PROCESSES, EQUIPMENT, AND APPARATUS FOR FOOD PRODUCTION

ULTRAFILTRATION OF MODIFIED MILK WHEY

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Abstract: The current trend of human community evolution comes to addressing two main tasks: to provide people with full-value food and environmental conservation. The tasks may be addressed only by the appropriate management of rational use of natural raw resources that cannot be disposed in full to practically limited models of food equipment of new generation manufactured with the use of latest scientific achievement. The activity to enhance the urban interference in the society development results in processes where the significance of mineral substances, vitamins and proteins is undervalued in production of purified food for human use that may be obtained by reprocessing of secondary dairy products during baromembrane separation. The study aimed to determine the best parameters of membrane-associated re-processing of the milk whey modified with plant extracts and validation of further use of retentate and permeate obtained. The milk whey was used obtained during production of the grained curd of the normalized cow milk. Employment of membrane methods in the milk whey re-processing may be useful to maintain the non-waste production and avoid ecological pollution. The use of these methods in modern food industry is the upcoming trend that allows opportunities to manufacture a wider range of dairy products, drinks, forage and other resource and energy saving solutions. This article describes the dependency of the membrane permeability and selectivity of type UAM-150 of the modified milk whey of the working pressure value and circulation rate of separated system in the feeder of the baromembrane machine. The impact of pH of the separated liquid polydisperse system on the value of this membrane rejection rate. The viability to use the permeate and retentate of the modified milk whey as the base for drinks manufacture.

Keywords: milk whey, membrane technology, ultrafiltration, herbal extracts

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INTRODUCTION

The milk whey is the waste product of curd, cheese and casein production process. It contains up to 50% of dry solids of the whole milk [8, 9] and this allows considering it as the valuable secondary raw material. The discharge of the milk whey to the atmosphere considerable impacts the environment [8, 9]. This kind of so-called waste of dairy industry may be re-processed through ultrafiltration. Since baromembrane separation of the milk whey is of low cost-efficiency for most standard and, in particular, low capacity dairy processing plants [8, 9], one of solutions to address this problem is to change its physical and chemical characteristics by adding herbal substance extracts. During ultrafiltration of the milk whey modified in this way the permeability of polymer membranes increases while retaining the specified selectivity parameter.

The study aimed to determine the best parameters of membrane-associated re-processing of the milk whey modified with plant extracts and validation of further use of retentate and permeate obtained.

OBJECTS AND METHODS OF STUDY

The milk whey was used obtained during production of the grained curd of the normalized cow milk. Main physical and chemical parameters of the whey pre-purified by conventional method and modified with the extract of herbal raw mixture (stevia herb + licorice rhizome), performance parameters of the polymer membrane are shown in Tables 1 and 2. The literature [8, 9] and results of in-house researches were analyzed and it was identified that in current conditions it is reasonable to use the following types of polymer membranes for ultrafiltration separation of the caseous whey: UPM-P, UPM-67, UAM-500 and UAM-150 of “Vladipor” manufacture.

Table 1. Physical and chemical whey parameters as the ultrafiltration item.

Parameter	Serum	
	Baseline	Modified
Content of dry substances, %, not less	6.5	6.3
Including:		
Lactose	5.0	5.0
Protein	1.1	0.7
Fat	0.1	0.1
Minerals	0.3	0.5
Acidity, ºT	45	42
pH value	5.0	5.1
Density, kg/m^3	1023	1024
Absorbancy of 10% solution	0.26	0.20

Table 2. Performance parameters of polymeric membranes of type UPM and UAM (Russia, "Vladipor").

Main parameters	Type of membrane			
	UPM-P	UPM-67	UAM-150	UAM-500
Pressure, MPa	0.1–0.4	0.1–0.4	0.1–0.5	0.1–0.5
Retention rate, kDa	30–35	45–50	20–25	50–55
Temperature, °C	5–40	5–40	10–50	10–50
Washing medium pH	2–10	2–10	2–12	2–12
Service life, h	up to 3500	up to 3500	up to 3000	up to 3000

By reference parameter (retention limit), these membranes may be used for ultra-filtration of dairy primary products. All other things constant, polyamide membranes (UPM) differ from cellulose acetate membranes (UAM) in higher cost and extended life cycle. However, while using membranes of type UAM-500 and UAM-150, the process is possible with the higher operation pressure and harder cleaning is practicable. The process of ultra-filtration was performed using the special laboratory unit. The area of membrane surface is up to 0.5 m^2. The value of operation pressure, circulation rate of the liquid polydisperse system to be separated in the pipeline of the baromembrane machine, its temperature varied within $\Delta P = 0.1 \div 0.4$ MPa, $V = 0.05 \div 0.45$ m/s and $t = 8 \div 18$ºC, accordingly. Permeability Q and selectivity φ parameters of the membrane of type UAM-150 were found by testing. The value Ψ was estimated by the formula 1 below:

$$\varphi = \frac{V_2 \cdot C_2}{V_1 \cdot C_1} \cdot 100\%, \quad (1)$$

where V_1 is the reference volume of the system to be separated and C_1 is the weight ratio of particles dispersed in it; V_2 and C_2 is the volume of retentate and weight ratio of particles dispersed in it.

The confidence factor of results obtained is 95%.

RESULTS AND DISCUSSION

As per modern knowledge on self-organization of protein molecule structure [1], protein globules of the milk whey may be estimated as the spherical particles of the disperse phase having adsorptive properties. During the process of the milk whey ultra-filtration, the concentration polarization phenomenon depends on the conventional supply of such globules to the membrane surface, their further agglomeration and the polymer film formation that, in fact, is the dynamic membrane that increases the flow resistance to permeate.

In compliance with the filtration concept (at constant pressure), the permeate flow rate is determined by the expression 2:

$$w\ t\ = \frac{1}{S}\frac{dV}{dt} = \frac{\Delta P}{(R_m + R_g)\eta}, \quad (2)$$

where ΔP is the operation pressure in the baromembrane machine, R_m and R_g is the flow resistance of polymeric and dynamic membranes, η is the permeate viscosity, S is the area of membrane, V is the permeate volume, t is the time. Resistance R_g may be determined as:

$$R_g = r\delta_g, \quad (3)$$

where r is the filtration resistance and δ_g is the thickness of the dynamic membrane layer.

Filtration resistance is expressed in the dependence:

$$r = a(1 - \varepsilon)\rho, \quad (4)$$

where a is the specific resistance, ε is the porosity, ρ is the density of the deposit layer on the membrane surface.

Thickness of the dynamic membrane is determined as follows:

$$\delta_g = \frac{Vk\ 1-d\ C_b}{S(1-\varepsilon)\rho}, \quad (5)$$

where k is the retention factor, C_b is the concentration of disperse phase particles in the separated system, k is the particle share of the disperse phase that is carried from the membrane surface into the main flow due to the reverse diffusion.

In respect of (3)–(5) it can be written as:

$$R_g = \frac{1-d\ aVkC_b}{S}, \quad (6)$$

Substituting for the equation (6) to the expression (2) we obtain the following:

$$w\ t = \frac{1}{S}\frac{dV}{dt} = \frac{\Delta P}{R_m\eta + aVkC_b\ 1-d\ \eta/S}, \quad (7)$$

As the equation is integrated (7), its solutions towards V and substitution for V to the equation:

$$G = \frac{1}{w^2} = \left(\frac{R_m\eta}{\Delta P}\right)^2 + \frac{2aRC_b\ 1-k\ \eta}{\Delta P}t, \quad (8)$$

At k = 1 and d = 0, the equation (8) goes over into the formula determined by the authors (Chudacek M.W. and Fane A.G.) of the acquainted work [2].

Fig. 1 shows the dependence $G = f(\tau)$ in graphic form. The plot is the straight line; a slight linear change is seen at the initial section. The line extension cuts out a section on the X-axis consistent with $\tau \approx 0.1$ hours, that is, in our opinion, relevant to the primary formation of the deposit layer on the membrane surface. In fact, similar dependence values were obtained [3] during ultra-filtration of other protein solutions. Upon baromembrane separation of 0.5÷0.6 kg of the modified whey on the membrane, about 0.1^{-3} kg of dry deposits. This allows to determine that the factor (1 – d) = 0.2. At C_b = 1.8 kg/m^3, k = 94÷96%, $\eta = 2\cdot10^{-3}$ ns/m^2 and $\Delta P = 10^5$ N/m^2, the calculation by the slope of straight line in Fig. 3 shows the value of specific resistance $a \approx 2.2\cdot10^5$ m/kg. Specific resistance of high-molecular deposit layer on membrane surfaces may correlate with the size of protein globules as per the Carman-Kozeny equation [4]

$$a = \frac{180\ (1-\varepsilon)}{\rho d^2 \varepsilon^3}, \quad (9)$$

where *d* is the mean specific diameter of protein globule.

If the value of density ρ = 1÷1.13 kg/m³ and d = 40÷43 nm are taken, the formula (9) shows that the porosity of high-molecular deposit layer will be equal ε = 0.5÷0.52, which is lower but comparable to the relevant value of cellulose acetate membranes [6]. This suggests that initially polarizing processes (including intrapore area) on the membrane surfaces with further jellification are the main reason of the membrane permeability reduction. This is consistent with conclusions in the work [7] on the comprehensive nature of impact caused by the disperse phase structure on the permeability of ultra-filtration membranes when separating liquid high-molecular systems.

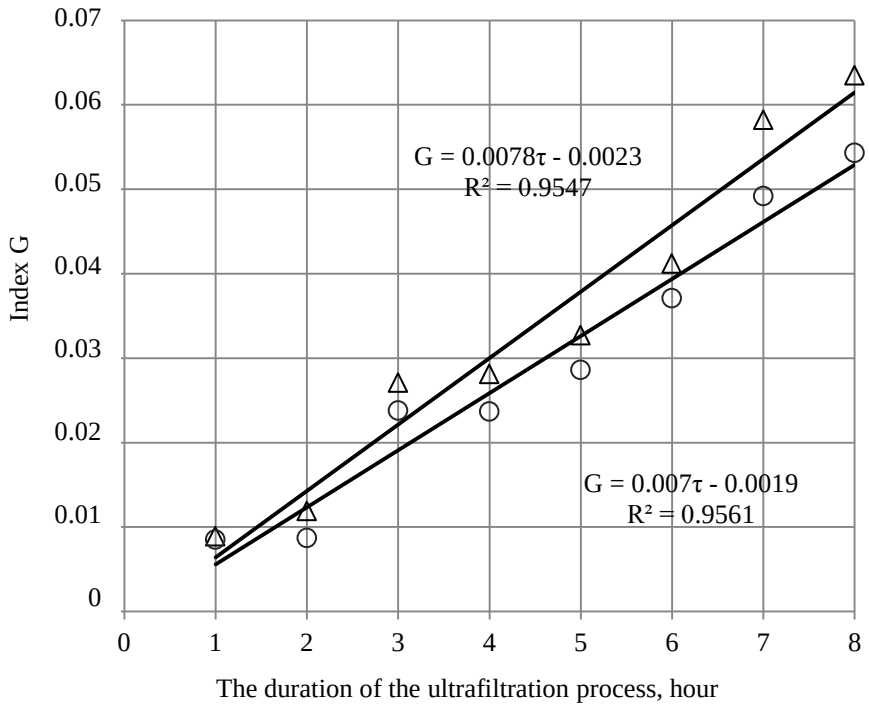

Fig. 1. Dependence of the value G on the time of ultrafiltration process of common (○) and modified (Δ) milk whey on the membrane UAM-150.

It should be noted that sizes of colloidal particles of the disperse phase that change into the whey during the milk re-processing, vary within quite a wide range (nm): α-lactoalbumin – 15÷20, β-lactoglobulin – 25÷30; casein micelle – 40÷300. Macromolecules of whey proteins are folded in dense globules with the negative charge and quite steady hydration shells. They are highly stable in the dispersed medium but in certain conditions they may coagulate when they reach the relevant isoelectric point, and with the reduction in pH, they form associates of several monomers. Due to H-particle adsorption, such globules are positively charged [1]. Since the intensity of globule interaction with the membrane surface and the pore walls may be due to the globule charge, the study was conducted to assess the impact of the separated system pH on the value of the membrane UAM-150 retention factor during ultra-filtration of the common (○) and modified (□) milk whey. With the increase of pH value, the membrane retention rate gradually increases and reaches its highest value at pH = 4.5÷5.0. The, it decreases remaining constant at pH = 6.5÷7.5 (Fig. 2). This way to change the dependence of the retention factor of the disperse phase protein particles in the common milk whey on pH of the system to be separated is easily explained based on the frictional translation model. In case if the protein globules travel in the pore space of the dynamic membrane, they repulse from each other and from the pore walls at similar charge indexes. This results in the decrease of the friction ratio between the membrane and globules. As a result, at lower pH values of the separated system, the value of the retention factor of the membrane increases. Within the range of pH > 7.5, the friction factor between the membrane and globules presumably decreases to a considerable extent which causes reduction in its value of retention rate. This explanation is supported with the fact that as a result of milk whey modification with the *stevia extract*, the physical and chemical properties of the separated system considerably change. This mainly relates to interaction between the protein particles and several components as parts of this plant [10]. In case of separation of the modified milk whey by ultra-filtration, the value of the membrane retention factor is practically the same at changes in the pH of the separated system; its slight increase is reported within pH = 4.5÷5.5, that does not contradict the frictional translation model.

To develop practical recommendations to increase the performance of the modified milk whey ultra-filtration, comparative experiments were conducted to evaluate the dependence of permeability Q and selectivity φ of UAM-150 membrane on the operation pressure index of the separated system in the pipe of the baromembrane machine (Fig. 3 and 4).

As it is seen from data shown, the way the dependence of type Q=f(Δp) changes for the UAM-150 membrane during separation of the common and modified milk whey by ultra-filtration is quite similar: an increase in permeability is propportional to the increase in the operation pressure in the pipe of the baromembrane machine. However, the values $tg\varphi_i=dQ/d\Delta p$ for relevant plots differ. Since the physical significance $tg\varphi_i$ is the rate of increment of function Q=f(Δp), this suggests that both the membrane permeability Q and its growth intensity increase during ultra-filtration of the modified whey. This phenomenon is derived from the fact that the stevia's extract added to the milk whey obtained from the production of the grained curd by the conventional method causes changes in the whey physical and chemical properties due to separation by ultra-filtration method. Review of plots for the function Q=f(Δp) show that, all other things constant, the increment in the membrane permeability is seen with the increase in the operation pressure within Δp = 0.1÷0.12 MPa to Δp = 0.3÷0.32 MPa. The, the Q value remains practically stable. The increase in the value of Δp parameter over 0.42÷0.44 MPa insignificantly impacts the membrane permeability during ultra-filtration of both liquid systems, and when the common whey is used, as the object of separation, the Q value tends to decrease.

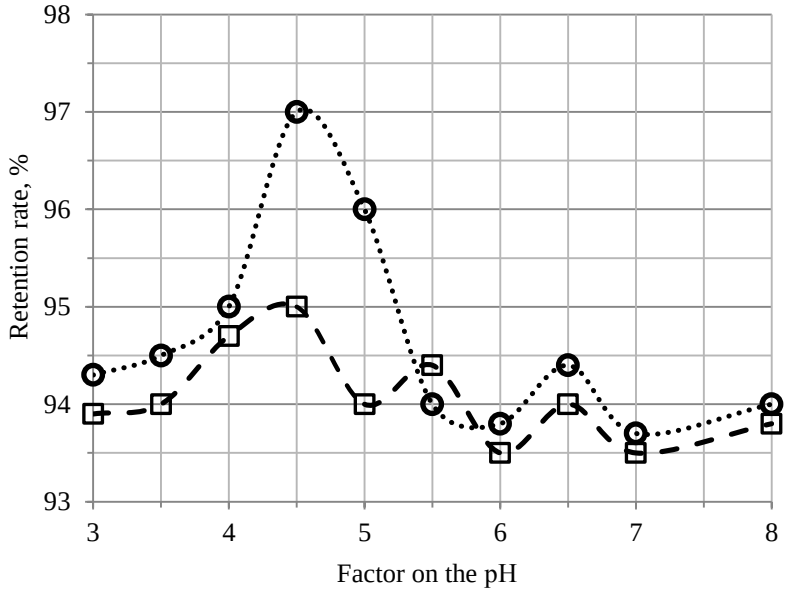

Fig. 2. Dependence of the membrane retention factor on pH value of the separated system during ultrafiltration of the common (○) and modified (□) milk whey on the UAM-150 membrane.

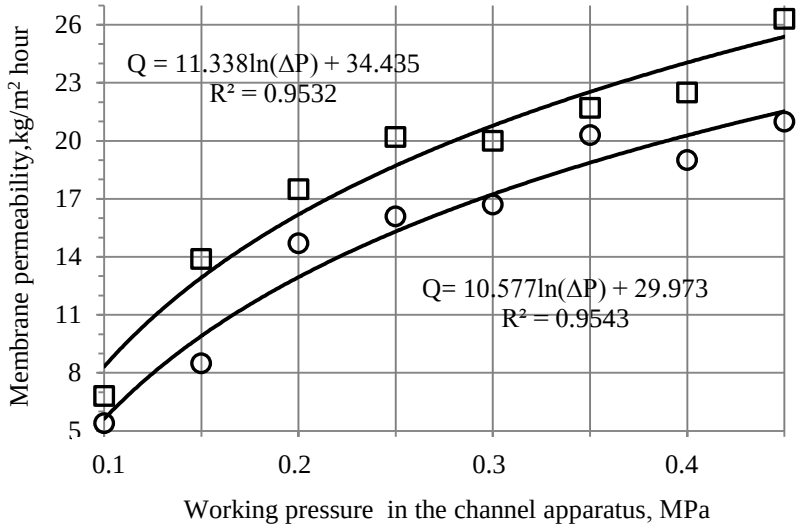

Fig. 3. Dependence of permeability Q of UAM-150 membranes on the operation pressure index Δp (t = 10÷12°C, *v* = 0.1÷0.3 m/s, $C_{d.m.}$= 8÷8.2%) during ultra-filtration of common (○) and modified (□) milk whey.

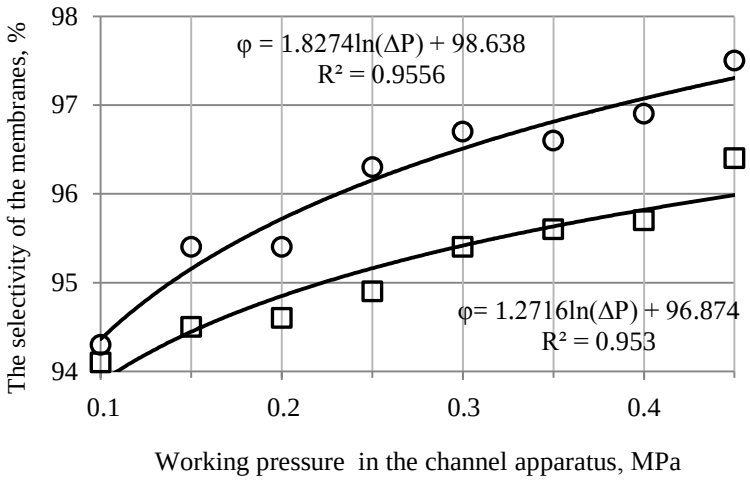

Fig. 4. Dependence of selectivity φ of membranes of type UAM-150 on the value of operation pressure Δp (t = 10÷12°C, *v* = 0.1÷0.3 m/s, $octal_{notation}$= 8÷8.2%) during ultra-filtration of common (○) and modified (□) milk whey.

A significant increase in the membrane selectivity at Δp > 0.42÷0.44 MPa in case of sieve model of ultra-filtration most probably relates to the start of mechanic obstruction of pores with disperse phase particles complicated with partial deformation of polymer membrane structure. In total, this causes reduction in the effective size of the flow section of pore space. This suggests that the area of the efficient operation pressure value in the pipeline of the baromembrane machine should be limited within Δp = 0.3÷0.4 MPa. The validity of such conclusion is proved by the results of experimental finding review to assess the dependence of the membrane selectivity φ on the value of operation pressure. In general, the pattern of changes in the parameter φ for both wheys is also identical, but, during ultra-filtration of the modified whey, the rate of increase in φ is somewhat lower as compared with that of the common whey as the object of baromembrane separation. This suggests that the intensity of adsorptive intermolecular interactions "disperse phase particles – membrane" identified by physical and chemical properties of the modified milk whey, is lower against that in the common whey.

It should be noted, that in case of tangential flow of the separated liquid system, the permeability value Q and the membrane selectivity φ are considerably affected by the value of circulation rate *v*, apart from the operation pressure, in the circuit of the baromembrane machine. Characteristic curves expressed as Q = f(*v*) and φ = f(*v*) of membranes of type UAM-150 obtained from ultra-filtration of the modified and common milk whey are shown in Fig. 5 and 6.

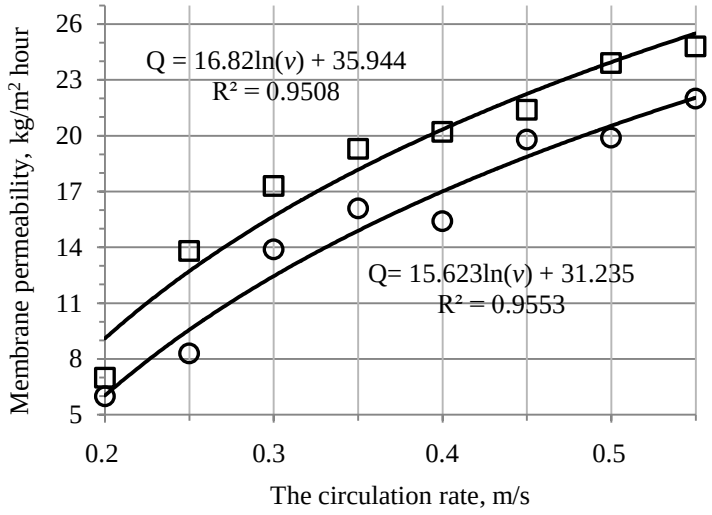

Fig. 5. Dependence of permeability Q of UAM-150 type membranes during ultrafiltration of the common (○) and modified (□) milk wheys on the rate of the separated system circulation in the membrane pipe of the machine (t = 10÷12°C, Δp = 0.1÷0.4 MPa, , $C_{d.m}$ = 8÷8.2%).

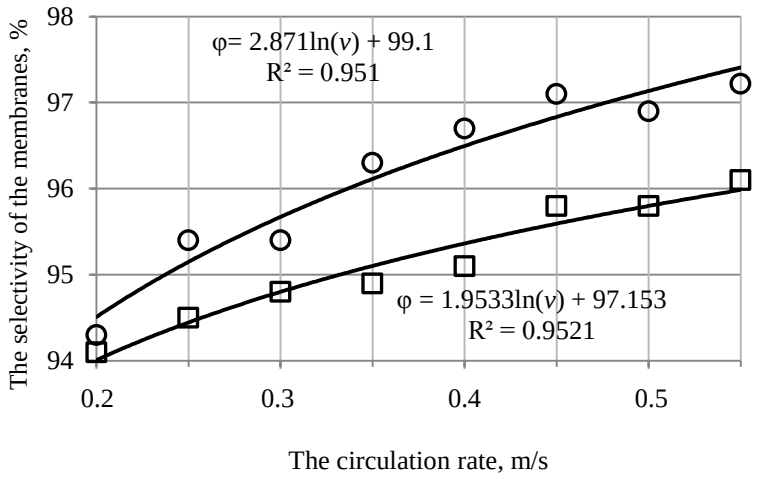

Fig. 6. Dependence of selectivity φ of UAM-150 membranes during ultra-filtration of the common (○) and modified (□) milk whey on the rate of separated system circulation in the membrane pipe of the machine аппарата (t = 10÷12°C, Δp = 0.1÷0.4 MPa, , $C_{d.m.}$= 8÷8.2%).

The results of analysis of dependence curves Q = f(*v*) and φ = f(*v*) allow concluding that, at all other things constant, the obvious increase in the membrane permeability is seen against an increase in the circulation rate for both common (○) and modified (□) milk whey within *v* = 0.2÷0.4 m/s. If the sieve ultra-filtration is used, the changes in the membrane selectivity φ at *v* > 0.4 m/s may be explained by the fact that, this circulation rate causes destruction of poorly attached deposit layers in the pipe of the membrane unit that formed on the membrane surface [8, 9]. However, this parameter increased higher than *v* =0.6 m/s in cassette units is not adequate to remove mainly "primary" protein fields, strongly attached to the membrane. This conclusion may be proved by the fact that the flow rate rise over *v* = 0.5 m/s has practically no impact on membrane permeability during ultra-filtration of the milk whey. And, when the modified whey is used as the object of separation, the Q value tends to rise insignificantly which may be due to probable changes in physical and chemical properties of the separated system and, as a result, to the reduction in intramolecular binding between the membrane and the disperse phase particles of the separated system. Therefore, it may be suggested that the scope of the best circulation rate MES in the baromembrane unit pipeline should be limited to within *v* = 0.4÷1.0 m/s.

To identify the potential to use the permeate of modified milk whey as the base for production of drinks, its physical and chemical properties have been investigated and, first of all, organoleptic evaluation has been performed in comparison of the permeate of the common milk whey obtained using one and the same type of UAM-150 membranes. The investigation results are shown in Table 3.

As per the overall evaluation, the permeate of the modified milk whey 0.25 scores excels the common whey permeate. Physical and chemical properties of permeates are given in Table 4.

Table 3. Comparative organoleptic evaluation of modified and common milk whey permeates

Parameter	Caseous whey permeate	Modified milk whey permeate
Appearance	Homogenous liquid, clear, of greenish to yellow color	Homogenous liquid, clear, of light-yellow color
Odor	Fermented-milk, clean flavor	
Taste	Sour, with strong wheyish after-taste	Slightly acid to sweet flavor, with weak wheyish flavor, with no after-taste
Overall evaluation	0.5	0.75

Table 4. Physical and chemical properties of permeates of modified and common milk wheys (p = 0.95)

Parameter	Modified whey permeate	Common whey permeate
w/w of dry substances, %	5.0	5.1
Total protein, %	0.10	0.15
Lactose, %	4.4	4.4
Minerals, %	0.5	0.5
Acidity, pH	4.3	4.2
Acidity, ºT	88	85
Density, kg/m^3	1020	1018

During ultra-filtration of the secondary milk product, the structure of permeate is considerably affected by the main separation processes and concentration factor. Tables 5 and 6 show the results of experimental testing of this parameter impact on the content of nitrogen compounds, weight ratio of dry substances, lactose and mineral substances in the permeate of the modified milk whey.

It is specified that the content of dry substances in the permeate increases during ultra-filtration of the modified milk whey. This is presumably due to an increase in the membrane selectivity parameter caused by the pore obstruction with the whey protein molecules and the relevant increase in the concentration of the disperse phase particles of the retentate. This results in the partial rise of weight ratio of lactose, nitrogen compounds and mineral complex components in the permeate. In addition, higher content of potassium, calcium, sodium, phosphor and magnesium ions in the permeate shows its value as the source of macro and micro elements of the similar significance for the dietary structure as other components of the secondary diary stock. It may be supposed that the hydrous and mineral complex of such permeate may be used as the base to produce a different class of natural mineralized drinks.

The complete cycle of the modified whey comprehensive re-processing should be arranged so that to ensure efficient application of both permeate and retentate obtained in less volumes but being the valuable source of native serum proteins.

To assess the competitively of the modified milk whey retentate with selected types of protein products used to produce different food products, its organoleptic parameters (Table 7) are shown against the concentrate of serum proteins obtained by the conventional method of thermal denaturation (KSBT).

Comparison of organoleptic parameters of the retentate of modified milk whey and KSBT showed that stevia extract added commit to neutralize the wheyish flavor and taste in the semi-finished food obtained. Since concentrates of serum proteins are used to produce various food staff [8, 9] to a wider extent with their consumer features mostly specified by physical and chemical parameters of such raw material, one of the goals of this stage of study was to assess the relevant parameters of the retentate obtained during separation of the modified milk whey by ultra-filtration. Table 8 shows main parameters which allow, upon analysis thereof, defining main paths of further use of such retentate to manufacture food products or for other use.

Thus, it may be suggested that the modified milk whey retentate is superior to KSBT in its organoleptic characteristics and does not yield to KSB-UF in terms of physical and chemical parameters.

The capacity to use protein semi-finished products as one of components in food manufacturing process should be assessed in terms of heavy metal content. The raw stock to produce stevia extract used for MES production was obtained from the scientific-experimental farm of the Stavropol State Agrarian University. The test results of the retentate obtained from the modified milk whey separation by ultra-filtration method are shown in Table 9.

Table 5. Dependence of the physical and chemical structure of the modified milk whey permeate on the concentration level (p = 0.95)

Concentration factor	Weight ratio, %				
	Dry substances	Protein	Non-protein nitrogen	Lactose	Mineral salts
1.5	5.20	0.1	0.07	4.22	0.49
2	5.20	0.1	0.08	4.25	0.49
2.5	5.21	0.1	0.08	4.29	0.50
3	5.21	0.1	0.09	4.31	0.50
3.5	5.22	0.1	0.09	4.33	0.50
4	5.22	0.1	0.10	4.40	0.51

Table 6. Mineral structure of permeates of modified and common milk wheys (p = 0.95)

Description of speciment	Mineral structure mg/100 ml (mg, %)				
	Na^{+}	K^{+}	Ca^{+2}	Mg^{+2}	P^{+5}
Common whey permeate	38.8	156.0	92.4	9.2	48.0
Modified permeate	57.4	187.0	146.7	10.8	85.0

Table 7. Organoleptic evaluation of MES and KSBT retentate

Parameter	Modified milk whey retentate	KSBT
Appearance	Homogenous mass of creamy tint	Non-homogenous mass with fine factures
Consistence	Delicate	Arenaceous, coarse
Color	Light beige	Yellowish to cream-colored
Odor	Wheyish, with slight herbal flavor	Obvious wheyish
Taste	Sour to sweet, milky, with fruit flavor	Sour, with wheyish after-taste

Table 8. Main characteristics of MES retentate (p = 0.95)

Parameter	KSB-UF	Modified milk whey retentate
Weight ratio of dry substances, %	10.20	10.25
Weight ratio of protein, %	3.83	3.78
Lactose, %	5.10	5.08
Minerals, %	0.71	0.76
pH	4.7	4.8
Acidity, ºT	50	48

Table 9. Content of heavy metals in the MES retentate (p = 0.95)

Name of heavy metal	Concentration in the retentate of modified milk whey, mg/kg	Allowable level of concentration as per SanPiN 2.3.2.1078-01 for similar products, mg/kg
Lead	not detected	0.3
Arsenic	not detected	0.5
Cadmium	0.01	0.2
Mercury	not detected	0.03

Accessibility efficiency of protein substances in the organism may be qualified at a first approximation by the main parameter – balanced state for amino acid content. This evaluation is taken as a basis to classify proteins as per their biological value which is the basic criterion of the protein potential to fit human needs in amino acids. For such evaluation, the amino-acid score method is traditionally applied which ensures to give a comparative description of any protein against the reference protein as per the content of amino acids in it. The test results of the amino acid content in the retentate of the modified milk whey is shown in Table 10.

It should be noted that certain amino acids (for example, lusine) in proteins may form compounds hardly accessible in the organism during long-term raw material storage or treatment. It means they become practically fully unavailable to the action of digestive enzymes which results in considerable decrease in the value of proteins themselves. And, since the study used the process of ultra-filtration of the modified milk whey at higher pressure but at the temperature up to

10 ± 2°C, the process length should be considered as the limiting external factor to process the modified milk whey. It is specified that amino acids (leucine, valine, histidine, phenylalanine and others) contained in proteins of milk whey basically transfer to the retentate of the modified milk whey to the fullest extent.

As specified in the official SanPiN document 2.3.2.1078-01 (Hygienic requirements to safety and value of food products), all food products should, apart from the direct intent to fit the human physiological needs in nutrients, comply with standards in terms of the accessible level of potentially hazardous microorganisms for the human health. This is what explains the necessity of the study of microbiological parameters of the modified milk whey retentate both directly upon its production and in process of storage at (4 ± 1)ºC in the sealed package (Table 11).

Based on the results of experimental studies reviewed, it is established that the retentate obtained by separation of the modified milk whey by ultra-filtration method, may be referred to valuable protein semi-finished products, in terms of physical and chemical parameters, microbiological points and content of amino acids, that differ from closest analogs in higher organoleptic parameters. This allows using the retentate in production technique of food products.

Table 10. Amino acid content of the modified milk whey retentate as compared with serum proteins (p = 0.95)

Amino acid	Content of amino acids, g/100 g proteins	
	Proteins (milk whey)	Modified milk whey retentate
Asparagine acid	10.6	8.6
Threonine	5.2	4.7
Serine	5.2	4.1
Glutamic acid	17.1	16.1
Glycine	1.7	1.2
Alanine	5.3	4.4
Valine	5.7	5.2
Methionine	2.3	1.7
Isoleucine	6.5	6.1
Leucine	12.3	9.8
Thirosine	3.8	3.5
Phenylalanine	4.4	4.1
Histidine	1.7	1.6
Lysine	9.1	7.4

Table 11. Microbiological parameters of the modified milk whey retentate (p = 0.95)

Parameter	Modified milk whey retentate		
	Fresh	4-day	8-day
Total viable count, CFU/g	$0.7 \cdot 10^3$	$0.9 \cdot 10^3$	$3.0 \cdot 10^4$
	(at least $5 \cdot 10^4$ is allowed)		
Coliforms, in 1 g	not detected		
Yeasts, CFU/g	absent		
Fungi, CFU/g	absent		

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