 MMt of it, in the form of liquid whey, is never used in nutrition. This means that the food and ingredients market loses about 5.5–8.7 KMt of whey proteins and 45.8–49.1 KMt of lactose.

Since the potential of whey is significant, its rational use should include its processing to manufacture new types of food and ingredients that have new functional and technological properties and are needed to produce other foods. A. Khramtsov considers whey to be "a complex biotechnological system, which is a type of renewable natural raw material of animal origin." According to him, its processing should be based on the life cycle and logistics principles and carried out at the three interrelated levels: whey, whey components, and whey-based derivatives [6].

The most common types of products derived from whey are lactose (milk sugar), unsweetened condensed whey, sweet condensed whey, whey powder, demineralised whey powder, low-lactose whey, whey protein concentrates [15]. Membrane technologies introduced at dairy plants allow increasing the productiveness due to energy saving, fuller use of raw materials, a wider range of products, and extra profit [16,17]. However, whey processing, despite significant progress and numerous developments in this area, is constrained for many reasons, including the high cost of equipment, and inadequate state environmental control unable to make milk processing enterprises reduce whey waste in their sewage.

Trends in the development of whey processing technologies. Membrane processes of the separation of polydisperse systems are highly selective. The technologies used in the dairy industry are based on baromembrane processes, in which substances are transferred through membranes due to pressure difference (microfiltration, nanofiltration (NF), ultrafiltration, reverse osmosis), and on electrodialysis (ED), during which ions are removed from the whey under the action of the electric field [18-20].

Microfiltration is separation of particles larger than 100 nm on porous membranes. It ensures the simultaneous separation of the fat and casein phases of whey in one fraction containing about the same amounts of fat and protein. Nanofiltration is separation of particles sized 1–10 nm under the influence of pressure in the range 0.1 to 3.0 MPa. It is an alternative to vacuum distillation, with simultaneous partial demineralisation (removal of monovalent ions Na, K, Cl). This makes nanofiltration the most appropriate for pre-concentration of whey, since this process, compared to vacuum evaporation, consumes less energy and involves simultaneous partial demineralisation [19,20]. Ultrafiltration requires membranes with the pore diameters 10 to 1000 nm, which can retain components sized 20 to 100 nm. The working pressure is mainly within the range 0.1 to 1.0 MPa [18]. Reverse osmosis is a baromembrane

process during which the solvent is transferred against the gradient of its osmotic pressure.

During nanofiltration, besides whey demineralisation, concentration of solids up to 18–22% takes place. So, nanofiltration is more energy-saving than vacuum evaporation of whey [17].

From a practical point of view, the ideal nanofiltration is that which removes the maximum amounts of mineral salts and lactic acid from various whey types, with the fullest retention of the most valuable whey components – proteins and lactose, – which results in obtaining concentrates of such technological parameters that allow their using to manufacture other products [21-23].

Since it is cheese whey that is mainly used for drying, there are very few methods of acid whey processing. The electrodialysis technology allows removing up to 90% of ash and 50% of lactic acid from cheese whey and acid whey, although for practical purposes, desalination at a level of 50–60% is usually enough [24].

An acute problem is processing casein whey. It contains hydrochloric or sulphuric acid, which makes it impossible to use it in the unprocessed form. When this whey is neutralised with a caustic or slaked lime, the content of mineral salts increases significantly. Salty whey contains 7.4–8.0% of solids, including 2.3–2.8% of ash. Due to the high ash content, the use of salty whey as food or feed is also limited. A significant lactose content in this whey, which is 70% of its initial content in milk, also complicates its condensing and drying because of the crystallisation processes.

Electrodialysis used to demineralise cheese whey and acid whey is an effective way to reuse it for food purposes [25]. During electrodialysis, a decrease in the salt content is accompanied by a simultaneous decrease in the titrated acidity of whey, and the sensorial parameters are improved as soon as at the 50% level of demineralisation [26].

Electrodialysis allows increasing demineralisation target values up to 90%, which is especially promising for processing salty cheese whey, acid whey, and casein whey [26,27]. Demineralised whey can be standardised in terms of its physical and chemical composition and sensorial characteristics to reach a quality that allows its use as baby food [17]. However, achieving a higher level of demineralisation is accompanied by a significant increase in energy consumption, which makes it uneconomical [28].

To increase its effectiveness, electrodialysis is combined with other membrane methods of separation [24]. In particular, combining nanofiltration and electrodialysis is not only recommended to increase the effectiveness of the whey processing technology and to save energy, but also to reduce the effect of high temperatures on the temperature-sensitive components of whey. This, ultimately, increases the biological value of the produce obtained and improves its technological properties [21]. The taste, physical and chemical characteristics, and functional technological properties of this demineralised whey powder are better than those of whey powder obtained by the traditional technology [29].

When milk whey is processed by ultrafiltration, concentration of high molecular weight protein components takes place (concentrate or retentate), and most of the low molecular weight compounds and lactose transforms into a filtrate (permeate) [18]. Besides whey proteins, the retentate also contains other whey components. For their further separation, diafiltration is used, which consists in washing the obtained concentrate with water. Ultrafiltration is mainly used to isolate proteins from cheese, acid and casein whey in order to obtain protein-carbohydrate concentrates. Obtaining lactiprotein and whey protein concentrates (WPC) by ultrafiltration does not involve treatment with acids, alkalis, and high temperatures, thus preserving the native protein structure and helping improve their sensory and nutritional properties [18].

Ways to use the products of whey processing. Today, significant progress in using whey and its components is possible due to numerous studies and publications in this field [30-39]. Whey is viewed as "forgotten treasure" that, due to its unique properties, is now "rediscovered" [31,32]. Changing the composition of whey by the membrane processing methods allows expanding the range of functional and technological properties of the products. With an increase in the protein content and in whey proteins' ability of to bind water, emulsify and retain fats, the technological properties improve in the following order: WPS > demineralised whey > dry whey. Whey proteins are highly soluble and resistant to processing, can form various types of gels, stabilise emulsions and foams, appearance and flavour. All these properties of whey proteins make it possible to form various textures of dairy products and of many other foods containing them.

Whey protein concentrates are used in the manufacture of dairy and meat products [33,34], soft drinks, bakery products, special dietary and medical foods (including baby foods) [35,36], protein pastes, sauces, mayonnaises, etc. [35,37,38]. The use of whey protein concentrates to manufacture cheese allows reducing the time of its maturation, improving its sensory characteristics, and increasing the yield of the finished product, as well as accelerating milk coagulation [36]. In the confectionery industry, whey protein concentrates are used to substitute egg whites in different fillings based on whipped egg mixes containing no butter and fewer calories [30]. In bakery

products, whey proteins added to the dough have a positive effect on its water-holding ability, specific volume, and ability to remain fresh during storage [35,39].

Due to the foaming properties, dry concentrates can be used in the creation of aerated dairy products [40,41]. They can completely or partially replace egg yolk, hydrocolloids, soy protein, or modified starch. The most important functions of whey protein concentrates in low fat products are: binding with water, emulsification, high solubility, gelation, increased viscosity and adhesive interactions [35]. In yoghurts, protein concentrate counteracts synaeresis and stabilises the consistency. Even 1% of a protein concentrate added to milk has a positive effect. A way to reduce fat in milk-protein products without losing their sensory properties is using whey protein microparticulates [42]. The technology of obtaining these products is based on thermal denaturation of whey proteins while producing whey protein concentrates under a strong mechanical shear action (homogenisation) [43]. This process allows getting protein particles of microparticulates with an average diameter of 0.5–2 μm. Within this range, the microparticles give the product the taste and consistency characteristic of milk cream. By its composition and nutritional value, a microparticulate does not differ from an ordinary whey protein concentrate, is easily dispersed, and quickly dissolves without any special equipment. When manufacturing low-fat sour milk cheese according to the traditional technology (by the acid method), the product often has an unsatisfactory consistency. One of the principal conditions for obtaining high-quality sour milk cheese is synaeresis of the curd. However, the low fat content in the raw milk makes it extremely difficult to achieve the formation of dense and elastic curd. Adding microparticulates to whey proteins enriches milk with protein and allows obtaining a product of the required consistency [41]. Particles of the microparticulate improve the consistency and rheological characteristics of protein coagula due to the presence of hydrophilic areas of whey protein molecules and to blocking the microcapillaries of the protein matrix. They also participate in the formation of a casein coagulum, where their structure-forming function is similar to that performed by fat globules in traditional foods.

Whey processing products with a protein content of 30–50% can be used to substitute skimmed milk powder and improve the adsorption of fat and water in various meat-based foods [35]. They have high water-binding properties, that is why they can prevent the loss of fat and moisture in chopped and minced meat products [33]. Some part of powdered milk can be substituted for demineralised whey powder or whey protein concentrates. Due to the gel-forming ability of whey proteins, during the cooking process, they support the three-dimensional polymer network, thus strengthening the texture of the finished product. Besides, it has been proved that, when manufacturing restructured meat products, whey can be used in the brine (5% of the total weight of the unsalted raw materials). The output of products increases by almost 8%, and their colour and strength improve. Microstructural studies of samples of ham made with and without whey demonstrated a denser arrangement of structural elements. The introduction of whey into the injected brine increases the degree of swelling of muscular fibres [34].

Demineralised whey obtained by a complex of membrane methods (nanofiltration and electrodialysis) contains about 26–27% of whey proteins. Due to an increase in the protein content in demineralised dry whey, its foaming, water-holding, fat-holding, and emulsifying capacities significantly increase compared with those of whey obtained by the traditional technology [44].

One of the factors limiting the use of whey is the high content of lactose that causes gastrointestinal disorders in lactose intolerant consumers. The problem was solved by hydrolysis of milk lactose. Industrially, bacterial and fungal lactase enzymes are used to manufacture lactose-free dairy products and for hydrolysis of whey lactose. Lactose is hygroscopic and causes crystallisation in foods with its high content. B-galactosidase enzymes are used to reduce the lactose crystallisation in concentrated products, in particular, in ice cream and condensed milk. Using β-galactosidase for hydrolysis of lactose not only improves the texture of a product by reducing lactose crystals, but also enhances the nutritional properties of the product. The products of lactose hydrolysis (glucose and galactose) are fermented faster in such products as yoghurts and cheese. Besides, they make it possible to add fewer sweeteners, thus reducing the calorie content of the final product. Hydrolysed lactose whey is used to produce ethanol and glucose-galactose syrup. Whey and other lactose-rich raw materials are a source of lactose, a necessary substrate for the production of lactose concentrates, lactose derivatives (galactooligosaccharides), pharmacopoeial lactose, and prebiotics [18].

Biological value of the products of whey processing. The properties of whey proteins give them a significant advantage over other proteins of animal origin [45]. As for their nutritional value, they have a well-balanced amino acid composition, and the sequence of amino acids in polypeptide chains forms various types of biologically active peptides that are discretely released during protein hydrolysis [46]. They contain microelements, minerals, vitamins, and fatty acids, have antimicrobial, antiviral, and antitumor

effects, and stimulate the immune system [45]. Milk proteins are evaluated as high-quality proteins because of their amino acid composition, digestibility, and bioavailability [47]. They are quite high in essential acids that are more digestible than most other proteins [48]. It is the differences in the amino acid composition of casein and whey proteins that are responsible for the differences in their physiological activities [49-51]. Compared to casein, whey proteins contain more branched-chain amino acids: isoleucine, leucine, and valine [50], which affect protein synthesis in the case of type 2 diabetes [51]. Casein of essential amino acids is higher in histidine, methionine, phenylalanine compared to whey proteins, and contains a higher proportion of arginine, glutamic acid, proline, serine, tyrosine [49].

The results of clinical studies in many laboratories indicate that an increase in dairy consumption reduces the risk of metabolic disorders and cardiovascular diseases [52,53]. Whey proteins, casein, and minerals are considered to be the driving force of this positive effect [52]. More and more data are confirming the effect of milk proteins and peptides on the formation of human metabolic health [54,55]. It has been shown that whey proteins stimulate insulin secretion [55] and increase the feeling of fullness, which indirectly helps lose weight and reduce obesity [56]. Whey proteins effect on the increase in skeletal muscle mass by stimulating the synthesis of muscle proteins, and peptides derived from milk protein are involved in regulating the blood pressure and immune system [57-59].

Besides the pronounced therapeutic effect of reducing the lactose content in products, galactose and galactose-containing oligosaccharides are important for the functional properties. The physiological role of galactose is to ensure healthy development of the human body [60,61]. In particular, galactose is potentially helpful in removing neurotoxic compounds from the brain in patients suffering from hepatic encephalopathy or Alzheimer's disease [62,63]. Oral administration of galactose may be a new and promising non-toxic therapy for the syndromes of certain diseases [63]. Galactose as a prebiotic is present in oligosaccharides of the raffinose and galactose types [64]. These prebiotics have a beneficial effect on the gastrointestinal tract, stimulating the development of certain types of intestinal microbiota and exhibiting antiadhesive activity to some pathogens [60]. The main food source of galactose is milk lactose. Also, a small amount of free galactose (about 0.3 g/100 g) is contained in low-lactose milk, yoghurts, cheeses, creams, ice cream, and other food products artificially sweetened with galactose.

Whey processing in Ukraine. Various aspects of the problem of whey processing were studied by domestic scientists, in particular, V. Gutsalyuk, G. Deinichenko, Yu. Zmievsky, V. Mironchuk, A. Chagarovsky, etc. A set of studies of whey processing by the membrane methods of desalination and hydrolysis of lactose was carried out at the Institute of Food Resources of the NAAS. Fig. 1 shows a process flow chart of electrodialysis, nanofiltration and ultrafiltration, which were tested and implemented in an industrial environment.

Nanofiltration, electrodialysis, and ultrafiltration are the most used methods. Such milk processing enterprises as JSC "Dubnomoloko," PrJSC "Litynsky Dairy Plant," LLC "Tekhmolprom," LLC "Ovrutsky Milk Canning Plant," LLC "Khmelnytsky Dried Skim Milk Plant *Molochny Vizyt*," LLC "Andrushivsky Butter and Cheese Plant," LLC "Cheese Club," LLC "Gaisinsky Dairy Plant," PrJSC "Milk Alliance," Subsidiary "Milkiland-Ukraine," LLC "Akhtyrsky Dairy Industrial Company *Slavia*," ALC "Khersonsky Butter Plant" process raw milk whey and obtain dry demineralised whey with the demineralisation level 40%. Nanofiltration and electrodialysis are introduced at CJSC "Zolotonisky Butter Plant" that manufactures dry demineralised whey with the demineralisation level 90%. Ultrafiltration of whey is introduced at LLC "Buchatsky Cheese Plant," LLC "Gadiachsyr," and LLC "Tekhmolprom."

In the original whey formed as a by-product of milk processing when cheese is manufactured, the most part of the total solids is lactose (about 58–78% for all types of whey). The ash content can reach 10% to 31%, depending on the technology of the main product. The protein content can be as high as 7.5 to 12.5%. Table 1 shows the average values of the target parameters of whey processing products obtained by the membrane technologies. The data presented are the results of our research [28,29,44,65].

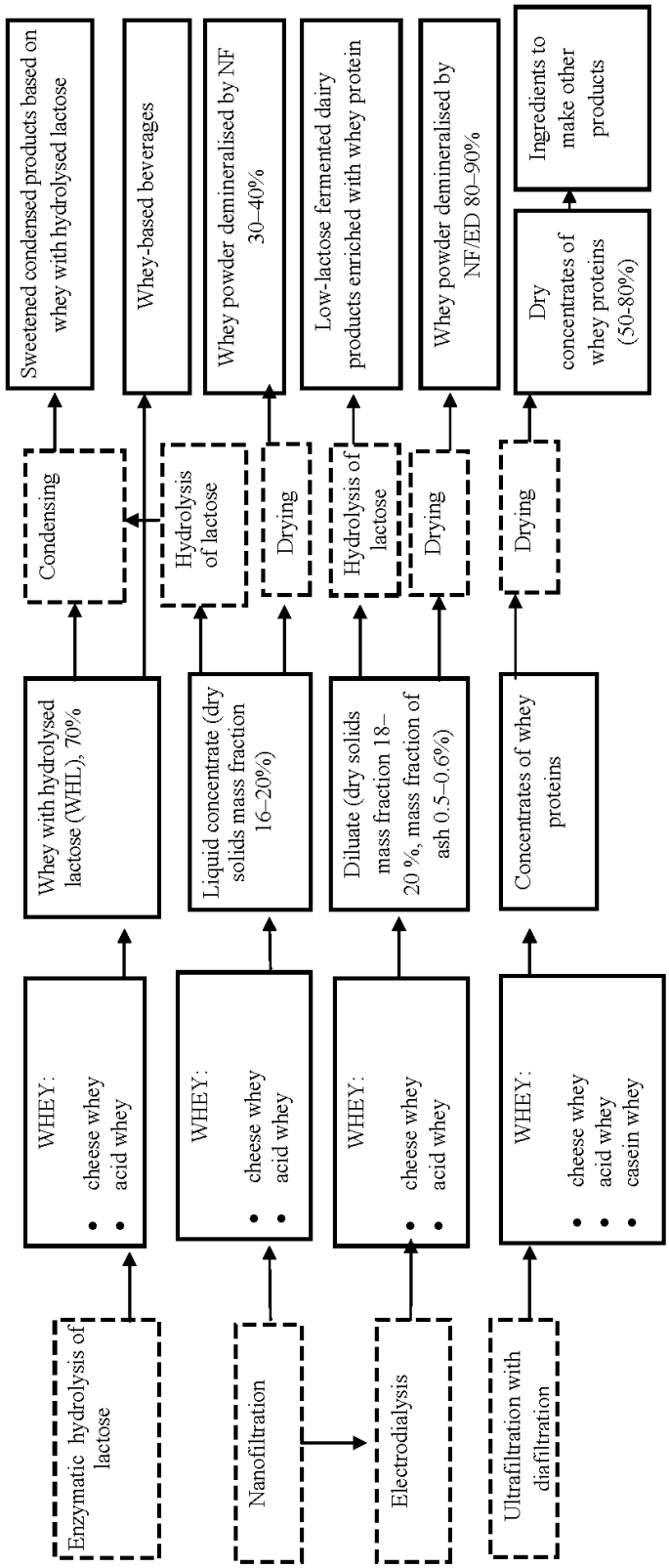

Fig. 1. Technological chart of obtaining whey processing products

Table 1 – Average values of the target parameters of whey processing products

Product	Content (mass fraction), %			
	dry matter	ash	protein	lactose
Cheese whey powder (control)	97.0	7.3	12.5	74.5
Acid whey powder (control)	95.2	8.3	11.1	73.0
Cheese whey powder, demineralised by ED	95.1	1.55	9.0	82.6
Acid whey powder, demineralised by ED	94.5	2.82	9.8	76.0
Liquid cheese whey, demineralised by NF	19.4	1.0	2.3	15.2
Cheese whey powder, demineralised by NF	97.9	5.12	15.9	76.2
Cheese whey powder, demineralised by NF/ED	97.0	2.63	27.0	65.9
Acid whey powder, demineralised by NF/ED	94.8	2.72	26.1	63.7
Cheese whey proteins concentrate (WPC 50)	93.8	7.3	50.0	32.1
Cheese whey proteins concentrate (WPC 65)	94.2	3.8	65.0	17.3
Cheese whey proteins concentrate (WPC 70)	94.0	2.0	70.0	11.8
Sweetened low-lactose condensed whey	70.0	8.0	4.8	2.5

It is obvious that combining various methods of desalination or concentration of whey components can significantly improve its quality, and allows obtaining products with the required composition and properties.

Thus, by expanding the range of methods that allow influencing the protein and carbohydrate components of whey, we can improve its technological properties and use it in the technologies of other dairy products.

Conclusion

In recent years, Ukraine has been facing the growing need for an integrated approach to improving the industrial processing of secondary dairy raw materials, as they are one of the main sources that make the diet of a lot of consumers biologically valuable and healthy. To use raw milk resources effectively, it is practical to introduce the technologies based on modifying protein-carbohydrate and mineral components. Combining different methods allows fractioning and concentrating the components of whey, significantly improving its quality, and obtaining products with the required composition and properties. The existing industrial equipment makes it possible, due to the changes in the protein-mineral composition of whey, to obtain products with a wide range of functional and technological properties and increased nutritional characteristics.

References:

1. Silske hospodarstvo Ukrainy. Ofitsiinyi veb-sait Derzhavnoi sluzhby statystyky Ukrainy. URL : http://www.ukrstat.gov.ua
2. Deineko LV, editors. Rynok produktsii kharchovoi promyslovosti. Rozvytok promyslovosti dlia zabezpechennia i onovlennia ukrainskoi ekonomiky: naukovo-analitychna dopovid. Kyiv: NAN Ukrainy, DU «Instytut ekon. i prohnozuv. NANU»; 2018.
3. Sychevskyi MP. Kharchova promyslovist yak osnova prodovolchoi bezpeky ta rozvytku derzhavy: monohrafiia. Kyiv: Ahrar. Nauka; 2019.
4. Vintoniak V. Ukrainska molochna industriia. Molochnyi biznes-2018: materialy KhI Vseukrainskoi konferentsii z mizhnarodnoiu uchastiu «molochnyi biznes. [Internet]. 2018 15 lys; Kyiv. URL: https://infagro.com.ua/ua/molochniy-biznes-2018/
5. Zolotareva MS, et al. Tendentsyy pererabotky molochnoi syvorotky. Pererabotka moloka. 2015;8:23-4.
6. Khramtsov AH. Lohystyka formyrovanyia novoho tekhnolohycheskoho uklada molochnoi otrasly pyshchevoi yndustryy APK v uslovyiakh ohranychennykh resursov tradytsyonnoho syria. Yndustryia pytanyia. Food Industry. 2018;3(4):8-24. https://doi.org/10.29141/2500-1922-2018-3-4-1
7. Nutrient-Rich Dairy Foods and You. IDF Fastsheet. [Internet]. 2012. Des. URL: www. fil-idf.org.
8. EWPA European Whey Products Association . URL:http://ewpa.euromilk.org/about- ewpa/facts-figures.html.
9. Final Report Summary – WHETLAC (Transformation of the residual whey permeate from the cheese manufacture: lactic acid production). Project ID: 222400. Funded under: FP7-SME. Country: Spain. [Internet]. URL : http://www.WHETLAC.cartif.com.es.
10. Marketynhovoe yssledovanye ukraynskoho rynka molochnoi syvorotky. Alliance Capital Management. Moskva: Eksmo; 2016.
11. Asotsiatsiia vyrobnykiv moloka [Internet]. URL: http://avm- ua.org/uk
12. Derzhavna sluzhba statystyky. Ofitsiinyi veb-sait Derzhavnoi sluzhby statystyky Ukrainy. URL: http://www.ukrstat.gov.ua/
13. Ukraynskaia syvorotka polzuetsia myrovym sprosom. URL http://agroportal.ua/
14. Pidsumky roku molochnoi haluzi vid analityka Asotsiatsii vyrobnykiv moloka Yany Muzychenko. URL : https://agro-online.com.ua/uk/public/blog/ 3195/details/.
15. Havrylov HB, Kravchenko HP. Puty ratsyonalnoho yspolzovanyia molochnoi syvorotky. Syrodelye y maslodelye. 2013;2:10-13.
16. Zolotareva MS, et al. O pererabotke molochnoi syvorotky y vnedrenyy nayluchshykh dostupnykh tekhnolohyi. Pererabotka moloka. 2016;7:17- 9.
17. Evdokymov YA. et al. Membrannye tekhnolohyy v molochnom proyzvodstve. Molochnaia promyshlennost. 2013; 9:25-26.
18. Synelnykov BM, Khramtsov AH, et al. Laktoza y ee proyzvodnye. SPb: Professyia; 2007.
19. Myronchuk VH, Kucheruk DD. Kompleksnaia pererabotka molochnoi syvorotky s yspolzovanyem membrannykh tekhnolohyi. Pyshchevye tekhnolohy. 2007; 2:28-9.
20. Myronchuk VH, Zmiievskyi YuH. Membranni protsesy v tekhnolohii kompleksnoi pererobky molochnoi syrovatky. Kyiv: NUKhT; 2013.
21. Zolotareva MS, et al. Membrannoe oborudovanye dlia pererabotky razlychnykh vydov molochnykh resursov. Molochnaia promyshlennost. 2016; 9:60-61.
22. Hinkova A, Zidova P, Pour V, Bubnik Z. Potential of membrane separation processes in cheese whey fractionation and separation. Procedia Engineering. 2012;42:1554–1565. https://doi.org/10.1016/j.proeng.2012.07.536

23. Varyvoda AA. Molochnaia syvorotka membrannoi obrabotky v tekhnolohyy plavlenkh syrov. Mezhdunarodnyi nauchno-yssledovatelskyi zhurnal. 2014;2-1(21):80-84.
24. Evdokymov YA, et al. Analyz pererabotky molochnoi sivorotky y sozdanye perspektyvnykh resursosberehaiushchykh tekhnolohyi. Nauka, ynnovatsyy, tekhnolohy. 2013;1:37-44.
25. Zolotareva MS, et al .Elektrodyalyz – naybolee effektyvnyi protsess demyneralyzatsyy molochnoi syvorotky. Molochnaia promyshlennost. 2014;3:37.
26. Produkty, poluchaemye s pomoshchiu metodov membrannoi fyltratsyy. [avtor teksta OOO «HEA Protsessnyi ynzhynyrynh]. Molochnaia promyshlennost. 2010;1:38–39.
27. Volodyn DN, et al. Osobennosty pererabotky tvorozhnoi syvorotky. Pererabotka moloka. 2017;3:6-8
28. Hondar OP, Romanchuk YO, Mynorova AV. Pererabotka kysloi ssvorotky s prymenenyem kompleksa membrannikh metodov. Pyshchevaia promishlennost: nauka y tekhnolohyy. Nauchno-tekhnycheskyi zhurnal, Respublyka Belorus. 2015;4(30):85-88.
29. Hondar OP, Romanchuk IO. Zmina mineralnoho skladu sukhoi molochnoi syrovatky za riznykh metodiv obroblennia. zb. Nauk. pr. Vinnytskyi nats. ahrar. univer. Vinnytsia, 2015;1(89):94-99.
30. Królczyk JB, Dawidziuk T, Janiszewska-Turak E, Sołowiej B. Use of whey and whey preparations in the food industry – a Review. Pol. J. Food Nutr. Sci. 2016;66(3):157-165. https://doi.org/10.1515/pjfns-2015-0052
31. Smithers GW. Whey and whey proteins – from "gutter-to-gold". Int.Dairy Journal. 2008;18(7):695-704. http://dx.doi.org/10.1016/j.idairyj.2008.03.008
32. Smithers GW. Whey-ing up the option – yesterday, today and tomorrow. Int.Dairy Journal. 2015;48:2-14. http://dx.doi.org/10.1016/j.idairyj.2015.01.011
33. Keaton J. Whey protein and lactose products in processed meats. [Internet]. URL: http://www.usdec.org/files/ pdfs/6meat.pdf
34. Kamsulina NV, Ildirova SK, Bolshakova VA. Vykorystannia riznykh vydiv molochnykh preparativ u tekhnolohiiakh kovbasnykh vyrobiv. Prohresyvni tekhnika ta tekhnolohii kharchovykh vyrobnytstv restorannoho hospodarstva i torhivli. 2011;2:280-288.
35. De Wit J.N. Lecturers handbook on whey and whey products. European Whey Products Association. Brussels, Belgium. [Internet]. 2001. URL: http://ewpa.euromilk.org/publications.html
36. Marshal K. Therapeutic applications of whey protein. Alternative Medicine Review. 2004; 9(2):136-56.
37. Somov VS, et al. Funktsyonalnye ynhredyenty na osnove molochnoi syvorotky v proyzvodstve marzhynalnykh molochnykh produktov. Molochnaia promyshlennost. 2014;8:54-55.
38. Svyrydenko YuYa, Volkova TA. Vtorychnoe molochnoe syr`e kak effektyvnyy resurs dlia proyzvodstva produktov maslodelyia y syrodelyia. Syrodelye y maslodelye. 2013;3:34-38.
39. Kochubei-Lytvynenko OV, Bylyk EA. Khranymosposobnost sukhoi molochnoi syvorotky, poluchennoi s yspolzovanyem elektroyskrovoi obrabotky, y ee prymenenye v khlebopechenyy. Trudy BHTU. Respublyka Belorus. 2016;4:200-205.
40. Prosekov AIu, Yvanova SA, Smetanyn VS. Molochno-belkovыe kontsentraty s penoobraznoi strukturoi. Molochnaia promyshlennost. 2011;5:64-65.
41. Evdokymov YA, et al. Tvoroh y tvorozhnye yzdelyia s molochnoi syvorotkoi y ee komponentamy. Molochnaia promyshlennost. 2011;11:62-63.
42. Khramtsov AH. Mykropartykuliatsyia syvorotochnykh belkov. Pererabotka moloka. 2007;5:25-26.
43. Guyomarch F. Formation of heat-induced protein aggregates in milk as a means to recover the whey protein fraction in cheese manufacture, and potential of heat-treating milk at alkaline pH values in order to keep its rennet coagulation properties. A review. 2006;86:1-20. https://doi.org/10.1051/lait:2005046
44. Romanchuk IO, Minorova AV, Krushelnytska NL. Physico-chemical composition and technological properties of milk dimerialized synthesis, received by membrane methods. Agricultural science and practice. 2018;5(3):33-39.
45. McGregor R, Poppitt SD. Milk protein for improved metabolic health: a review of the evidence. Nutrition & Metabolism. 2013;10(1):46. https://doi.org/10.1186/1743-7075-10-46
46. Korhonen H, Pihlanto A. Bioactive peptides: production and functionality. Int. Dairy. J. 2006;16(9):945-960. https://doi.org/10.1016/j.idairyj.2005.10.012
47. Boye J, Wijesinha-Bettoni R, Burlingame B. Protein quality evaluation twenty years after the introduction of the protein digestibility corrected amino acid score method. Br J Nutr. 2012;108:183-211. https://doi.org/10.1017/S0007114512002309
48. Dietary protein quality evaluation in human nutrition. Edited by: FAO United Nations Expert Consultation; Auckland. New Zealand. 2011.
49. Pennings B, Boirie Y, Senden JM, Gijsen AP, Kuipers H, Van Loon LJ. Whey protein stimulates postprandial muscle protein accretion more effectively than do casein and casein hydrolysate in older men. Am J Clin Nutr. 2011; 93 (5):997-1005. https://doi.org/10.3945/ajcn.110.008102
50. Hall WL, Millward DJ, Long SJ, Morgan LM. Casein and whey exert different effects on plasma amino acid profiles, gastrointestinal hormone secretion and appetite. Br J Nutr. 2003;89(2):239-248. https://doi.org/10.1079/BJN2002760
51. Bassil MS, Gougeon R. Muscle protein anabolism in type 2 diabetes. Curr Opin Clin Nutr Metab Care. 2013;16(1):83-8. https://doi.org/10.1097/MCO.0b013e32835a88ee
52. Rice BH, Cifelli .J, Pikosky MA, Miller GD. Dairy components and risk factors for cardiometabolic syndrome: recent evidence and opportunities for future research. Adv Nutr. 2011;2(5):396-407. https://doi.org/10.3945/an.111.000646.
53. Ricci-Cabello I, Herrera MO, Artacho R. Possible role of milk-derived bioactive peptides in the treatment and prevention of metabolic syndrome. Nutr Rev. 2012;70 (4):241-255. https://doi.org/10.1111/j.1753-4887.2011.00448.x
54. Crichton GE, Bryan J, Buckley J, Murphy KJ. Dairy consumption and metabolic syndrome: a systematic review of findings and methodological issues. Obes Rev. 2011;12(5):190-201. https://doi.org/10.1111/j.1467-789X.2010.00837.x
55. Esteves De Oliveira FC, Pinheiro Volp AC, Alfenas RC. Impact of different protein sources in the glycemic and insulinemic responses. Nutr Hosp. 2011;26(4): 669-676. https://doi.org/10.1590/S0212-16112011000400002.
56. Westerterp-Plantenga MS, Nieuwenhuizen A, Tomé D, Soenen S, Westerterp KR. Dietary protein, weight loss, and weight maintenance. Annu Rev Nutr. 2009;29:21-41. https://doi.org/10.1146/annurev-nutr-080508-141056
57. Morr CV, Ha EY. Whey protein concentrates and isolates: processing and functional properties. Crit Rev Food Sci Nutr. 1993;33(6):431-476 https://doi.org/10.1080/10408399309527643
58. Mitchell C, McGregor R, D'Souza R, Thorstensen E, Markworth J, Fanning A, et al. Consumption of milk protein or whey protein results in a similar increase in muscle protein synthesis in middle aged men. Nutrients. 2015;7(10): 8685-8699. https://doi.org/10.3390/nu7105420
59. Saito T. Antihypertensive peptides derived from bovine casein and whey proteins. Adv Exp Med Biol. 2008;606:295-317. https://doi.org/10.1007/978-0-387-74087-4_12
60. Reasons why galactose is good for you. IDF Factsheet [Internet]. 2017 Mar [002/2017-03]. URL: www.idfdairynutrition.org
61. Coelho AI, et al. Galactose metabolism and health. Curr.Opin.Clin.Nutr.Metab.Care. [Internet]. 2015;18:422-27 / URL: https://www.researchgate.net

62. Waisbren SE, Potter NL, Gordon CM, Green RC, Greenstein P, Gubbels CS, et al. The adult galactosemic phenotype. J Inherited Metab Dis. 2012;35(2):279-286. https://doi.org/10.1007/s10545-011-9372-y.
63. Berry GT, et al. The rate of de novo galactose synthesis in patients with galactose-1-phosphate uridyltransferase deficiency. Mol Genet Metab. 2004;81(1):22-30. https://doi.org/10.1016/j.ymgme.2003.08.026
64. Vera C, Córdova A, Aburto C, Guerrero C, Suárez S, Illanes A. Synthesis and purification of galacto-oligosaccharides: state of the art. World J Microbiol Biot.2016;32(12):197-217.https://doi.org/10.1007/s11274-016-2159-4
65. Minorova AV, Romanchuk IO, Zhukova YaF, Krushelnytska NL, Vezhlivtseva SP. Protein composition and technological properties of milk whey concentrates. Agricultural Science and Practice. 2017;4(2):52-58. http://nbuv.gov.ua/UJRN/asp_2017_2_10

ПЕРЕРОБКА МОЛОЧНОЇ СИРОВАТКИ: ПЕРСПЕКТИВИ В УКРАЇНІ

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Анотація. Переробка молока не тільки забезпечує виробництво традиційних молочних продуктів для харчування населення, але й супроводжується утворенням побічних продуктів, які використовуються не у повній мірі, а їх викиди у стічні води погіршують стан довкілля. Сучасний технічний та технологічний рівень переробки молока здатен забезпечити повне використання побічних продуктів, які є джерелом сироваткових білків, лактози та інших потенційно корисних інгредієнтів на їх основі. В умовах зменшення обсягів виробництва молока за останні роки актуальною проблемою є підвищення ступеня переробки молока з метою отримання продуктів з високою доданою вартістю. У статті представлено результати аналітичних досліджень стану питання щодо переробки сироватки в Україні. Наведено сучасні концептуальні підходи вирішення проблем переробки різних видів молочної сироватки, яка утворюється як побічний продукт під час виробництва сирів, кисломолочного сиру, казеїну. Показано, що нові види продуктів та інгредієнтів, одержаних із сироватки, володіють широким спектром функціонально-технологічних властивостей та знаходять попит під час виробництва інших харчових продуктів. Проаналізовано тенденції розвитку новітніх технологій для одержання широкого спектру продуктів та інгредієнтів на основі сироватки, наведено нові дані досліджень стосовно їх ролі у забезпеченні здоров'я людини. Стаття є оглядовою та обґрунтовує доцільність впровадження сучасних мембранних технологій переробки сироватки на вітчизняних молокопереробних підприємствах, що дозволяє раціонально використовувати ресурси молочної сировини, зменшувати негативний вплив на довкілля, підвищувати рентабельність виробництва. Наведено науково-прикладні результати досліджень щодо використанням мембранних методів та ферментативного гідролізу лактози в технологіях сухої демінералізованої сироватки, згущеної низьколактозної сироватки. Застосування існуючого промислового обладнання дозволяє за рахунок зміни білково-мінерального складу сироватки одержувати продукти з широким діапазоном функціонально-технологічних властивостей, підвищеними показниками харчової цінності.

Ключові слова: молочна сироватка, мембранні технології, електродіаліз, сироваткові білки, лактоза, харчова цінність

Список літератури:

1. Сільське господарство України. Офіційний веб-сайт Державної служби статистики України. URL : http://www.ukrstat.gov.ua
2. Ринок продукції харчової промисловості. Розвиток промисловості для забезпечення і оновлення української економіки: науково-аналітична доповідь/ за ред. Л.В. Дейнеко. НАН України, Київ: ДУ «Інститут екон. і прогнозув. НАНУ», 2018. 158 с.
3. Сичевський М.П. Харчова промисловість як основа продовольчої безпеки та розвитку держави: монографія. Київ: Аграр. наука, 2019. 388 с.
4. Вінтоняк В. Українська молочна індустрія. Молочний бізнес-2018: матеріали XI Всеукраїнської конференції з міжнародною участю «молочний бізнес., Київ, 15 листопада 2018 р. [Internet]. URL: https://infagro.com.ua/ua/molochniy-biznes-2018/
5. Тенденции переработки молочной сыворотки / Золотарева М.С. и др. // Переработка молока. 2015. №8. С.23-24.
6. Храмцов А.Г. Логистика формирования нового технологического уклада молочной отрасли пищевой индустрии АПК в условиях ограниченных ресурсов традиционного сырья. Индустрия питания. // Food Industry. 2018. Т.3. №4. С. 8-24. DOI: 10.29141/2500-1922-2018-3-4-1
7. Nutrient-Rich Dairy Foods and You. IDF Fastsheet. [Internet]. Desember, 2012. URL: www. fil-idf.org.
8. EWPA European Whey Products Association [Internet] URL:http://ewpa.euromilk.org/about- ewpa/facts-figures.html.
9. Final Report Summary – WHETLAC (Transformation of the residual whey permeate from the cheese manufacture: lactic acid production). Project ID: 222400. Funded under: FP7-SME. Country: Spain. [Internet] URL : http://www.WHETLAC.cartif.com.es.
10. Маркетинговое исследование украинского рынка молочной сыворотки.// Alliance Capital Management. Москва: Эксмо, 2016. 220 с.
11. Асоціація виробників молока [Internet]. URL: http://avm-ua.org/uk
12. Державна служба статистики. Офіційний веб-сайт Державної служби статистики України. [Internet] URL: http://www.ukrstat.gov.ua/
13. Украинская сыворотка пользуется мировым спросом. [Internet]. URL http://agroportal.ua/
14. Підсумки року молочної галузі від аналітика Асоціації виробників молока Яни Музиченко. [Internet]. URL : https://agro-online.com.ua/uk/public/blog/ 3195/details/.
15. Гаврилов Г. Б, Кравченко Г. П. Пути рационального использования молочной сыворотки// Сыроделие и маслоделие. 2013. № 2. С. 10-13.
16. О переработке молочной сыворотки и внедрении наилучших доступных технологий /Золотарева М.С. и др. // Переработка молока. 2016. № 7. С.17-99.
17. Мембранные технологии в молочном производстве / Евдокимов И.А. и др. // Молочная промышленность. 2013. № 9. С.25-26.
18. Лактоза и ее производные /Синельников Б.М., Храмцов А.Г. и др. - СПб.: Профессия, 2007. 768 с.
19. Мирончук В.Г., Кучерук Д.Д. Комплексная переработка молочной сыворотки с использованием мембранных технологий // Пищевые технологи. 2007. №2. С.28-29.

20. Мирончук В.Г., Змієвський Ю.Г. Мембранні процеси в технології комплексної переробки молочної сироватки. Київ: НУХТ, 2013. 152 с.
21. Мембранное оборудование для переработки различных видов молочных ресурсов /Золотарева М.С. и др. // Молочная промышленность. 2016. № 9. С. 60-61.
22. Hinkova A., Zidova P., Pour V., Bubnik Z. Potential of membrane separation processes in cheese whey fractionation and separation // Procedia Engineering. 2012. № 42. P. 1554–1565. DOI: 10.1016/j.proeng.2012.07.536
23. Варивода А. А. Молочная сыворотка мембранной обработки в технологии плавленых сыров // Международный научно-исследовательский журнал. 2014. Т. 2–1, № 21. С. 80-4.
24. Анализ переработки молочной сыворотки и создание перспективних ресурсосберегающих технологий/ Евдокимов И.А. и др. // Наука, инновации, технологи. 2013. № 1. С. 37-44.
25. Электродиализ – наиболее эффективный процесс деминерализации молочной сыворотки /Золотарева М.С. и др. // Молочная промышленность. 2014. № 3. С.37.
26. Продукты, получаемые с помощью методов мембранной фильтрации / [автор текста ООО «ГЕА Процессный инжиниринг] // Молочная промышленность. 2010. № 1. С. 38-39.
27. Особенности переработки творожной сыворотки / Володин Д.Н. и др. // Переработка молока. 2017. №3. С.6-8
28. Гондарь О.П., Романчук И.О., Минорова А.В. Переработка кислой сыворотки с применением комплекса мембранных методов // Пищевая промышленность: наука и технологии. Научно-технический журнал, Республика Белорусь. 2015. №4 (30). С. 85-88.
29. Гондар О. П, Романчук І. О. Зміна мінерального складу сухої молочної сироватки за різних методів оброблення // зб. Наук. пр. /Вінницький нац. аграр. універ. Вінниця, 2015. №1 (89). Т.1. С. 94-99. ISSN 2306-756X
30. Królczyk, J.B., Dawidziuk T., Janiszewska-Turak E., Sołowiej B. Use of whey and whey preparations in the food industry – a Review.// Pol. J. Food Nutr. Sci. 2016. V. 66(3). P. 157–165. DOI: 10.1515/pjfns-2015-0052
31. Smithers, G.W. Whey and whey proteins – from "gutter-to-gold" // Int.Dairy Journal. 2008. V. 18(7). P. 695-704. http://dx.doi.org/10.1016/j.idairyj.2008.03.008
32. Smithers, G.W. Whey-ing up the option – yesterday, today and tomorrow // Int.Dairy Journal. 2015. V. 48. P 2-14. http://dx.doi.org/10.1016/j.idairyj.2015.01.011
33. Keaton J., Whey protein and lactose products in processed meats. [Internet]. URL: http://www.usdec.org/files/ pdfs/6meat.pdf
34. Камсуліна Н.В, Ільдірова С.К, Большакова В.А. Використання різних видів молочних препаратів у технологіях ковбасних виробів // Прогресивні техніка та технології харчових виробництв ресторанного господарства і торгівлі. 2011. № 2. С. 280-88.
35. De Wit J.N. Lecturer's handbook on whey and whey products // European Whey Products Association. Brussels, Belgium. [Internet]. 2001. URL: http://ewpa.euromilk.org/publications.html
36. Marshal K. Therapeutic applications of whey protein // Alternative Medicine Review. 2004. № 9(2). P. 136-156.
37. Функциональные ингредиенты на основе молочной сыворотки в производстве маржинальных молочных продуктов / Сомов В. С. и др. // Молочная промышленность. 2014. № 8. С. 54-55.
38. Свириденко Ю. Я., Волкова Т. А. Вторичное молочное сырье как эффективный ресурс для производства продуктов маслоделия и сыроделия // Сыроделие и маслоделие. 2013. №3. С.34-38.
39. Кочубей-Литвиненко О.В., Билык Е.А. Хранимоспособность сухой молочной сыворотки, полученной с использованием электроискровой обработки, и ее применение в хлебопечении // Труды БГТУ. Республика Белорусь. 2016. № 4. С.200-205.
40. Просеков А.Ю., Иванова С.А., Сметанин В.С. Молочно-белковые концентраты с пенообразной структурой // Молочная промышленность. 2011. № 5. С.64-65.
41. Творог и творожные изделия с молочной сывороткой и ее компонентами / Евдокимов И.А. и др. // Молочная промышленность. 2011. № 11. С.62-63.
42. Храмцов А.Г. Микропартикуляция сывороточных белков // Переработка молока. 2007. № 5. С.25-26.
43. Guyomarc'h F Formation of heat-induced protein aggregates in milk as a means to recover the whey protein fraction in cheese manufacture, and potential of heat-treating milk at alkaline pH values in order to keep its rennet coagulation properties. A review. 2006. V. 86. P. 1-20. DOI: 10.1051/lait:2005046
44. Romanchuk I.O., Minorova A. V., Krushelnytska N. L. Physico-chemical composition and technological properties of milk dimerialized synthesis, received by membrane methods// Agricultural science and practice. 2018. V. 5(3). P. 33-39.
45. McGregor R., Poppitt S.D. Milk protein for improved metabolic health: a review of the evidence. // Nutrition & Metabolism. 2013. V.10 (1). P. 46. doi: 10.1186/1743-7075-10-46
46. Korhonen H., Pihlanto A. Bioactive peptides: production and functionality. Int. Dairy. J. 2006. V. 16 (9). P. 945-960. DOI: 10.1016/j.idairyj.2005.10.012
47. Boye J., Wijesinha-Bettoni R., Burlingame B. Protein quality evaluation twenty years after the introduction of the protein digestibility corrected amino acid score method. // Br J Nutr. 2012. V. 108. P. 183-211. doi: 10.1017/S0007114512002309
48. Dietary protein quality evaluation in human nutrition. Edited by: FAO United Nations Expert Consultation. Auckland. New Zealand. 2011.
49. Pennings B., Boirie Y., Senden J.M., Gijsen A.P., Kuipers H., Van Loon L.J. Whey protein stimulates postprandial muscle protein accretion more effectively than do casein and casein hydrolysate in older men. // Am J Clin Nutr. 2011. V. 93 (5). P. 997-1005. DOI:10.3945/ajcn.110.008102
50. Hall W.L., Millward D.J., Long S.J., Morgan LM: Casein and whey exert different effects on plasma amino acid profiles, gastrointestinal hormone secretion and appetite. // Br J Nutr. 2003. V.89 (2). P. 239-248. DOI:10.1079/BJN2002760
51. Bassil M.S., Gougeon R: Muscle protein anabolism in type 2 diabetes. // Curr Opin Clin Nutr Metab Care. 2013. V.16 (1). P. 83-88. DOI:10.1097/MCO.0b013e32835a88ee
52. Rice B.H., Cifelli C.J., Pikosky M.A, Miller G.D. Dairy components and risk factors for cardiometabolic syndrome: recent evidence and opportunities for future research. // Adv Nutr. 2011. V. 2 (5). P. 396-407. doi: 10.3945/an.111.000646.
53. Ricci-Cabello I., Herrera M.O., Artacho R. Possible role of milk-derived bioactive peptides in the treatment and prevention of metabolic syndrome. // Nutr Rev. 2012. V.70 (4). P. 241-255. DOI: 10.1111/j.1753-4887.2011.00448.x
54. Crichton G.E., Bryan J., Buckley J., Murphy K.J. Dairy consumption and metabolic syndrome: a systematic review of findings and methodological issues. // Obes Rev. 2011. V.12 (5). P. 190-201. https://doi.org/10.1111/j.1467-789X.2010.00837.x
55. Esteves De Oliveira F.C., Pinheiro Volp A.C., Alfenas R.C. Impact of different protein sources in the glycemic and insulinemic responses. // Nutr Hosp. 2011. V. 26(4). P. 669-676. doi: 10.1590/S0212-16112011000400002.
56. Westerterp-Plantenga M.S., Nieuwenhuizen A., Tomé D., Soenen S., Westerterp K.R. Dietary protein, weight loss, and weight maintenance. // Annu Rev Nutr. 2009. V. 29. P. 21-41. doi: 10.1146/annurev-nutr-080508-141056
57. Morr C.V., Ha E.Y. Whey protein concentrates and isolates: processing and functional properties // Crit Rev Food Sci Nutr. 1993. V. 33 (6). P. 431-476 https://doi.org/10.1080/10408399309527643

58. Mitchell C., McGregor R., D'Souza R., Thorstensen E., Markworth J., Fanning A., Cameron-Smith D. Consumption of milk protein or whey protein results in a similar increase in muscle protein synthesis in middle aged men.// Nutrients, 2015. 7(10), P. 8685-8699. doi:10.3390/nu7105420
59. Saito T. Antihypertensive peptides derived from bovine casein and whey proteins // Adv Exp Med Biol. 2008. V.606. P. 295-317. doi: 10.1007/978-0-387-74087-4_12.
60. Reasons why galactose is good for you. IDF Factsheet [Internet]. 2017 Mar 002/2017-03 // URL: www.idfdairynutrition.org
61. Galactose metabolism and health. / Coelho A.I. et al. // Curr.Opin.Clin.Nutr.Metab.Care. [Internet]. 2015. V.18. P. 422-427 URL: https://www.researchgate.net
62. The adult galactosemic phenotype /Waisbren S.E. et al.// J Inherited Metab Dis. 2012. V. 35(2). P. 279-286. doi: 10.1007/s10545-011-9372-y.
63. The rate of de novo galactose synthesis in patients with galactose-1-phosphate uridyltransferase deficiency /Berry GT et al. // Mol Genet Metab. 2004. V. 81(1). P. 22-30 https://doi.org/10.1016/j.ymgme.2003.08.026
64. Synthesis and purification of galacto-oligosaccharides: state of the art/ Vera C, et al. // World J Microbiol Biot. 2016. V. 32(12). P.197-217. https://doi.org/10.1007/s11274-016-2159-4
65. Minorova A.V., Romanchuk I.O., Zhukova Ya.F., Krushelnytska N.L., Vezhlivtseva S.P. Protein composition and technological properties of milk whey concentrates. //Agricultural Science and Practice. 2017, V. 4 (2). P. 52-58. http://nbuv.gov.ua/UJRN/asp_2017_2_10