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Quality and safety of new types of dairy products based on cow's and mare's milk with vegetable additives

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Abstract

The modern market of dairy products is quite developed, but the issue of compliance with the quality and safety of their production remains relevant. The purpose of this paper was to study the organoleptic, physicochemical and safety indicators of combined dairy products based on mare's and cow's milk using herbal supplements. In the course of the research, analytical and statistical methods of information processing were used; experimental studies of raw materials and the finished combined product, namely the determination of acidity, solids, fat and protein; energy and biological values of the product were calculated. Technological processes of combined dairy products based on cow's and mare's milk using a vegetable origin filler were studied. Of the three prototypes of the proposed dairy products, it was determined to recommend samples No. 2 and 3. High quality indicators are observed in them, in particular, a rich taste with a pronounced taste of additional components, a pleasant smell and appearance. Also, the finished product in samples No. 2 and 3 have high safety indicators. Pathogenic and harmful microorganisms and substances were not found, acceptable microorganisms are within the maximum permissible limits. According to the research results, new dairy products are recommended using vegetable raw materials with different fat, protein, energy value, caloric content and lactose content. In the process of writing this paper, indicators of nutritional, energy value and safety of new types of dairy products based on cow and mare's milk with vegetable additives were determined. Taking into account the research results and the materials of previous scientific papers, authors consider it promising to develop and sell dairy products based on cow's and mare's milk using a filler of plant origin. The advantages of the resulting product include: consumer interest in such products, high quality indicators, product safety, the possibility of using products in functional and specialized nutrition.

Keywords Combined products, Quality indicators, Production technology, Chemical composition, Raw materials

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Graphical Abstract

Introduction

The quality and safety of food raw materials has always been a strategic goal of any processing enterprise, sales markets and the country as a whole. With the development of the latest technologies, consumer demands, as well as legal requirements, new types of products are being developed, including dairy products. When developing new products, it is important to maintain indicators of nutritional, biological, energy value, as well as safety. For this, various types of natural milk raw materials are used, including cow's or mare's milk with herbal supplements. When developing new types of dairy products, new technologies for processing raw materials and additional components are also considered. One of these technologies is a pulsed electric field, which makes it possible to obtain a high-quality dairy product with long shelf life and the appropriate features that characterize freshness. This technology inactivates most microorganisms, as well as some lactic enzymes that affect the safety of the finished product (Soltanzadeh et al. 2022).

Most often in the dairy industry, including in Kazakhstan, heat treatment of raw materials and finished products is used to deactivate pathogenic microorganisms, ensure food safety and extend shelf life. Scientific advances and industrial developments offer other processing methods due to consumer demand for more natural and healthier products with non-thermal manufacturing techniques. Cow's milk is typically processed using thermal and nonthermal methods. Thermal processing involves heating the milk to high temperatures to kill bacteria and extend shelf life. This can be done through pasteurization or ultra-high temperature (UHT) processing (Geiselhart et al. 2021). Nonthermal processing methods include microfiltration, which removes bacteria and other particles from the milk, and high-pressure processing, which uses high pressure to kill bacteria. Mare's milk is traditionally used for the production of koumiss, a fermented milk widely produced in Central Asia (Musaev et al. 2021). The milk is fermented using a starter culture, which converts lactose into lactic acid, giving the milk a tangy flavour. The product is stored at below 6 °C until sold (Cais-Sokolińska et al. 2023). Freeze-drying is also used to preserve the physical and chemical stability of the milk powder during storage.

The production and consumption of dairy products in the world is different. Thus, China has seen significant growth over the past 5 years. At the same time, the problem of safety and quality of such products is growing. In their paper, Wu et al. (2018) considered the supply of dairy products to markets, indicators of quality and safety of dairy products. They believe that it is possible to establish the production of safe products through the reform and improvement of systems that organize the safety of milk and products from it, increased control over the safety of dairy products, as well as changes in laws, by-laws, management and oversight mechanisms that were not perfect. Sarsembayev et al. (2021) developed a sports nutrition formula with the addition of freeze-dried mare's milk, which increases the biological value of the product that gives it direction. Their paper also presents the chemical composition and biological value of mare's milk. The expediency, influence and effect of the use of the new product have been proven by experimental studies on rats. The results obtained confirm the positive effect of the developed product on endurance, performance and the state of antioxidant protection, as well as the energy metabolism of laboratory animals.

Tultabayeva et al. (2022) confirm that mare's milk can be used to treat diseases of the gastrointestinal tract, disorders of the intestinal microflora, as well as some pulmonary diseases. Also, compared with cow's milk and other types of milk of farm animals, mare's milk has a high biological value. To get the maximum benefit from mare's milk, it is necessary to preserve its physical and chemical characteristics during processing and storage. The authors established the average characteristics of the fat content within the range of 1.2–2.8% protein content ranging between 2–2.36%, and dry skim dairy residue (SOMO) within the range of 8.35–8.73% in the studied samples of mare's milk from four farms in the Almaty region. Scientists are convinced that the indicators fluctuate depending on the breed and age of mares, feeding conditions, time of year, methods of their maintenance. The conducted organoleptic and physico-chemical studies of mare's milk confirm the possibility of its use as a raw material for the production of combined dairy products using herbal supplements, including for dietary nutrition.

In the manufacture of new dairy products, combined dairy products, including those with the addition of fillers of vegetable origin, attention should be paid to the quality of physicochemical parameters (fat and protein content, absence of inhibitory substances, the number of microbial and somatic cells), on which the biological value of these products depends (Shahini et al. 2023). Also, due to the growing demand in the world for dairy products with less technological impact, domestic production, local products (from a specific region with geographical indication), product safety risks are increasing (Fusco et al. 2020).

The research topic, focusing on the quality, safety, and nutritional aspects of combined dairy products derived from cow's and mare's milk with herbal supplements, is highly relevant in today's food industry. Ensuring the quality and safety of dairy products remains a persistent concern, while the introduction of innovative ingredients like herbal supplements responds to evolving consumer interests in healthier and more diverse dietary choices. The aim of this study was to determine how technical advancements in the production of mixed dairy products made from cow's and mare's milk with a filler of vegetable origin affected quality and safety parameters. Furthermore, the study subjects served as markers for the nutritional, biological, and energetic content of the suggested novel varieties of dairy products. Thus, the central problem addressed in this study is the development and evaluation of combined dairy products derived from a blend of cow's and mare's milk, enriched with plant-based additives.

Materials and methods

The research employed analytical and statistical methods of information processing to delve into the properties and characteristics of both raw materials and the combined finished product. Extensive experimental studies were conducted to ascertain specific parameters, including the determination of acidity levels, the presence of solids, and the content of fats and proteins. Beyond these basic measures, the study also calculated the overall energy and biological value of the product, offering a comprehensive understanding of its nutritional profile and potential benefits. In the course of this research, the scientific and technical literature of the scientometric were carried.

Sampling was carried out in accordance with ST RK ISO 707–2011 "Milk and dairy products. Guidance on sampling" (2012); organoleptic indicators were determined according to ST RK 1732–2007 "Milk and dairy products. Organoleptic method for determining quality indicators" (2007); physicochemical and safety indicators were determined according to ST RK 1734–2007 "Milk and dairy products. Acceptance rules and test methods" (2007) and the standards referred to in this document; finished combined dairy products met the requirements of ST RK 1733–2015 "Milk and dairy products. General specifications" (2015), as well as the regulations referred to in this standard.

The milk sampled was raw, unpasteurized, 12 h from collection. Milk was received from farms. The number of samples was 12 (6 cow's and 6 mare's milk). After sampling, the samples were stored in a refrigerator at 4 °C. Chia seeds (3%), flax seeds (4%), nettle shoots (*Urtica dioica* L.) (1%), and cranberries (2%) were used as plant components. Plant raw materials were purchased in retail trade, and at the time of the research, all samples had a valid expiration date and corresponded to the regulatory document indicated on the label.

Before the study of combined dairy products with the addition of fillers of vegetable origin, the chemical composition of cow's and mare's milk was studied to correct the composition and quality indicators of the finished product. At the next stage, the organoleptic and physico-chemical indicators, safety indicators of the finished combined products were studied. In addition, the indicators of the nutritional and energy value of the finished combined dairy products were calculated. The energy value of dairy products was calculated per 100 g of the product. To do this, a certain number of components of the composition of such products was multiplied by the generally accepted standards: 1 g of protein – 4 kcal (17.2 kJ), 1 g of fat – 9 kcal (38.9 kJ), 1 g of carbohydrates – 3.75 kcal (17.6 kJ).

Determination of solids in dairy products was carried out as follows: 3 cm^3 of the test product was added to the prepared bottle with a pipette, distributing it evenly over the entire surface of the gauze and covered with a lid, after which it was weighed. Next, the opened bottle and the lid were placed in an oven at a temperature of 105 °C for 60 min; after the drying stage, the bottle was closed, cooled in a desiccator, and weighed. Drying and weighing continued for 20–30 min until the difference in weight between two successive weightings was not more than 0.001 g. For a more accurate determination, all analyses were carried out in triplicate. The results obtained were processed using the MS Excel built-in package of statistical functions.

Results

Dairy production is an important part of Kazakhstan's agricultural sector, accounting for around 4% of total agricultural output. The main dairy products produced are milk, sour cream, kefir, yogurt, butter, and a variety of cheeses. Milk production has increased significantly in Kazakhstan over the past couple of decades, from around 3.5 million tonnes in 2000 to over 5.5 million tonnes in 2020 (Aimen et al. 2022). This growth has been driven by investments in larger dairy farms and improved cattle breeds. Per capita dairy consumption in Kazakhstan is relatively high compared to other countries in Central Asia, estimated at around 240–270 kg per person per year (Akhmedyarov et al. 2023). This is due to long-standing dietary habits and the affordability of dairy products. Kazakhstani production meets around 90% of dairy demand, with the remainder imported mainly from Russia, Belarus, and Ukraine. Imports help fill seasonal gaps in milk supplies. Food manufacturing companies in Kazakhstan, like FoodMaster, Ramstore, and Raimbek Agro, have invested in expanding their dairy product ranges and modernizing processing technologies in recent years (Kaliyeva et al. 2021).

Combined dairy products using vegetable origin fillers were studied in three experimental formulations with different ratios of raw materials (Table 1).

In the obtained experimental samples of cow's and mare's milk, which were used for the production of dairy products using vegetable raw materials, quality and safety indicators were studied, in particular organoleptic, physicochemical and microbiological indicators (Table 2).

As can be seen from Table 2, the results of the research confirm the possibility of developing new dairy products from existing raw materials, because the prototypes meet the quality and safety indicators. Milk received from farms meets the requirements of the Technical regulation of the Customs Union 033/2013 "On the safety of milk and dairy products" (2013). Cow's milk is characterized by higher mass fractions of protein and fat, which

Table 1 The ratio of raw materials for the production of dairy products

No	Amount of cow's milk	Amount of mare's milk	Amount of vegetable filler
1	45%	45%	10%
2	65%	25%	10%
3	75%	15%	10%

Table 2 Indicators of quality and safety of raw materials

No	Indicator	Cow's milk	Mare's milk
1	Appearance	Opaque liquid, no sediment, no fat deposits	
2	Consistency	Homogeneous, inflexible, free from protein flakes and fat lumps	
3	Colour	Creamy white[a]/White with a bluish tint[b], uniform throughout the mass	
4	Smell, taste	Clean, sweetish, typical for cow's/mare's milk, without foreign flavours and odours	
5	Density, kg/m^3	1027	1036
6	Mass fraction of protein, %	2.95	2.25
7	Mass fraction of fat, %	2.2	1.85
8	Mass fraction of SOMO, %	8.3	9.45
9	Acidity, T°	18.7	5.7
10	Lactose, %	4.7	6.15
11	Pathogenic microorganisms in 25 cm^3 of product, including: *Salmonella, L. monocytogenes*	Not found	
12	*Staphylococcus aureus* in 1 cm^3 of product	Not found	

[a] For cow's milk

[b] For mare's milk

amount to 2.95% and 2.2%, respectively. The acidity of cow's milk (18.7, T°) is within the limits of limits (16–21, T°). Mare's milk, in turn, is characterized by higher levels of lactose and SOMO. All obtained indicators in cow's and mare's milk are within their boundary limits, regulated by regulatory documents. Also, mare's milk is the farthest from the ideal white colour, which must be taken into account when developing products.

When developing a dairy product with plant components, attention was paid to the need to obtain high organoleptic indicators (appearance and taste), biological and energy value, as well as compliance with safety indicators. In the manufacture of such a product with the addition of herbal additives that have personal properties and affect the product, it was necessary to take into account a number of indicators, including the colour of the finished product. To obtain the optimal milky white colour, three options for the ratio of milk in the finished dairy product were proposed. According to the results of milk mixing, Sample No. 2 and 3 were visually attractive. An organoleptic study of the dairy product was carried out 24 h after the production of the finished product, and the characteristics obtained are presented in Table 3.

Considering the results of the organoleptic examination presented in Table 3, it can be concluded that sample No. 1 with the ratio of raw materials of 45% mare's milk, 45% cow's milk and 10% herbal supplements received the lowest quality scores. In particular, the dairy product began to take on the characteristics of a fermented milk product; due to the higher content of mare's milk, they received a colour with a blue tint and a tart taste. Samples No. 2 and 3 generally got similar results, with slight difference in colour, taste and smell. The physical and chemical study presents the main indicators that directly affect the quality and safety of dairy products (Table 4).

The obtained results of the physicochemical study allow correcting the process of production of dairy products, determining the stage at which production is completed and changing the ratio of product components to obtain the desired results. Considering the data from Table 4, samples No. 2 and 3 can be considered successful and used for consumption as a dairy product with a lower fat content (sample No. 2) and as a product with a high protein and fat content (sample No. 3). Sample No. 1 has a higher acidity index, which may indicate its rapid deterioration and the development of harmful microflora, while other indicators are on the verge of the maximum permissible. In addition, the lactose content is also higher compared to other samples, which may be less desirable when purchasing such a dairy product due to heavy consumer tolerance. One of the main experiences of the proposed new dairy products was the determination of microbiological indicators and safety. The results are shown in Table 5.

Table 4 Physical and chemical parameters of prototypes of the dairy product

No	Indicator	Sample 1	Sample 2	Sample 3
1	Mass fraction of protein, %	2.7	3.4	3.8
2	Mass fraction of fat, %	1.9	2.3	2.5
3	Mass fraction of SOMO, %	8.5	9.55	9.95
4	Acidity, T°	142	98	113
5	Lactose, %	5.7	4.1	4.3
6	Phosphatase or peroxidase	Not found	Not found	Not found

Microbiological and safety indicators are important for determining the quality and safety of food products, in particular dairy products with the addition of vegetable raw materials. They must be controlled at all stages of production and conditions must be created to prevent the development of pathogenic microorganisms or the ingress of harmful substances into the product. Analysing the results obtained in the study, the indicators in samples No. 2 and 3 are acceptable as required by law and national standards. The number of mesophilic aerobic and facultative anaerobic microorganisms in sample No. 1 exceeds the limit, which is unacceptable and such a

Table 3 Organoleptic characteristics of prototypes of a new dairy product

Indicator	Sample 1	Sample 2	Sample 3
Appearance and texture	Homogeneous, viscous, with slight gas formation in the form of separate gas bubbles	Homogeneous, rare. No delamination and parts of fat, no lumps and sediment	Homogeneous, rare. Without clots and flakes of protein and sediment
Colour	Pale blue, with characteristic inclusions of added components	Uniform throughout the mass. Creamy white with characteristic inclusions of added components	Light white, uniform, with characteristic inclusions of added components
Smell and taste	Sour milk, tart. Without extraneous tastes and odours, with a slight yeasty odour and additives present in the product	Saturated, sweetish, corresponds to the available additional components. Free from foreign sweets and odours	Pleasant, without extraneous sweets and smells. Corresponds to the available additives in the product

Table 5 Microbiological and safety characteristics of proposed dairy products

No	Indicator	Sample 1	Sample 2	Sample 3
1	Pathogenic microorganisms in 25 cm^3 of product, including: *Salmonella, L. monocytogenes*	Not found		
2	*Staphylococcus aureus* in 1 cm^3 of product	Not found		
3	Bacteria of the group of *Escherichia coli* (coliforms), in 0.1 g	Not found		
4	Number of mesophilic aerobic and facultative anaerobic microorganisms, (CFU/cm^3)	$2.18*10^5$	$6.05*10^4$	$7.15*10^4$
5	Lead	0.02	0.01	0.007
6	Cadmium	0.02	0.009	0.0095
7	Mercury	0.0035	0.001	0.0001
8	Arsenic	0.02	0.01	0.009

product should not be used for human consumption. The rest of the indicators are within the boundary.

One of the indicators of the expediency of developing new dairy products, including the use of plant components, is the determination of the energy value and nutritional value of the finished product. It was possible to improve these indicators thanks to the combination of dairy raw materials in various ratios and the use of vegetable raw materials, in particular, chia seeds, flax, nettle shoots and freeze-dried cranberries (Shonte et al. 2020): 1) chia seeds contain fibre, protein, antioxidants, and omega-3 fatty acids. The antioxidants in chia seeds include chlorogenic acid, caffeic acid, and flavonoids like quercetin. These compounds have anti-inflammatory and antioxidant effects in the body; (2) flax seeds also contain fibre, protein, and omega-3 fatty acids like alpha-linolenic acid (ALA). They are rich in lignans like secoisolariciresinol diglucoside, which have antioxidant and phytoestrogenic effects; (3) nettle shoots contain compounds like flavonoids, polyphenols, minerals, and vitamins. Specific bioactive components include quercetin, kaempferol, and caffeic acid derivatives, which have antioxidant and anti-inflammatory properties; (4) cranberries are high in polyphenol antioxidants like anthocyanins, proanthocyanins, flavanols, and phenolic acids. Key compounds include anthocyanins like cyanidin-3-galactoside and peonidin-3-galactoside, which give cranberries antioxidant and anti-inflammatory activities.

The characteristics were calculated per 100 g of the finished product (Table 6).

The energy value of the product directly depends on the content of fat, protein and carbohydrates. Since in prototypes No. 2 and 3 compared to sample No. 1, the content of protein and fat is higher, hence the higher caloric content and energy value of the finished product – by 9% in sample No. 2 and by 18% in sample No. 3. Thus, by combining raw materials, in particular cow's and mare's milk in various proportions and adding additional components, in this case herbal supplements, you can get a finished dairy product of a given caloric content and energy value, satisfying the needs of consumers.

Table 6 Energy and nutritional value of 100 g of the finished product

No	Indicator	Sample 1	Sample 2	Sample 3
1	Energy value, kJ/kcal	280/66.9	305/72.9	330/78.9
2	Fats (of which saturated), g	1.9 (0.8)	2.3 (1.1)	2.5 (1.25)
3	Carbohydrates, g	11.3	9.65	10.3
4	Sugar, g	5	4.4	4.1
5	Proteins, g	2.7	3.4	3.8
6	Salt[a], g	0.1	0.1	0.1

[a] Due exclusively to the natural content of NaOH

Given the prospects for the production of dairy products, the constant demand of consumers for new types of products, an increase in production volumes, it is necessary to constantly provide producers with raw materials – cow's and mare's milk. To find out whether it is possible to use for the manufacture of products exclusively from raw materials produced in the Republic of Kazakhstan, statistical data on the number of cattle in the Republic of Kazakhstan over the past four years were analysed. The indicators of the number of livestock monthly were taken into account, in which months there was the largest number of livestock and the average for the year (Fig. 1).

Figure 1 shows that there is an annual trend towards an increase in the number of cattle kept. Therefore, for the period from 2019 to 2022 inclusive, the number of livestock increased by an average of 1219 thousand heads per year (15%). The smallest number of livestock in a certain period was kept in January – 8264.2 thousand heads in 2022, which is 1040.2 thousand heads (14%) more than in 2019, and the largest number was observed in May – 10,073.3 thousand heads in 2022, which is by 2047.9 thousand heads (25%) more than in 2019 (Bureau of National Statistics 2023). As for the number of horses

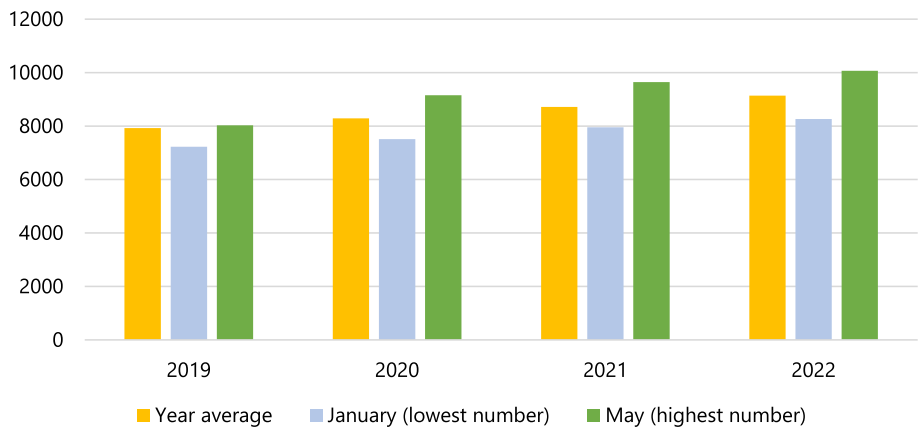

Fig. 1 The number of cattle in the Republic of Kazakhstan, thousand heads

that are kept, in particular, for obtaining milk for the production of products, the data of the Bureau of State Statistics of the Republic of Kazakhstan (2023) are shown in Fig. 2.

The analysis of information was carried out for the period 2019–2022. Authors also determined the months, in which there was the smallest and largest number of animals kept. Given the data obtained, there has been a significant increase in the number of horses in the Republic of Kazakhstan over the past four years. In 2022, the country's farms numbered 3770.5 thousand heads, which is 928.2 thousand heads (33%) more than in 2019. Again, there is a tendency to reduce the number of animals in January, so in January 2022 there were 3423.2 thousand heads, which is 834.3 thousand heads (32%) more than in the same period in 2019. The largest number of animals kept by farms was in May. In 2022, there were 4110.4 thousand heads, which is 975.2 thousand heads (31%) more than in 2019 (Bureau of National Statistics 2023). It was important to analyse the production of cow's milk in the Republic of Kazakhstan. The analysis compares how much milk production has changed during 2019–2022, as well as in which months more and less milk was produced (Fig. 3).

Despite the fact that the largest number of livestock was kept in May, the largest milk production was noted in June of each analysed year. The least milk was received in January, with the least number of kept cattle. In general, the production of cow's milk in 2022 amounted to 539.9 thousand tons, which is 54.9 thousand tons (11.3%) more than in 2019. At the same time, the number of livestock increased by 15% over the same period. In January 2020, milk production was the lowest in a year – 259.3 thousand tons, which is 20.6 thousand tons (9%) more than in 2019. The largest amount of milk produced was in June – in 2022 it was 889.2 thousand tons, which is 63.9 thousand tons (8%) more than in 2019 (Bureau of National Statistics 2023). The retail trade in dairy products and eggs in the Republic of Kazakhstan over the past 7 years, from 2015 to 2021, was also analysed. In view of the fact that the number of animals, from which raw materials were obtained, and cow's milk produced has

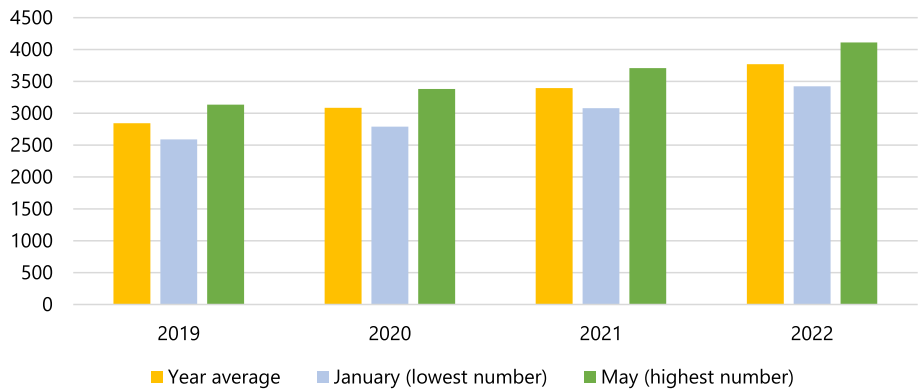

Fig. 2 The number of horses in the Republic of Kazakhstan, thousand heads

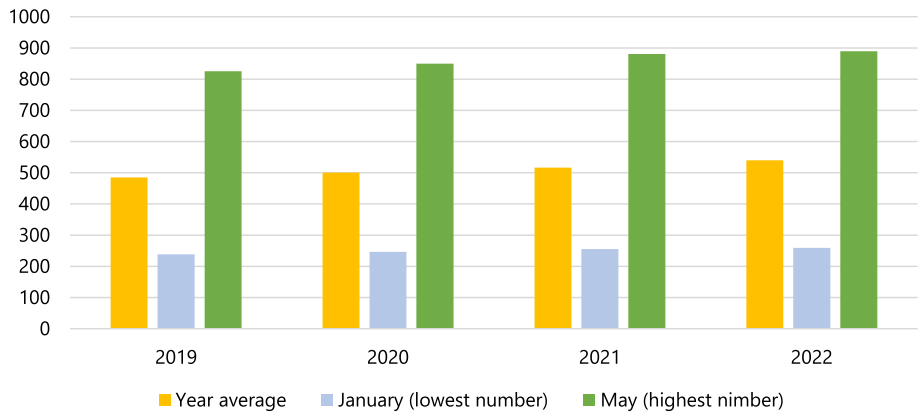

Fig. 3 Production of cow's milk in the Republic of Kazakhstan, thousand tons

systematically increased in recent years, the profit from the sale of raw materials or value-added processed products should also increase. The results of the analysis of statistical information are presented in Fig. 4.

During 2015–2020, there is a significant increase in the volume of retail sales of dairy products and eggs. So, at the end of 2020, the increase amounted to KZT 281143.7 million, or 131%. If we compare the volume of retail trade in 2021 with 2015, then the increase was by KZT 213522.7 million or 96%. For the period 2020–2021, there is a slight decrease – by KZT 67.621 million or 16%. There was a smaller volume of retail trade in dairy products and eggs in the Republic of Kazakhstan. This may be influenced by a number of factors, including the impact of the COVID-19 pandemic, the political situation in the Asian region, low subsidies and reimbursements to farmers and producers. The data for the analysis of the situation for 2022 has not yet been released by the Bureau of State Statistics (2023), but it is expected to control the situation and prevent a decrease in indicators.

Discussion

India is one of the largest milk producers in the world, and the country is also seeing a growing market for milk and dairy products. As noted in the article by Kumar (2020), the demand for dairy products began to increase with the increase in the income level of the population. But relative to the increase in these indicators, the productivity of dairy animals remains low, which hinders the expansion of trade in dairy products on the international market. It also describes the issues of improving the domestic market, competitiveness in the foreign market, and the introduction of advanced technologies in the manufacturing industry. In their paper, scientists Pilvere et al. (2020) explored the development opportunities for dairy farms of various sizes in Latvia over the

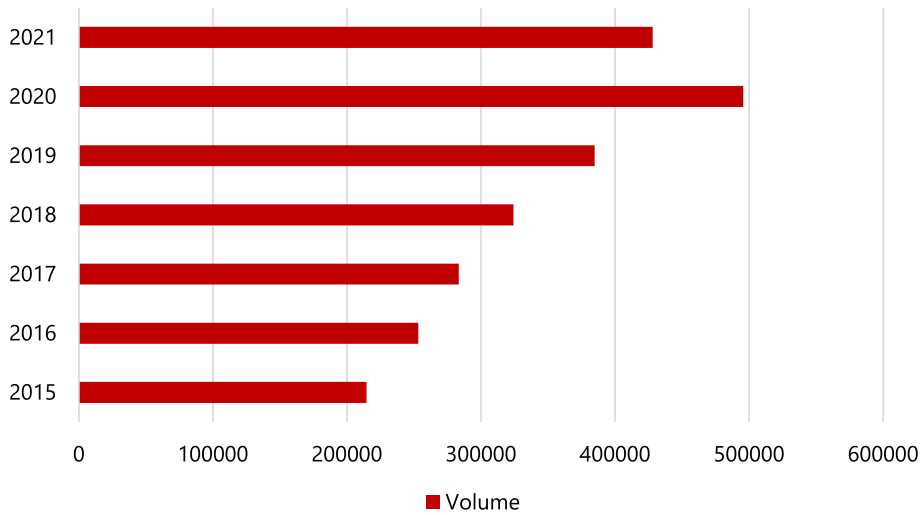

Fig. 4 Volume of retail trade in dairy products and eggs in the Republic of Kazakhstan, KZT million

next 30 years due to the increase in the world's population, as well as different levels of income. Thus, Latvia has a tendency to reduce the number of dairy cows, but at the same time to increase milk production, which indicates an improvement in the productivity of animals in general.

Even the largest producers in the world do not have a large share of the international market due to the poor quality and safety of milk as well as products made from it. Srivastava et al. (2020) examined the attitude of dairy farmers towards pure milk production practices, as well as the implementation of measures to improve local production in the field of hygiene and product safety. In turn, Kazakhstan experiences an increase in the number of cattle, horses, and, accordingly, the production of milk. Although there are still some obstacles to competition in the world market, in particular, compliance with international and regional standards for the quality and safety of dairy raw materials, mechanization of the production of the dairy industry, the introduction of outdated technologies in production and personnel responsibility (Asangalieva et al. 2015).

Dairy products during production and processing must be constantly monitored for microbial spoilage to ensure their quality and safety throughout the supply chain (Kukhtyn et al. 2020). The shelf life of milk, and therefore the quality and safety of the product, depends on its initial microbial load, the type and distribution of microbes, and how well these microbes can grow under specific storage conditions (Musiy et al. 2017). Ziyaina et al. (2020) review new methods for testing dairy products that are fast, reliable, and provide a comprehensive understanding of the microbial status of foods. Also, the application of these techniques can open up new markets for dairy products and reduce overhead costs. The development of new dairy products using vegetable raw materials requires fast, sensitive, cost-effective quality assessment technologies (Kairbayeva et al. 2022). In the course of this paper, it was investigated that microbiological safety is important in the production of dairy products. Thus, in one of the studied samples, an excess of mesophilic aerobic and facultative anaerobic microorganisms was found, and the amount of some heavy metals is within the maximum allowable limit.

In their studies, Teichert et al. (2020) determined the stability and colour change in fermented mare's milk and fermented cow's milk drinks. After all, colour, like the appearance of the product, is important for the consumer (Honchar et al. 2022). Research has focused on colour change during production and storage. Compared with fermented cow's milk, lower colour stability of mare's milk during production and storage was observed. The determined colour parameters (L*, a*, b*) and calculated values (WI, C*, YI) found that the mare's milk in the composition of the mixed milk product or the dairy product only from mare's milk is less white, although the saturation of the C* indicator was higher. In this study, among the three proposed ratios of raw materials, the colour of the future dairy product was also taken into account. It was determined that a higher amount of mare's milk negatively affects the colour of the finished product, and such a sample received the lowest score in the organoleptic study.

The results of experimental studies by scientists Hsu et al. (2021) prove the positive effect of nutritional supplementation of mare's milk powder to increase physical strength and endurance. Studies also did not reveal gross anomalies or visible lesions in various tissues and organs. In addition, they claim that there is no risk to the health of the body when using such a supplement. In their paper, the scientists also note that Mongolian mare's milk can be used as a supplement to meet some of the basic nutritional and health needs. They also recommend supplementing mare's milk powder to combat fatigue and increase endurance. The resulting dairy product in the course of this research, depending on the technological task, is characterized by a higher or lower content of fat, protein, lactose, and can also be more high-calorie and with a higher energy value, which is important for consumers who need it.

Teichert et al. (2021) determined that milk from Polish mare's milk from a typical dairy farm is a source of many ingredients that may be important for the intended use. It has been studied that in the process of production and fermentation, the amount of phenylalanine, lysine, isoleucine, aspartic acid, alanine in such milk increases, as well as there are more free amino acids than in the milk of other farm animals. Also, during fermentation, the amount of tryptophan increases by almost 25%. Fermentation does not affect the final content of riboflavin and cobalamin in the finished product (Nagovska et al. 2018). Xia et al. (2020) studied the fermentation of mare's milk for processing it into koumiss. During the study using the metabolic method based on UPLC-Q-TOF–MS (ultra-high performance liquid chromatography with quadrupole time-of-flight mass spectrometry), 354 metabolites were identified, of which 61 were activated, and 105 were reduced. As a result of their work, scientists determined that many useful functional compounds are formed in koumiss during the fermentation of mare's milk, depending on the metabolism of the initial microbial flora (Abzhanova et al. 2022).

The technologies of innovative functional food products using cranberry puree and cranberry juice as additives with hypolipidemic, hypoglycemic and coagulative properties were also studied. With the help of cranberry juice, approaches were developed to enrich the protein

matrix of coagulant albumin. Cranberry puree was used as a coagulant in milk protein concentrates (Deinychenko et al. 2020; Stephanova et al. 2021). Scientists have studied nettle (*Urtica dioica* L.) for the content of useful, medicinal substances and the prospects for use in human life, including in the food industry. For example, the leaves, stem, roots of nettles contain high amounts of fibre, minerals, vitamins and antioxidant compounds such as polyphenols and carotenoids, as well as antioxidant compounds such as polyphenols and carotenoids (Medvedkov et al. 2021; Topchii et al. 2021). In addition, nettle has anti-proliferative, anti-inflammatory, antioxidant, analgesic, anti-infective, antihypertensive, and anti-ulcer properties (Bhusal et al. 2022; Subba & Pradhan 2022). In their paper, the authors draw attention to the fact that there is a growing demand for food products, including dairy products with high biological activity, as well as ingredients that can enrich ordinary products. They researched yogurts with bioactive compounds using chia seeds and their antioxidant properties. Chia seeds were characterized by a high content of bioactive compounds, namely polyphenols and flavonoids. All analysed seed extracts showed a high ability to inactivate stable radicals and prooxidant iron chelate ions (Drużyńska et al. 2021).

Melo et al. (2019) and Kulczyński et al. (2019) also studied the qualitative composition and nutritional parameters of chia seeds. According to them, the seeds contain fat from 20 to 34%, among polyunsaturated fatty acids α-linolenic (60%) and linoleic (20%) acids, a high level of protein – from 16 to 26%, as well as dietary fibre – from 23% up to 41%. As the authors note, due to the lack of gluten, these seeds are suitable for patients with celiac disease. Also, experimental studies have confirmed their hypotensive, hypoglycaemic, antimicrobial and immunostimulant effects, and due to the ability of chia seeds to absorb water and form gels, they can be used in the food industry as a replacement for emulsifiers and stabilizers. The use of plant components (chia, flax, nettle, cranberry) in the production of dairy products makes it possible to enrich the product with minerals, vitamins, amino acids of natural origin, not to use synthetic thickeners, dyes, flavours and taste improvers, as well as to avoid the use of sugar or sweeteners (Gutyj et al. 2017). In general, the analysis of materials and studies of specialists in this field confirm the feasibility and rationality of the development of dairy products using plant-derived components from the proposed raw materials and its combination, as well as their advantage over conventional dairy products.

The research gap in this study concerns the requirement for additional exploration and enhancement in multiple crucial parts of combined dairy product development. Although the study extensively evaluated quality, safety, and nutritional attributes, there is still scope for more in-depth examination of optimal formulation ratios, long-term product stability, consumer acceptance, health effects, environmental sustainability considerations, cost-effectiveness, processing methods, and market feasibility. Investigating these gaps would not only improve our comprehension of the possibilities of mixing cow's and mare's milk with vegetable-origin fillers in dairy products, but also enable the creation of inventive, trade-ready options that coincide with changing consumer demands and industry sustainability targets.

Conclusions

The research involved a thorough assessment of cow's and mare's milk raw materials, including organoleptic, physicochemical, and microbiological analyses. Notable differences in organoleptic indicators were observed, particularly in colour, with cow's milk appearing light white and mare's milk having a white-blue tint. Other organoleptic indicators were largely similar. Mare's milk exhibited lower protein and fat content, while cow's milk had lower SOMO and lactose levels. Importantly, harmful and pathogenic microorganisms were not detected in either type of milk.

The evaluation of finished dairy products, incorporating different ratios of milk raw materials and vegetable supplements, yielded valuable insights. Sample No. 1 did not meet the intended expectations, suggesting that the ratio of 45% mare's milk, 45% cow's milk, and 10% herbal supplements is not suitable for dairy product production. Sample No. 2 emerged as the most promising, with superior organoleptic qualities. Sample No. 3 also showed favourable results, albeit with minor variations in colour, taste, and odour. Based on physicochemical analyses, it is evident that Sample No. 2 is suitable for consumers seeking a dairy product with lower fat and lactose content, whereas Sample No. 3 is rich in protein and fat. Sample No. 1 fell short of meeting the study's predefined criteria, indicating issues with its formulation and production.

Microbiological and safety assessments of Samples No. 2 and 3 demonstrated compliance with established standards. However, Sample No. 1 exceeded the allowable limits for mesophilic aerobic and facultative anaerobic microorganisms, highlighting deficiencies in its formulation and production process. Furthermore, the calculation of energy and nutritional values revealed that the new dairy products developed from cow's and mare's milk, specifically Sample No. 2 (low fat, low lactose, low calorie) and Sample No. 3 (high calorie, high fat, high protein), offer distinct options for consumers. The inclusion of plant-based components such as chia seeds, flax, nettle shoots, and freeze-dried cranberries has significantly improved the chemical and biological

composition of these products, enhancing their taste properties and overall organoleptic characteristics.

This article significantly contributes to the field of dairy product development by introducing an innovative approach that combines cow's and mare's milk with plant-based fillers, expanding the range of dairy options available to consumers. Through rigorous quality and safety assessments, it ensures that the newly developed dairy products meet stringent industry standards. Furthermore, the proposal of future research directions, such as exploring antioxidant properties and assessing the impact on stomach microflora, underscores the forward-thinking nature of the study and its potential contributions to the broader field of dairy product development.

Abbreviations

UHT	Ultra-high temperature
SOMO	Dry skim dairy residue
CFU	Colony forming units
ALA	Alpha-linolenic acid

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Not applicable.

Authors' contributions
MI and AO conceived the ideas of the study; FD and ZS conceived the ideas for the analysis; FD and GZ performed the analyses; and ZS wrote the manuscript; FD, MI and AO were major contributors in writing the manuscript and all other authors commented on the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
All procedures performed using animals were revised and approved by the Scientific Committee of Ethics of the Department of Technology of Food Products at the Almaty Technological University, Almaty, Republic of Kazakhstan.

Consent for publication
Not applicable.

Competing interests
There is no conflict of interest.

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