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A RESEARCH OF THE COMPOSITION AND FUNCTIONAL PROPERTIES OF BUTTERMILK CONCENTRATE OBTAINED THROUGH ULTRAFILTRATION

T.Ch. Tultabaeva, G.N. Zhakupova, K.K. Makangali, A.T. Sagandyk, A.K. Muldasheva, K.Sh. Dairova

«S.Seifullin Kazakh Agro Technical Research University», Astana, Kazakhstan

Corresponding author: dairova111@mail.ru

Under the growing demand for functional and diet-oriented dairy products, this study is devoted to the development of a fermented beverage technology enriched with high-quality protein through the rational utilization of secondary dairy resources – specifically, buttermilk subjected to ultrafiltration. The objective was to investigate the composition, physicochemical parameters, and sensory attributes of buttermilk concentrates obtained under varying ultrafiltration conditions, and to assess their technological viability within multicomponent dairy matrices.

Experimental trials revealed the impact of processing temperature (20–60 °C) on changes in pH, titratable acidity, fat and protein contents, as well as total solids, in both retentate and permeate fractions. Ultrafiltration proved highly effective at retaining protein and fat components with minimal loss, producing a concentrate of notable nutritional and biological value.

The resulting buttermilk concentrate was incorporated into dairy blends containing various ratios of cow's and goat's milk. Across four formulated variants, a consistent trend was observed: increasing the proportion of buttermilk concentrate led to a corresponding rise in total solids (from 18.25% to 35.50%) and protein content (from 6.01% to 14.00%).

Thus, buttermilk concentrate derived via ultrafiltration emerges as a promising ingredient for the next generation of functional dairy products - capable of enhancing protein content, contributing to desirable texture formation, and reducing overall fat levels in the final formulation.

Keywords: buttermilk, functional properties, permeate, retentate, ultrafiltration.

УЛЬТРАСҮЗГІЛЕУ ӘДІСІМЕН АЛЫНҒАН ІРКІТ КОНЦЕНТРАТЫНЫҢ ҚҰРАМЫ МЕН ҚАСИЕТТЕРІН ЗЕРТТЕУ

Т.Ч. Тултабаева, Г.Н. Жакупова, Қ.Қ. Мақанғали, А.Т. Сағандық, А.Х. Мулдашева, Қ.Ш. Даирова

«С.Сейфуллин атындағы Қазақ агротехникалық зерттеу университеті», Астана, Қазақстан, e-mail: dairova111@mail.ru

Функционалдық және диеталық сүт өнімдеріне сұраныстың артуы жағдайында бұл зерттеу жоғары сапалы ақуызға бай ферменттелген сусындар технологиясын әзірлеуге бағытталған. Бұл мақсатқа сүт өнеркәсібінің екінші реттік ресурстарын, атап айтқанда, ультрасүзгіден өткен іркітті тиімді пайдалану арқылы қол жеткізілді. Зерттеудің мақсаты – іркіт концентраттарының құрамы, физика-химиялық және органолептикалық қасиеттерін әртүрлі ультрасүзу режимдерінде зерттеу, сондай-ақ оларды көп компонентті сүт қоспалары құрамында технологиялық тұрғыдан бағалау болды.

Жүргізілген тәжірибелер температураның (20–60 °C) pH, титрленетін қышқылдық, май, ақуыз және құрғақ заттардың мөлшеріне әсерін анықтады. Ультрасүзу процесі ақуыздар мен майларды ең аз жоғалту арқылы тиімді түрде ұстап, жоғары тағамдық және биологиялық құндылығы бар концентрат қалыптастыратыны дәлелденді.

Іркіт концентраты әртүрлі мөлшерде сиыр және ешкі сүтімен араласқан сүт негізіне енгізілді. Төрт тәжірибелік қоспада іркіт концентратының үлесі артқан сайын құрғақ заттар мөлшері (18,25%-дан 35,50%-ға дейін) және ақуыз мөлшері (6,01%-дан 14,00%-ға дейін) тұрақты түрде өсті.

Осылайша, ультрасүзу әдісімен алынған іркіт концентраты функционалдық сүт өнімдерін жасауға арналған келешегі зор ингредиент ретінде қарастырылады. Ол өнімнің ақуыздық құрамын байытып, құрылым түзілуіне ықпал етіп, дайын өнімнің майлылығын төмендетуге мүмкіндік береді.

Түйін сөздер: іркіт, функционалдық қасиеттері, пермеат, ретентат, ультрасүзгілеу.

ИССЛЕДОВАНИЕ СОСТАВА И СВОЙСТВ КОНЦЕНТРАТА ПАХТЫ, ПОЛУЧЕННОГО МЕТОДОМ УЛЬТРАФИЛЬТРАЦИИ

Т.Ч. Тултабаева, Г.Н. Жакупова, К.К. Маканғали, А.Т. Сагандык, А.Х. Мулдашева, К.Ш. Даирова

«Казахский агротехнический исследовательский университет им. С.Сейфуллина», Астана, Казахстан, e-mail: dairova111@mail.ru

В условиях растущего спроса на функциональные и диетические молочные продукты данное исследование направлено на разработку технологии ферментированных напитков с повышенным содержанием полноценного белка за счёт рационального использования вторичных ресурсов молочной промышленности – в частности, пахты, подвергнутой ультрафильтрации. Целью работы стало изучение состава, физико-химических и органолептических свойств концентратов пахты, полученных при различных режимах ультрафильтрационной обработки, а также оценка их технологического потенциала в составе многокомпонентных молочных смесей.

Экспериментально установлено влияние температуры (20–60 °C) на изменение pH, титруемой кислотности, содержания жира, белка и сухих веществ в ретентате и пермеате. Установлено, что ультрафильтрация обеспечивает эффективное удержание белковых и жировых компонентов при минимальных потерях, формируя концентрат с высокой пищевой и биологической ценностью.

Концентрат пахты использован в составе молочной основы с различным соотношением коровьего и козьего молока. В четырёх опытных вариантах смеси наблюдалось закономерное увеличение массовой доли сухих веществ (от 18,25% до 35,50%) и белка (от 6,01% до 14,00%) при возрастании доли концентрата пахты.

Таким образом, концентрат пахты, полученный методом ультрафильтрации, является перспективным ингредиентом для функциональных молочных продуктов, обеспечивающим белковое обогащение, текстурообразование и снижение жирности готового продукта.

Ключевые слова: пахта, функциональные свойства, пермеат, ретентат, ультрафильтрация.

Introduction. One of the strategic priorities in the current development of the dairy industry is the formulation and implementation of technologies for functional food products that support rational nutrition, sustain physical and cognitive performance, and enhance the human immune system. In this context, a particularly relevant objective is the production of fermented dairy products enriched with high-quality proteins.

Although the market already offers a broad range of fermented dairy items, there remains a notable shortage of products with reduced fat content, those derived from secondary dairy raw materials – particularly buttermilk - and specialized dairy products tailored for individuals with health conditions such as diabetes or lactose intolerance.

At present, new categories of fermented dairy products are being developed with pronounced therapeutic and prophylactic properties. The functionalization of such products can be achieved by utilizing milk from various agricultural species, applying membrane processing technologies, and adopting low-waste or zero-waste production systems in the development of fermented dairy products.

The dairy industry faces a persistent shortage of primary raw materials, which brings to the forefront the issue of rational utilization of secondary dairy

resources such as skim milk, buttermilk, and whey.

Comprehensive utilization of all milk components can significantly diversify the product range and positively impact the technical and economic performance indicators, as well as labor productivity in dairy enterprises. Given their considerable volume and high nutritional and biological value, the collection and processing of skim milk, buttermilk, and whey become not only justified but essential [1].

In countries with advanced dairy sectors, buttermilk is widely employed in the manufacture of various dietary natural and cultured beverages, including numerous variants with flavorings and additives, as well as an ingredient in food formulations. To extend shelf life and more efficiently utilize available buttermilk resources - especially during peak milk processing periods for butter production-– the manufacture of buttermilk concentrates is considered preferable.

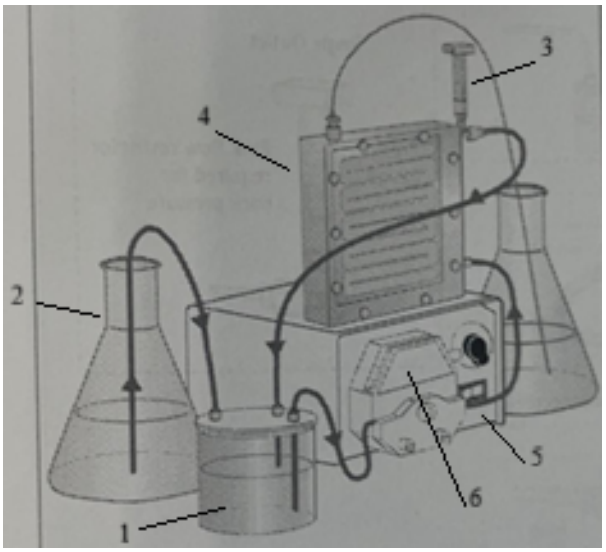
Materials and methods. In the course of the study, various dairy substrates were utilized as primary samples, chosen for their distinct protein-fat compositions and functional properties. The main object of analysis was buttermilk taken from the EC ”Astana-Onim” - a by-product of butter production characterized by reduced fat content and enriched with polar lipids as well as biologically active peptides.

By means of ultrafiltration of buttermilk using semipermeable membranes, two fractions were obtained:

- permeate, which predominantly contains low-molecular-weight compounds such as lactose, mineral salts, and soluble vitamins,

- retentate, enriched with proteins, phospholipids, and high-molecular-weight components [2].

The schematic representation of the ultrafiltration setup is shown in Figure 1.



The scheme of the ultrafiltration plant



The process of ultrafiltration of buttermilk

Fig.1 - The process of ultrafiltration of buttermilk

where, 1 - Sample / diafiltration reservoir, 2 - Filtrate versel, 3 - Pressure indicator, 4 - Pink flow restrictor, 5 - Masterflex pump, 6 - Masterflex easy load pump head.

In the VivaFlow ultrafiltration system, the process works as follows: the feed solution is placed in the diafiltration reservoir (1), from where it is pumped to the membrane using the Masterflex pump (5) with the Easy Load pump head (6). The membrane separates the liquid into concentrate and filtrate, with the filtrate collected in a separate vessel (2). System pressure is monitored by the

pressure indicator (3), and the flow is controlled by the pink flow restrictor (4), ensuring stable operation and efficient separation of the solution components.

Along with buttermilk and its derivatives, Simmental cow's milk from LLP «Moya ferma» and Saanen goat's milk from LLP «Arka Zerenda» were utilized in the study to enable a comparative analysis of species-specific differences in casein micelle structure and lipid composition.

Furthermore, the investigation included a buttermilk concentrate, produced by partial dehydration, aimed at modeling highly concentrated dairy systems.

Finally, the research incorporated blends of various dairy components, specifically prepared to explore synergistic effects between proteins, fats, and polar lipids within multiphase dairy matrices.

Active acidity (pH) was determined in accordance with «GOST 26188-84 - Food products. Method for pH determination», using an Atago pH meter, which ensures reliable and precise assessment of hydrogen ion concentration in the tested samples [3].

Titratable acidity (°T) was assessed using the acid-base titration method in accordance with «GOST 3624-92 - Milk and dairy products. Method for titratable acidity determination», providing an integral measure of all titratable acids present in the product [4].

Mass fraction of fats (%) was measured using Fourier-transform near-infrared (FT-NIR) spectroscopy on a Tango-R spectrometer, a rapid and non-destructive analytical method.

Mass fraction of proteins (%) was also determined using FT-NIR spectroscopy on the Tango-R device, which captures absorption spectra characteristic of protein molecular structures, serving as an effective alternative to classical chemical assays.

Mass fraction of dry substances (%) was determined according to «GOST 3626-73 - Milk and dairy products. Method for determination of dry matter content», by means of the refractometric method, which relates the refractive index of the sample to its concentration of dissolved solids [5].

The sensory analysis was carried out in accordance with GOST R ISO 22935-2-2011 «Milk and milk products. Sensory analysis. Part 2. Recommended methods for sensory evaluation» [6]. The tasting was attended by teachers and students of KATRU, a total of 7 degustators. The assessment was carried out in a tasting room at a temperature of (20 ± 2) ° C and diffused daylight, eliminating the influence of foreign odors and glare. The samples were presented in the same container, randomly, in increasing order of concentration of dry substances, with an interval of 2-3 minutes between assessments to restore taste buds. The sensory evaluation was carried out using a five-point scale, where 5 points corresponded to samples with the most desirable organoleptic characteristics and 1 point to those with pronounced defects or deviations from the standard. The results of the sensory evaluations were statistically processed by calculating the mean values and standard deviations.

Results and discussion. One of the promising avenues for the valorization of whey and buttermilk is membrane filtration, a technology that enables the selective separation of the product into two distinct fractions: permeate and retentate. The present study investigates the temperature-dependent changes (in the range of 20-60 °C) in the physicochemical properties of buttermilk and its ultrafiltration-derived fractions [7].

Ultrafiltration was performed using the Vivaflow 50/50R/200 system, and the technical specifications of the equipment are presented in Table 1.

The raw material - buttermilk - was poured into a product tank, from which it was transferred into a membrane module via a membrane pump. Within the module, the feed was separated into retentate (concentrate) and filtrate [8]. The ultrafiltration pressure was regulated using a needle valve and monitored by a manometer, while temperature was maintained by a heat exchanger. During the process, the retentate was recirculated back into the product tank, and the filtrate was collected in a separate container.

It is well established that increasing temperature

enhances filtration rate, whereas membrane selectivity remains largely unaffected. However, elevating the temperature beyond 40 °C can lead to the precipitation of soluble calcium and magnesium salts, resulting in pore blockage and a reduction in filtration efficiency [9].

Table 1 - Technical Specifications of the Ultrafiltration System Vivaflow 50/50R/200

Overall dimensions (length/height/width), mm	107/84/25
Channel dimensions (width/height), mm	15/0,3
Effective membrane area, cm²	50
Minimum recirculation volume, mL	10
Membrane material	TPX (PMF)
Manufacturer	SARTORIUS (UK)

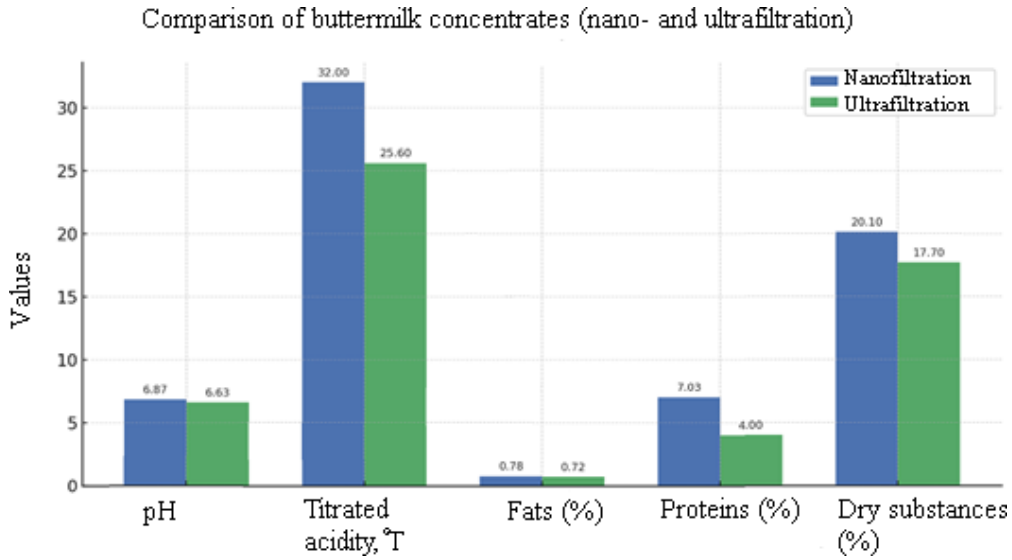


Fig.2 - Comparative characteristics of buttermilk processing methods

Buttermilk concentrates obtained through membrane separation technologies represent valuable ingredients for the food industry. Their composition and functional properties vary depending on the filtration method - whether ultrafiltration or nanofiltration [10]. Given the absence of a specific GOST standard regulating the physicochemical properties of ultrafiltered buttermilk concentrate, a comparative evaluation was carried out based on the existing GOST 34354-2017 «Dairy products. Buttermilk concentrate. Technical specifications» (which pertains to condensed buttermilk), as well as the study by Bobrova, which investigates the characteristics of nanofiltered buttermilk [11].

Figure 2 presents comparative characteristics of buttermilk processing methods.

According to GOST requirements for condensed buttermilk, titratable acidity must not exceed 21 °T. In both membrane-processed samples this level was surpassed: 32.0 ± 1.0 °T in the nanofiltration sample and 25.6 ± 1.0 °T in the ultrafiltration sample. The increase likely reflects active microbial development during concentration or insufficient thermal stabilization of the raw material. Since temperature rises were observed in

both processes, membrane filtration may intensify acidity either through microbiological activity or through concentration effects. Notably, the higher acidity of the nanofiltration sample may accelerate spoilage compared to ultrafiltration.

Fat content in both concentrates remained within the GOST-specified range (0.5–1.5%), amounting to 0.78 ± 0.08% after nanofiltration and 0.72 ± 0.08% after ultrafiltration, confirming effective lipid retention. The slight decrease in the ultrafiltration sample may be linked to the coarser membrane, which can allow finer lipid fractions to pass.

Protein content differed markedly: the nanofiltration concentrate reached 7.03 ± 0.30%, exceeding the normative range (2.5-4.0%), while the ultrafiltered sample contained 4.00 ± 0.20%, close to the upper GOST limit. This distinction highlights the higher selectivity of nanofiltration, which retains both high-molecular proteins and smaller peptides.

According to GOST, the dry matter content of condensed buttermilk should be 30-50% (or above 90% for dried products). In these membrane-concentrated samples, whey removal did not occur; concentration was achieved only by moisture reduction. As a result, dry matter reached 20.10 ± 0.50% after nanofiltration and 17.7 ± 0.50% after ultrafiltration.

Overall, the results show that membrane concentration effectively preserves proteins and fats. Ultrafiltration stands out as a practical and economically advantageous method, providing substantial retention of proteins and dry matter and making it suitable for the production of functional food ingredients, while maintaining lower acidity compared to nanofiltration.

The experiment was conducted with repeated measurements: each temperature condition (20, 30, 40, 50, and 60 °C) was tested in three parallel replicates, allowing for reliable mean values to be obtained and for statistical differences between the conditions to be assessed. Table 2 provides a comparative summary of key physicochemical parameters of buttermilk concentrates produced via different membrane methods, alongside the reference values from GOST 34354–2017 [12].

In the control buttermilk sample, the active acidity was measured at pH 7.14, indicating a mildly alkaline medium. Upon thermal treatment, a gradual decline in pH was observed, most notably in the permeate fraction. At 60 °C, the pH of the permeate decreased to 6.42, suggesting intensified acid-forming reactions. In contrast, the retentate exhibited a narrower pH fluctuation range (from 6.84 to 6.56), likely attributable to its higher protein content, which provides buffering capacity.

Titratable acidity increased with rising temperature, peaking at 40 °C with values of 30 ± 2 °T in the retentate and 27.0 °T in the permeate. A subsequent decline in acidity beyond 50 °C may reflect the thermal inactivation of microbial populations and modifications in the protein–mineral matrix.

The mass fraction of fat in the permeate remained consistently low (0.06–0.1%), confirming the efficiency of membrane separation in removing lipid components from the aqueous phase. Meanwhile, the retentate demonstrated a gradual increase in fat content with temperature elevation – from 0.70 to 0.95% - possibly due to fat globule densification and enhanced retention within the concentrated phase. The most pronounced changes were observed in the distribution of protein between the ultrafiltration fractions. In the permeate, the mass fraction of protein decreased from 1.90% to 1.44% at 40 °C, followed by a slight increase at higher temperatures. In contrast, the retentate maintained a relatively stable protein content, fluctuating between 3.80% and 4.00%, indicating efficient retention of high-molecular-weight compounds.

The mass fraction of dry matter in the permeate showed a steady decline from 5.29% to 4.94%, whereas in the retentate, dry matter content accumulated progressively, ranging from 10.29% to a maximum of 15.38–17.7%. These data underscore the effectiveness of thermal concentration at 30 °C, where the highest dry matter content (17.7%) was recorded, suggesting this temperature regime as the most favorable for obtaining highly concentrated

dairy products.

According to the experimental results presented in Table 2, the maximum protein yield (4%) was achieved at 30 °C. The concentration process was carried out at 30 °C and a pressure of 2.5 MPa. From an initial volume of 500 mL of buttermilk, the process yielded 400 mL of whey and 100 mL of buttermilk concentrate. The total processing time did not exceed 40 minutes.

Taken together, the results demonstrate that temperature treatment exerts a significant influence on the physicochemical characteristics of buttermilk and on the efficiency of membrane fractionation [13]. From the standpoint of optimizing acidity, protein, and fat retention, 30 °C emerged as the most advantageous processing temperature.

The following table presents the physicochemical characteristics of natural cow's milk, goat's milk, and buttermilk.

Table 2 - Physic-chemical parameters of buttermilk concentrate obtained by ultrafiltration

Name of indicators	Buttermilk control	Buttermilk t=20°C		Buttermilk t=30°C		Buttermilk t=40°C		Buttermilk t=50 °C		Buttermilk t=60 °C	
		Permeate(Whey Protein)	Retentate (Clarified Whey)	Permeate (Whey Protein)	Retentate (Clarified Whey)	Permeate (Whey Protein)	Retentate (Clarified Whey)	Permeate (Whey Protein)	Retentate (Clarified Whey)	Permeate (Whey Protein)	Retentate (Clarified Whey)
n=3											
Active acidity, pH	7.14 ± 0.98^{a}	6.84 ± 0.55^{ab}	7.14 ± 0.55^{a}	6,63 ± 0,02^{a}	7,05 ± 0,15^{a}	6.58 ± 0.55^{ab}	6,68 ± 0,14^{ab}	6,73 ± 0,25^{ab}	6,68 ± 0,75^{ab}	6,56 ± 0,85^{b}	6,42 ± 0,95^{b}
Titrated acidity, °T	16 ± 1.2^{a}	16.3 ± 0.55^{a}	22.1 ± 0.5^{b}	25.6 ± 0.4^{c}	23.6 ± 0.22^{b}	26.6 ± 0.48^{c}	27 ± 0.48^{c}	30.2 ± 0.15^{d}	27.1 ± 0.48^{c}	20.66 ± 0.85^{ab}	19.1 ± 0.45^{a}
Mass fraction of fats, %	0.69 ± 0.85^{a}	0.70 ± 0.11^{a}	0.06 ± 0.48^{b}	0.72 ± 0.44^{a}	0.08 ± 0.85^{a}	0.74 ± 1.02^{a}	0.09 ± 0.55^{b}	0.81 ± 0.87^{a}	0.10 ± 0.62^{c}	0.95 ± 0.75^{ab}	0.10 ± 0.62^{b}
Mass fraction of proteins, %	2.89 ± 0.15^{a}	3.94 ± 1.55^{b}	1.90 ± 0.84^{c}	4.00 ± 0.84^{b}	1.82 ± 0.99^{c}	3.90 ± 0.15^{b}	1.44 ± 0.56^{c}	3.98 ± 0.55^{b}	1.79 ± 0.45^{c}	3.80 ± 0.45^{b}	1.76 ± 0.96^{c}
Mass fraction of dry substances, %	10.16 ± 0.64^{a}	10.29 ± 0.95^{a}	5.29 ± 0.44^{b}	17.7 ± 0.44^{c}	5.10 ± 0.78^{b}	16.0 ± 0.35^{c}	4.06 ± 0.85^{b}	16.67 ± 0.42^{c}	5.02 ± 0.71^{b}	15.38 ± 0.16^{c}	4.94 ± 0.17^{b}

The average values in a row marked with different letters (a, b, c) differ from each other statistically at p 0.05. Values with the same letters, as well as combined symbols (ab), do not differ statistically.

Table 3 - Physicochemical characteristics of natural cow's milk, goat's milk, and buttermilk

Name of indicators	Cow's milk	Goat's milk	Buttermilk permeate after ultrafiltration
	n=3		
Active acidity, pH	6,2 ± 0,12	7,01 ± 0,11	6,63 ± 0,02
Titrated acidity, °T	16 ± 0,03	17 ± 0,01	25,6 ± 0,04
Mass fraction of fats, %	3,98 ± 0,59	4,5 ± 0,01	0,72 ± 0,45
Mass fraction of proteins, %	3,47 ± 0,12	3,1 ± 0,15	4,00 ± 0,85
Mass fraction of dry substances, %	10,56 ± 0,55	11,85 ± 0,78	17,7 ± 0,44

As shown in Table 3, cow's milk is characterized by moderate acidity, a fat content of about 3.98%, and a protein level of 3.47%, which are within the standard range for natural cow's milk. Goat's milk shows a slightly higher pH and fat content (4.5%), consistent with its naturally richer composition. The parameters of both types of milk meet standard physicochemical requirements. The buttermilk permeate obtained after ultrafiltration demonstrates lower fat and higher protein and dry matter contents, reflecting the concentration effect of the membrane process.

Table 4 - Evaluation of organoleptic parameters of buttermilk concentrates obtained by ultrafiltration, score

	Characteristics of organoleptic parameters	Score
Taste	Milky, clean, moderately sweet taste with a hint of pasteurization	5
	Unexpressed milky, moderately sweet	4
	Empty	3
	The intrusive sweet taste	2
	Uncharacteristic for this product	1
Consistency	Homogeneous, fluid, slightly viscous liquid without sediment and flakes	5
	Homogeneous liquid	4
	Excessively liquid or excessively viscous	3
	Heterogeneous, with a visible protein deposit	2
	Heterogeneous, floccose, stringy	1

The buttermilk obtained through ultrafiltration underwent a comprehensive organoleptic evaluation. Sensory attributes often exert a more profound influence on consumer preferences than the chemical composition or nutritional value of a product, ultimately shaping market demand [14].

This underscores the critical importance of in-depth sensory analysis at every stage of production.

In the case of fermented dairy products with a complex raw material matrix, the development of their sensory profile is largely dictated by the quality of the initial dairy base [15]. Among the various parameters that define its consumer appeal, taste, aroma, and texture stand out as the most pivotal. To quantify these attributes, a tailored scoring system was devised specifically for buttermilk concentrates in the Table 4.

The organoleptic evaluation revealed that the buttermilk concentrates obtained via ultrafiltration, containing between 10% and 17.7% total solids, exhibited a clean, pleasant flavor profile with a subtly sweet undertone. Notably, the intensity of flavor increased proportionally with the degree of concentration. Sensory attributes were assessed using a five-point scale. The results of the organoleptic analysis of buttermilk are presented in Table 5.

Table 5 - Results of organoleptic analysis of buttermilk

Indicators	Buttermilk, 10.29% TS	Buttermilk, 10,16 TS	Buttermilk, 10,29 TS	Buttermilk, 16 TS	Buttermilk, 16,67 TS	Buttermilk, 15,38 TS	Buttermilk, 17,7 TS
n=7							
Taste	4,5±0,12	4,2± 0,14	4,21±0,04	4,32±0,02	4,11±0,05	4,32±0,01	4,9±0,02
Consistency	4,12±0,02	4,23±0,05	4,20±0,05	4,32±0,07	4,74±0,04	4,8±0,01	4,9±0,01

Based on the data in the table, the best sensory results were obtained for the buttermilk sample with 17.7% total solids. This variant received the highest scores for both taste and consistency, indicating a richer flavor and a more stable, pleasant texture. The increased amount of total solids likely improves the product's structure, making it more balanced and more appealing in terms of sensory characteristics compared to the other samples.

Based on a comprehensive series of analyses, the ultrafiltered buttermilk concentrate with a 17.7% solids content was selected as the optimal base for the development of fermented dairy products enriched with high-quality protein.

Numerous studies [16] have demonstrated that the rheological behavior and syneresis of fermented milk gels are significantly influenced by the dispersion characteristics of protein particles in the starting material. In this context, investigating the transformations in the structural viscosity of buttermilk - driven by its protein components under the effect of ultrafiltration – as well as the nature of the resulting protein microstructures, presents both scientific and practical value [17].

As a dairy base meeting the defined requirements, the buttermilk concentrate obtained through ultrafiltration proved to be the most suitable candidate. Its compositional characteristics suggest it offers a favorable environment for the growth of starter cultures, including probiotic strains. Moreover, the incorporation of whey concentrate into the dairy matrix is expected to substantially enhance the content of high-quality whey proteins in the final product [18].

To develop technology for protein-enriched fermented dairy products, a tailored multicomponent

mixture was formulated using skimmed cow's milk, goat's milk, and buttermilk concentrate. Building on earlier studies that explored the optimal ratio of cow's to goat's milk, it was established that a 50:50 blend yielded the best functional and sensory balance. However, a higher proportion of goat's milk significantly increases production costs.

With this in mind, the current study sought to refine the formulation by systematically reducing the goat's milk content while compensating with increased levels of buttermilk concentrate. Four experimental formulations of the dairy base were prepared using the following proportions of cow's milk / goat's milk / buttermilk concentrate:

Variant 1: 50/40/10

Variant 2: 50/30/20

Variant 3: 50/20/30

Variant 4: 50/10/40

Each variant underwent detailed physicochemical analysis under laboratory conditions using standard methodologies. The resulting data are presented in Table 6.

Table 6 - Physic-chemical parameters of a multicomponent mixture using buttermilk concentrate

Variant	Milk mixture ratio (cow/goat/buttermilk, %)	Dry substance, % by mass (n=3)	Proteins, g/100 g (n=3)	Fats, g/100 g (n=3)
1	50/40/10	18.25±0,15	6.01±0,02	3.65±0,56
2	50/30/20	24.00±0,18	8.67±0,45	3.40±0,45
3	50/20/30	29.75±0,65	11.33±1,20	3.15±0,15
4	50/10/40	35.50±0,95	14.00±0,42	2.90±0,78

The results of the conducted study demonstrate a clear upward trend in both total solids and protein content as the proportion of buttermilk concentrate in the dairy base increases – from Variant 1 (10% concentrate) to Variant 4 (40%). Specifically, the total solids content rose from 18.25% to 35.50%, while protein levels increased from 6.01% to 14.00%. These findings underscore the beneficial role of buttermilk concentrate in enhancing the density, nutritional richness, and biological value of the final product.

It has been confirmed that buttermilk concentrate serves as a valuable source of high-quality protein, making it a promising ingredient in the formulation of functional food products.

Conclusion. Thus, the incorporation of buttermilk concentrates into a dairy blend containing cow's and goat's milk facilitates a simultaneous increase in complete protein content and a reduction in fat, offering a significant advantage in the development of functional and dietetic dairy products.

Moreover, it was found that increasing the proportion of buttermilk concentrate in the formulation leads to a marked rise in total solids and a notable improvement in sensory characteristics – such as taste, aroma, and texture. Owing to its finely dispersed protein composition and high biological value, buttermilk concentrate contributes to the formation of an optimal gel structure in fermented dairy matrices and creates a favorable environment for the growth of starter cultures, including probiotic microorganisms.

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Information about authors

Tultabaeva T.Ch. - Doctor of Technical Sciences, Professor, S.Seifullin Kazakh Agro Technical Research University, Astana, Kazakhstan, e-mail: tamara_tch@list.ru;

Zhakupova G.N. - Candidate of Technical Sciences, Professor, S.Seifullin Kazakh Agro Technical Research University, Astana, Kazakhstan, e-mail: gulmira-zhak@mail.ru;

Makangali K.K.- PhD, Associate Professor, S.Seifullin Kazakh Agro Technical Research University, Astana, Kazakhstan, e-mail: k.makangali@mail.ru;

Sagandyk A.T. - PhD, S.Seifullin Kazakh Agro Technical Research University, Astana, Kazakhstan, e-mail: assema.bukeyeva@gmail.com;

Muldasheva A.H. - Master of Technical Sciences, S.Seifullin Kazakh Agro Technical Research University, Astana, Kazakhstan, e-mail: aknurmuldasheva@gmail.com;

Dairova K.Sh - Master's student, S.Seifullin Kazakh Agro Technical Research University, Astana, Kazakhstan, e-mail: dairova111@mail.ru.

Сведения об авторах

Тултабаева Т.Ч. - д.т.н. профессор, Казахский агротехнический исследовательский университет имени С. Сейфуллина, Астана, Казахстан, e-mail: tamara_tch@list.ru;

Жакупова Г.Н. - к.т.н., профессор, Казахский агротехнический исследовательский университет имени С. Сейфуллина, Астана, Казахстан, e-mail: gulmira-zhak@mail.ru;

Макангали К.К.- доктор PhD, ассоциированный профессор, Казахский агротехнический исследовательский университет имени С. Сейфуллина, Астана, Казахстан, e-mail: k.makangali@mail.ru;

Сагандык А.Т. - доктор PhD, Казахский агротехнический исследовательский университет имени С. Сейфуллина, Астана, Казахстан, e-mail: assema.bukeyeva@gmail.com;

Мулдашева А.Х. - магистр технических наук, Казахский агротехнический исследовательский университет имени С. Сейфуллина, Астана, Казахстан, e-mail: aknurmuldasheva@gmail.com;

Даирова К.Ш. - магистрант, Казахский агротехнический исследовательский университет имени С. Сейфуллина, Астана, Казахстан, e-mail: dairova111@mail.ru.