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INVESTIGATING THE EFFECT OF CORN SILK EXTRACT ON THE PROPERTIES OF THE TRADITIONAL FERMENTED DAIRY PRODUCT AYRAN

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This study's object is the potential of fresh and dried corn silk (CS) as functional ingredients for fortifying the national fermented milk product – ayran.

There is an obvious need for comprehensive research into fermented products based on plant-milk synergy. The current study is aimed at solving the task of increasing the nutritional value of ayran by fortifying it with extracts from local raw materials.

A series of comprehensive studies were conducted to reveal the potential of fermented ayran products with CS extracts using the synergistic effect of plant and dairy matrices. A technology for ayran fortified with biologically active compounds of CS extract has been devised. It has been established that under the influence of CS extract, the content of polyphenols and flavonoids increases by 22.2%, which accompanies the antioxidant activity of corn silk in products. In the experimental sample, a significant increase (by 10.49%) in protein content was observed, which exceeds the control value. This activation led to the conclusion that corn silk significantly improves the amino acid profile of the product. The concentration of some amino acids increased significantly. The most pronounced increase is observed for proline (by 18.28%), methionine (by 15.67%), valine (by 13.36%), arginine (by 13%), and tyrosine (by 12.7%). An increase in the level of phenylalanine (by 10%), histidine (by 6.47%), alanine (by 6.7%), serine (by 4.9%), glycine (by 3.8%), lysine (by 2.1%), and isoleucine with leucine (by 0.98%) was also noted. Ayran with aqueous extract of corn silk demonstrated an improved mineral profile. The contents of important minerals such as sodium (4.77%), magnesium (1.21%), phosphorus (10.90%), potassium (18.08%), calcium (10.68%), chlorine (11.25%), and sulfur (0.71%) increased significantly. These changes indicate that the designed product could be considered an improved functional food and with the potential for commercialization

Keywords: corn silk, ultrasonic extraction, aqueous extract, amino acid profile, antioxidant activity

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1. Introduction

Functional fermented milk products fortified with biologically active components are becoming increasingly popular in the context of a deteriorating environmental situation and an increase in the number of chronic diseases associated with metabolic disorders. In this regard, traditional fermented milk products by the peoples of Central Asia, in particular Kazakh ayran, attract special attention as an example of a biologically complete product with proven probiotic properties. Its simple production technology and high digestibility make it a promising basis for creating new products with a functional focus [1].

Kazakh traditional yogurt is called ayran, like its Bulgarian and Turkish analogs. The process of its preparation includes cooling boiled milk to 30–35°C, adding a suitable starter (usually about 20 g/l) and fermenting for 7–10 hours at room temperature in a closed container. Ayran can also serve as a basis or component of various other dairy products and drinks. In many countries of the Balkans, Central Asia and the Caucasus, the famous drink made from sour milk with water and salt, also known as ayran, is popular [2, 3]. Kazakh national fermented milk products occupy an important place in traditional Kazakh cuisine. These products are known for their beneficial functional properties as they help normalize digestion, strengthen the immune system, and are good sources of proteins, calcium, and vitamins.

Using the method of "Ultrasonic extraction" (USE) to isolate active substances from plant materials makes it possible to obtain a fortified functional traditional product. Ultrasonic waves (20–50 kHz) cause mechanical destruction of the cell walls of the sample, facilitating the penetration of the solvent and the release of active components [4, 5]. Active USE is

more effective than stationary USE as it enables rapid removal of extracted substances and constant contact of the sample with fresh solvent, thereby accelerating the process [6, 7].

The global trend towards functional nutrition based on the synergy of probiotics and plant components predetermines the need for in-depth research. The goal is to expand the choice and increase the nutritional value of traditional fermented milk products by adding bioactive substances. One of the potential sources of such substances are by-products of plant processing – for example, corn silk, which has antioxidant, hepatoprotective, and mineralizing activity.

Corn silk (CS), traditionally considered waste, is a rich source of micro- and macroelements, vitamins, antioxidants, and phytochemicals. Modern extraction methods, in particular vacuum low-frequency ultrasound and microwave extraction, make it possible to effectively extract valuable substances from them, suitable for use in the food industry.

Thus, research into the development of an effective technology for extracting bioactive components from corn silk and justifying its use for fortifying ayran while preserving organoleptic properties and increasing nutritional value is relevant. This area meets modern demands of nutrition science and functional nutrition, as well as the tasks of rational use of natural resources and waste-free processing of agricultural raw materials.

2. Literature review and problem statement

Paper [8] reviews available data on corn silk (*Stigma maydis*), an agro-industrial by-product rich in antioxidant flavonoids (such as luteolin, apigenin, and formononetin), phenolic acids, and active carbohydrates. The study indicates the potential of corn silk as a natural preservative. Further interdisciplinary research is needed to ensure that this natural resource is fully integrated into modern food systems.

The authors of paper [9] investigated ethanol, microwave, ultrasound, supercritical fluid extraction, and multiple extraction technologies as effective technologies for the extraction of flavonoids from corn silk. The potential benefits of ingested flavonoids against some of the major risk factors selected have been shown. Antioxidant, antibacterial, antidiabetic, and antifatigue properties of flavonoids have been documented. *In vitro* and *in vivo* studies focus on elucidating the mechanisms of action of these compounds. This approach allows for more convincing proof of their effectiveness and the health benefits of flavonoid-rich foods. Studying the relationship between the structure and activity of corn flavonoids requires an interdisciplinary approach. This would create a scientific basis for the development and use of these valuable natural compounds.

Different parts of corn silk also differ in antioxidant activity, and high pigmentation is usually observed at an early stage of ripening; this is directly related to high antioxidant activity [10]. However, it is necessary to use the advantages of flavonoids to create a solid scientific basis for further development of natural and effective new food products, as well as for the full development and use of corn flavonoid resources.

Work [11] reports the results of studying the features of the chemical composition, as well as the pharmacological action of the columns and silk of corn Zeae maydis styli cum stigmatis. A lot of information on the chemical composition and pharmacological action of corn silk has been analyzed. However, there are unresolved issues related to the search for new aspects of their food use.

Work [12] reports the results of a study on the possibilities of efficient use of secondary resources of corn processing and maximum extraction of components with useful and specific physicochemical characteristics. It is shown that the use of secondary resources makes it possible to build a scientific basis for designing the composition of multicomponent food products and the use of non-traditional types of raw materials. However, there are still unresolved issues related to the development of innovative fermented milk products with functional and technological properties and high nutritional value.

The authors of [13] studied the antioxidant and free-radical activity of the extract and fractions of corn silk. It was shown that corn silk extracts could potentially be used as an easily accessible and valuable bioactive source of natural antioxidants. The study revealed only the total content of phenols and flavonoids. However, there are still unresolved issues related to the lack of identification of macro- and microelements and vitamin composition, as well as their use in the production of fermented milk products. Thus, the use of corn silk makes it possible not to pollute the environment, save resources, and fortifies products with biologically active substances from secondary raw materials, high nutritional and biological value.

Despite the accumulated knowledge about the composition and pharmacological properties of corn silk, the issue of their use as a functional additive in fermented milk products remains insufficiently studied. The scientific task is to devise an effective technology for extracting bioactive components from corn silk and justifying their use for fortifying ayran – while preserving its organoleptic properties and increasing its nutritional value.

In [14], the possibility of creating a symbiotic fermented milk product using hawthorn extract treated with microwaves was investigated. It was shown that such treatment promotes the activation of B. bifidum growth and also increases the antioxidant activity of the product. However, issues related to the lack of in vivo assessment of the effect on the human body and potential changes in organoleptic characteristics during long-term storage remain unresolved.

The authors of [15, 16] investigated the possibility of encapsulating sour cherry extract in chitosan liposomes to enrich mixed yogurt. It has been established that the liposomal form promotes stable release of polyphenols during storage, increasing the antioxidant activity of the product. It has also been shown to improve the microbiological stability and textural characteristics of yoghurt. However, the studies have also revealed certain limitations. Despite the protection of biologically active substances by liposomes, the technology requires the use of chitosan, which has a specific taste and possible allergenicity for sensitive groups of consumers. In addition, encapsulation increases the cost of production and requires fine-tuning of parameters to maintain the stability of the system, which may limit its industrial application without additional optimization. Thus, the use of liposomal delivery of plant extracts opens up new prospects in functional nutrition but requires an integrated approach to assessing the organoleptic and technological consequences.

Given the above, there is an obvious need for alternative methods of introducing plant extracts, as existing methods may negatively affect their bioavailability and organoleptic properties. Ultrasonic extraction may be one of the solutions to this problem.

Thus, there is an obvious need for comprehensive research aimed at implementing the potential of traditional fermented foods as a platform for the design of innovative functional food products based on plant-milk synergy.

3. The aim and objectives of the study

The aim of our study is to design an innovative functional food product by fortifying a traditional Kazakh fermented milk product with antioxidants extracted from corn silk using ultrasonic extraction. This could help create a healthier product by combining plant and dairy ingredients.

To achieve this aim, the following objectives were accomplished:

– to conduct a physicochemical analysis of corn silk (CS);

– to devise a technology for fortifying the national product, ayran, with CS extracts and study its organoleptic parameters;

– to examine the amino acid composition of fortified ayran;

– to define the vitamin and mineral composition of the fortified product;

– to evaluate the energy value and antioxidant activity of the finished product.

4. The study materials and methods

4. 1. The object and hypothesis of the study

The object of our study is the potential of corn silk (CS) in fresh (Fig. 1, a) and dried form (Fig. 1, b) as functional ingredients for fortifying the national fermented milk product – ayran.

a *b*

Fig. 1. Corn silk: a – fresh corn silk; b – dried corn silk

Our study focused on the development of a traditional fermented milk product, ayran, fortified with bioactive compounds extracted from corn silk (Zea mays L.) using ultrasonic extraction technology. Fresh corn silk of the DriverHybrids variety were collected from the Ali farm located in the Saryagash region of the Turkestan oblast, Republic of Kazakhstan. In addition, dried, packaged, and ready-to-use corn silk (ST TOO 39654522-07-2010) produced by Zerde-Fito TOO (Shymkent, Republic of Kazakhstan) were used in the study. The silk samples were yellow or brown in color (Fig. 1).

Fresh silks were collected 7 days after their emergence (at the panicle ejection phase), washed with tap water, rinsed with distilled water, and dried in an oven at 45–50°C until constant weight was achieved. Drying was carried out in a thermostatic drying oven/hot air sterilizer (Stericell 55 Standard, BMT Medical Technology, Czech Republic). Dried silks were ground in a tabletop blender (Philips HR2170/40, The Netherlands) to a fine powder (particle size <0.149 mm) and sieved through a sieve with a mesh size of 80 μm (Analysette 3, Fritsch, Germany). Commercial samples of corn silk were also ground and sieved before extraction.

The principal hypothesis of the study assumes that the addition of ultrasonic-assisted corn silk extract to the traditional fermented milk product ayran could improve its nutritional and functional value. This includes improved antioxidant activity, amino acids, minerals, and vitamins, as well as a possible increase in shelf life without negatively affecting organoleptic properties such as taste, texture, and appearance.

Assumptions adopted in our work: it is assumed that ultrasonic extraction makes it possible to preserve the high concentration of biologically active substances in corn silk, including polyphenols, flavonoids, and vital nutrients, making them suitable for use in functional foods. It is also assumed that the inclusion of the extract in the composition of ayran would not worsen its traditional organoleptic characteristics, but, on the contrary, could increase its nutritional value and health-promoting potential.

Simplifications accepted: to optimize the research process, the work was focused exclusively on ayran as a national fermented milk product, and the raw materials were limited to two local sources of corn silk. Our study covered only the key characteristics of the product, including physicochemical parameters, amino acid and mineral composition, vitamin profile, as well as energy value. Extended aspects, such as comparative analysis with other plant extracts or detailed tests of storage stability, as well as microbiological safety of the product were not included in the scope of this study.

4. 2. Preparation of corn silk (CS) extract and fermented milk product samples

Aqueous CS extract was obtained by grinding corn silk and using distilled water via ultrasonic extraction (frequency 40 kHz, temperature 50°C, intensity 70 W/cm^2, 45 min), cooled (45 minutes, 18–25°C), and sifted through a sieve with a mesh size of 80 μm (Analysette 3, Fritsch, Germany). After that, the corn silk was filtered before settling (24 hours, at 8–10°C) [17].

Ayran was obtained according to GOST 31702-2013 using KF40 starter culture (Micromilk) containing *Streptococcus thermophilus* and *Lactobacillus delbrueckii ssp. bulgaricus*. An aqueous extract of corn silk obtained by ultrasonic extraction (frequency 40 kHz, 50°C, 70 W/cm^2, 60 min) was used as a fortifier. The extract was added to the product in a ratio of 1:20 (raw material:extractant) before fermentation.

The fermentation process was carried out at 37–40°C until an acidity of 75 °T was reached; then the product was kept at 6–10°C for 12 hours for maturation [18].

4. 3. Amino acid composition

The amino acid composition of the protein was determined according to the M-04-38-2009 methodology (GOST R 55569-2013), using the KAPEL-105M capillary electrophoresis system, which has a special cassette for amino acid analysis [19].

4. 4. Determining the vitamin and mineral composition

The microelement composition was determined experimentally using a JSM-6490LV scanning electron microscope with INCA Energy dispersion microanalysis and HKL-Basic structural analysis systems.

Quantitative determination of the mass fraction of water-soluble B vitamins was performed by capillary electrophoresis on "Kapel 105M". The content of vitamins B1, B2, B3, B5 (nicotinic acid), B6, and Bc (folic acid) was determined using capillary-zonal electrophoresis (λ = 200÷267 nm; pH = 8.9; Leff/Lcomm = 65/75 cm; capillary diameter = 50 μm; voltage: +25 kV, temperature: +30°C) using programmable wavelength switching.

4. 5. Determining the phenolic compounds and antioxidants

We determined the mass concentration of volatile phenols (in total) using extraction with butyl acetate, re-extraction with alkali and butyl acetate according to RD 4.52.24.480-2006. Optical density was determined on a photometer with a continuous spectrum scan in the wavelength range $\lambda = 470 \div 490$ nm.

GOST ISO 14502-2010 focuses on determining the total content of polyphenols using extraction at a temperature of 70°C using the Folin-Ciocalteu reagent.

The process is spectrophotometric ($\lambda = 408 \div 420$ nm), the content of flavonoids and tannins was determined according to GOST P 553 12-2012 and GOST 24027-2-80, respectively, with aluminum chloride. Rutin is used as a standard.

Determining antioxidants according to GOST R 54037-2010 involves measuring the electric current that occurs during oxidation of the substance (or mixture of substances) under study on the surface of the working electrode at a certain potential [20, 21].

4. 6. Analysis of experimental data

Statistical data processing was performed using the software "Excel 7.0" (MS Office, USA), "Statistica 6.0" (StatSoft, USA). Values are expressed as mean values ± standard deviations based on the results of three independent experiments ($n = 3$) at a 90% confidence level ($P = 0.90$).

5. Results of the evaluation of quality indicators of the fortified national product technology – ayran

5. 1. Results of the physicochemical analysis of corn silk (CS) as an ingredient for fortification

Studies on the nutritional value of corn silk include the following data: caloric content, proteins, fats, carbohydrates, dietary fiber and water, various nutrients (Fig. 2).

The mass fraction of protein in fresh corn silk is 3.98%, in dried – 3.77%, by the mass fraction of carbohydrates, respectively, 6.28 and 36.64%, fats – 2.52 and 9.56%, dietary fiber – 9.03 and 12.38, carotene – 4.77 and 5.44%; vitamin A – not found, vitamin E – 10.73 and 8.98%, respectively. Humidity during drying of corn silk decreases and is 4.40%.

Our data indicate a high nutritional and biological value of corn silk, both fresh and dried. The significant content of protein, dietary fiber, and fat, as well as the presence of biologically active substances such as carotene and vitamin E, allow us to consider this plant material as a promising ingredient for the functional fortification of fermented milk products. It is especially important to note the high concentration of dietary fiber (9.03% in fresh and 12.38% in dried stigmas), which help normalize digestion, as well as antioxidant compounds (carotene, vitamin E), which play a role in protecting the body's cells from oxidative stress.

When the humidity decreases to 4.40% during the drying process, the concentration of nutrients occurs, which makes dried stigmas especially convenient for use in the form of an extract or powder. The high content of carbohydrates in the dried form (36.64%) can additionally contribute to the activation of lactic acid fermentation, creating a favorable environment for the development of probiotic microorganisms.

As a result of our experiment on quantitative analysis of 100 g of corn silk sample, the presence of phenolic and flavonoid compounds was revealed. The content of total phenols, expressed in terms of gallic acid, was 1050 mg, and the content of total flavonoids, expressed in terms of rutin, was 1330 mg. The results of the study demonstrate that extraction is a promising method for extracting phenolic compounds and flavonoids from corn silk. This opens up new opportunities for studying the chemical composition of this plant material and its use in the development of innovative technologies for the production of ayran.

As a result of our studies using water extraction, it was found that the content of phenols, polyphenols, and flavonoids in the aqueous extract of fresh corn silk is higher than that in the aqueous extract of dried corn silk. The amount of extractant in relation to the raw material is 1:20. The results of our study are given in Table 1.

Water extraction of corn silk (CS) is optimal compared to fresh and dried corn silk, and this is due to the fact that water extraction makes it possible to use substances that cannot be isolated from the silk in pure form. The quantitative content of flavonoids in CS varies depending on the extractant and is about 0.36–0.5%.

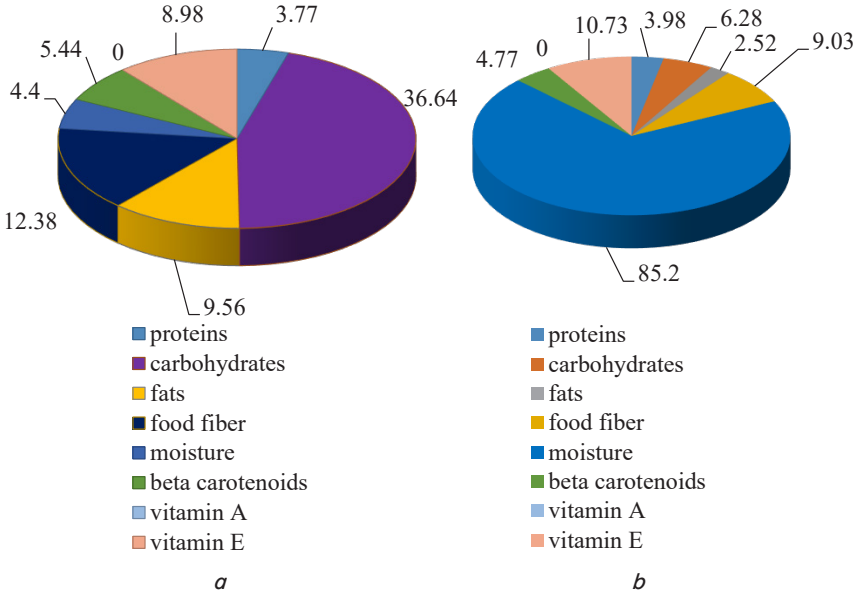


Fig. 2. Chemical composition of corn silk: *a* – dried corn silk; *b* – fresh corn silk

Table 1

Physicochemical properties of corn silk extract

No.	Name of indicators, units of measurement	Actual results	
		Aqueous extract from fresh corn silk	Aqueous extract from dried corn silk
11	Phenolic content, mg/g	3.68 ± 0.02	0.97 ± 0.004
22	Polyphenol content, mg/g	6.08 ± 0.03	1.22 ± 0.006
33	Flavonoid content, mg/g	1.82 ± 0.01	0.36 ± 0.001
44	Tannins, %	5.20 ± 0.03	1.04 ± 0.004

Thus, corn silk has the potential to be used as a natural plant supplement aimed at increasing the nutritional and functional value of ayran, improving its organoleptic properties, and expanding the range of preventive products.

5. 2. Results from devising a technology for fortifying ayran with corn silk extracts and evaluation of its organoleptic properties

For fortification of the national fermented milk product ayran, an aqueous extract of corn silk (CS) obtained using ultrasound treatment was used. Ayran prepared in accordance with GOST 31702-2013 [17] by means of lactic acid and alcoholic fermentation was used as a base. Starter cultures: thermophilic lactic acid streptococci (*Streptococcus thermophilus*), Bulgarian bacillus (*Lactobacillus delbrueckii ssp. bulgaricus*), and yeast.

The starter (rotary series KF40, manufactured by Micromilk) was added in an amount of 2%. Fortification was carried out by adding corn silk extract in a ratio of raw materials:extractant = 1:20. The extract was obtained by the water method using an ultrasonic bath: frequency 40 kHz, temperature 50°C, intensity 70 W/cm^2, treatment duration 60 minutes (in three cycles of 20 minutes). After completion of the extraction, the solution was filtered and left to settle at a temperature of 8–10°C for 24 hours.

Ayran fermentation was carried out for 10 hours until titratable acidity reached 75°T, after which the product was sent for maturation at a temperature of 6–10°C for 12 hours.

The devised technology has made it possible to obtain a product with pronounced organoleptic characteristics typical of traditional ayran, fortified with biologically active compounds of CS extract (Fig. 3).

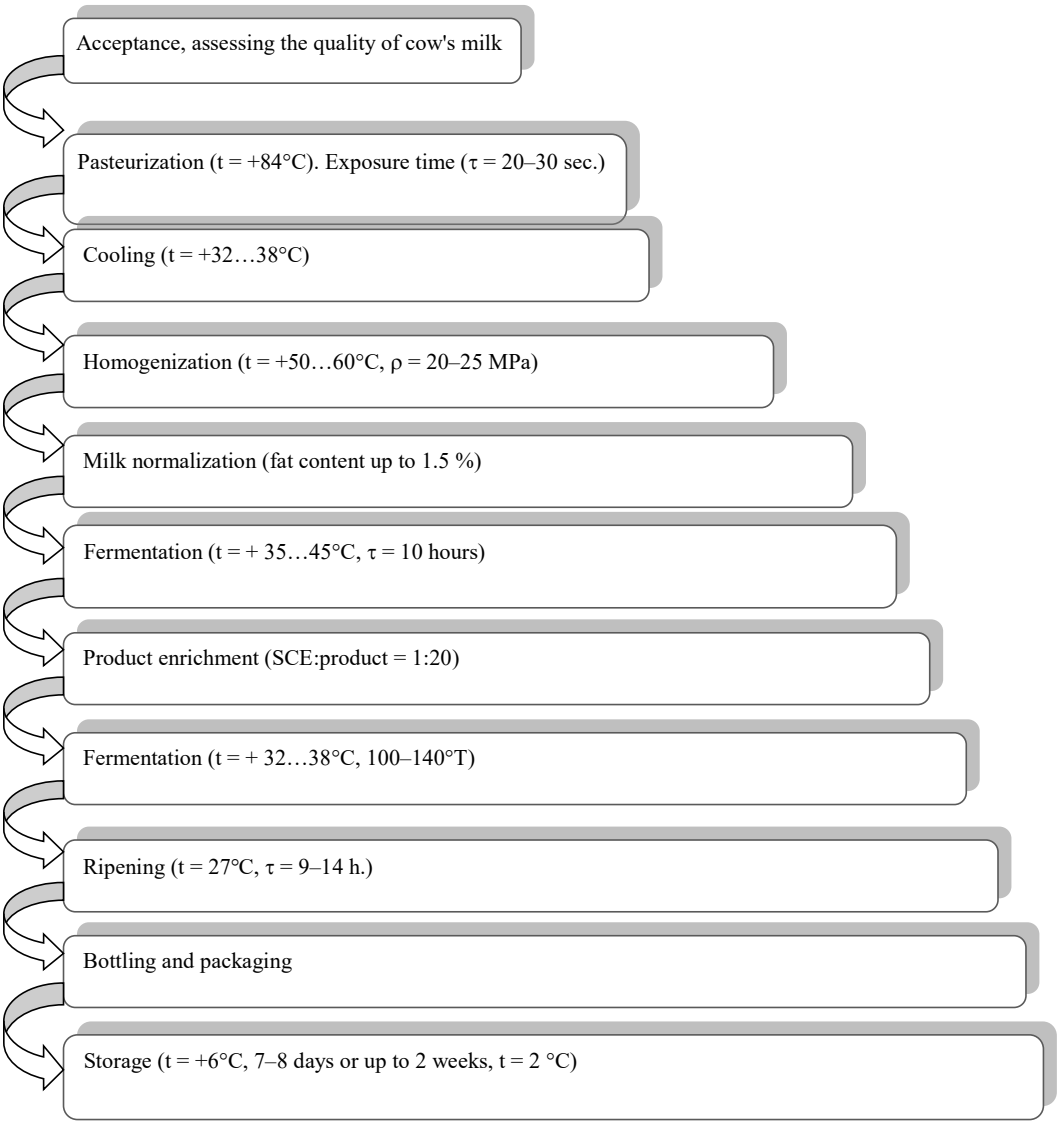


Fig. 3. Technology of ayran fortification with corn silk extracts

The introduction of aqueous extracts of fresh and dried corn silk into the composition of the fermented milk drink has a significant effect on its organoleptic characteristics. The extract content varied in the range from 5 to 15% of the total volume of the product (Fig. 4).

Continuing the study, a comparative assessment of the organoleptic properties of ayran samples with the addition of two variants (fresh and dried) of corn silk extracts was carried out. The extracts were obtained by the water method using ultrasound treatment.

Sensory analysis revealed that samples with the extract from fresh CS received higher scores compared to samples containing the extract from dried CS. In particular, ayran with 10% extract from fresh CS had a more balanced taste, soft consistency, and a pleasant aroma with herbal notes. At the same time, ayran with a similar content of dried CS had a less pronounced aroma and insignificant sedimentation during storage, which may be due to the less stable composition of the extract.

The color of the product with the extract from dried CS was also less uniform, with a slight sediment and slight granularity at a concentration of 12–15%, which reduced its organoleptic assessments. At the same time, samples with 5–8% extract from dried CR had satisfactory taste properties but were inferior in harmony and overall balance to the product with an extract from fresh CR.

Thus, the extract from fresh CR obtained by the ultrasonic extraction method demonstrated better technological and sensory characteristics compared to the extract from dried CR. This allows us to recommend it for further use in the fortification technology of ayran.

5. 3. Results of investigating the amino acid composition of the fortified ayran product

To determine the biological value of the studied product sample, the content of essential and replaceable amino acids was determined, which are given in Table 2 and Fig. 5.

Ayran prepared using aqueous extract of fresh corn silk contains more certain amino acids than ayran with dried silk extract. One of the advantages of the first product is a higher content of isoleucine + leucine (by 0.98%), phenylalanine (by 10%), histidine (by 6.47%), valine (by 13.36%), arginine (by 13%), tyrosine (by 12.7%), methionine (by 15.67%), proline (by 18.28%).

In particular, there is an increase in the concentration of lysine (by 2.1%), serine (by 4.9%), alanine (by 6.7%), and glycine (by 3.8%). However, the content of threonine in products with aqueous extract remains almost unchanged.

Our analysis of the results in Table 2 and Fig. 5 revealed that the developed national ayran product with the addition of corn silk extract contains all the essential amino acids necessary for the human body.

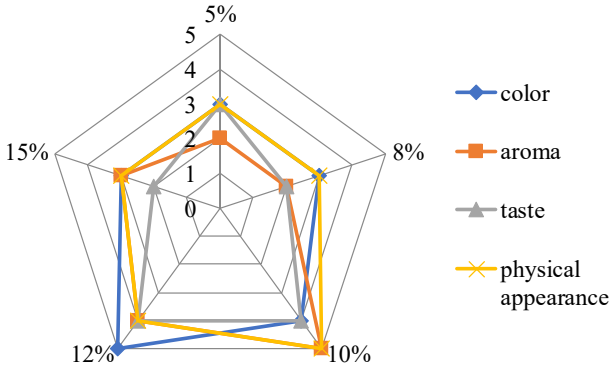


Fig. 4. Evaluation of fermented milk product ayran in points with changes in the content of extract from fresh corn silk in the range from 5 to 15%

Table 2

Amino acid composition of fermented milk product ayran, %

No.	Component	fermented milk product ayran (control)	fermented milk product ayran with water extract from fresh corn silk	fermented milk product ayran with water extract from dried corn silk
1	Arginine	0.776 ± 0.310	0.910 ± 0.364	0.805 ± 0.322
2	Lysine	0.261 ± 0.089	0.289 ± 0.096	0.283 ± 0.098
3	Tyrosine	0.199 ± 0.060	0.239 ± 0.072	0.212 ± 0.064
4	Phenylalanine	0.164 ± 0.049	0.198 ± 0.059	0.180 ± 0.054
5	Histidine	0.135 ± 0.068	0.148 ± 0.074	0.139 ± 0.070
6	Leucine+isoleucine	0.303 ± 0.079	0.307 ± 0.080	0.304 ± 0.079
7	Methionine	0.122 ± 0.041	0.155 ± 0.053	0.134 ± 0.045
8	Valin	0.176 ± 0.070	0.246 ± 0.098	0.217 ± 0.087
9	Proline	0.435 ± 0.113	0.576 ± 0.150	0.487 ± 0.127
10	Threonine	0.152 ± 0.061	0.180 ± 0.072	0.179 ± 0.072
11	Serin	0.202 ± 0.053	0.235 ± 0.061	0.224 ± 0.058
12	Alanine	0.100 ± 0.026	0.143 ± 0.037	0.134 ± 0.035
13	Glycine	0.073 ± 0.025	0.081 ± 0.028	0.078 ± 0.027

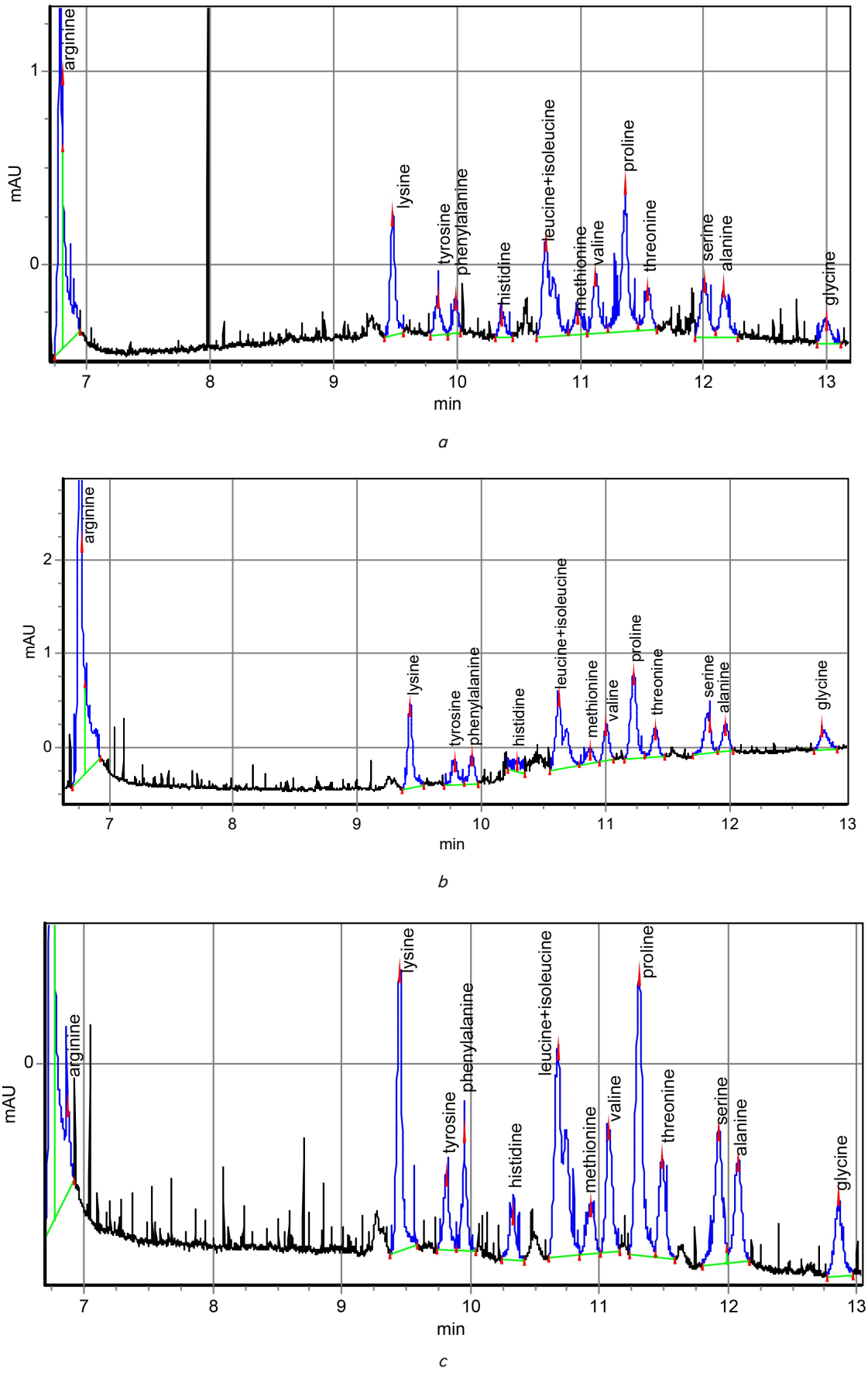


Fig. 5. Chromatogram of the amino acid composition of the fermented milk product ayran, %:
a — fermented milk product ayran (control); *b* — fermented milk product ayran with an aqueous extract from fresh corn silk;
c — fermented milk product ayran with an aqueous extract from dried corn silk

5. 4. Results of investigating the vitamin and mineral composition of the ayran product

Considering the advantages of corn silk (mineral content, weight %: Mg–2.39; P–5.51; Cl–3.05; K–28.94; Ca–1.96: Si–2.42; S–1.46). the vitamin and mineral composition of the fermented milk product ayran with an aqueous extract of fresh and dried corn silk is noticeably improved (Table 3 and Fig. 6).

The mineral composition of the ayran product with aqueous extracts of corn silk (fresh and dried) has improved; the sodium content has increased to 4.77% in the product from fresh corn silk and 4.48% in the product from dried corn silk, magnesium – 1.21%, phosphorus – 10.90%, potassium – 18.08%, calcium – 10.68%, chlorine 11.25%, and sulfur by 0.71%. (Fig. 6)

Table 3

Vitamin and mineral composition of the product

Name of indicators, units of measurement	Actual results		
	Physical and chemical indicators:		
	Fermented milk product ayran (control)	Fermented milk product ayran with aqueous extract from fresh corn silk	Fermented milk product ayran with an aqueous extract from dried corn silk
Water-soluble vitamins, mg/100 g			
B1 (thiamine chloride)	0.011 ± 0.002	0.019 ± 0.004	Not found
B2 (riboflavin)	0.049 ± 0.020	0.064 ± 0.027	0.058 ± 0.024
B6 (pyridoxine)	0.010 ± 0.002	0.023 ± 0.005	0.023 ± 0.005
C (ascorbic acid)	0.027 ± 0.009	0.027 ± 0.009	Not found
B3 (pantothenic acid)	0.071 ± 0.013	0.863 ± 0.155	Not found
B5 (nicotinic acid)	0.005 ± 0.001 ()	0.320 ± 0.064	0.264 ± 0.053
Bc (folic acid)	0.014 ± 0.003	0.014 ± 0.003	0.004 ± 0.001
Macro and microelements, weight %			
Na	3.51	4.77	4.48
Mg	0.97	1.21	1.10
P	7.47	10.90	8.90
K	11.56	18.08	14.84
Ca	7.25	10.68	8.88
Cl	6.17	11.25	8.32
S	–	0.71	0.53

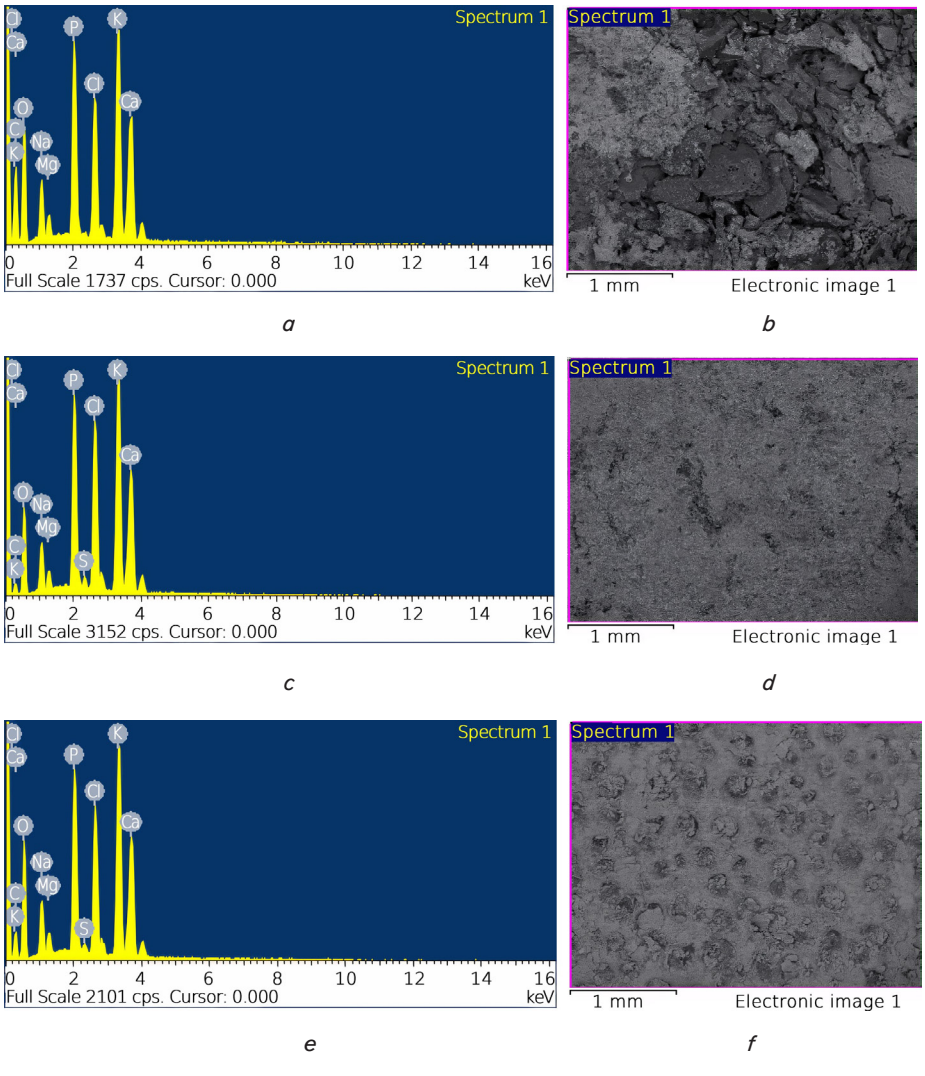
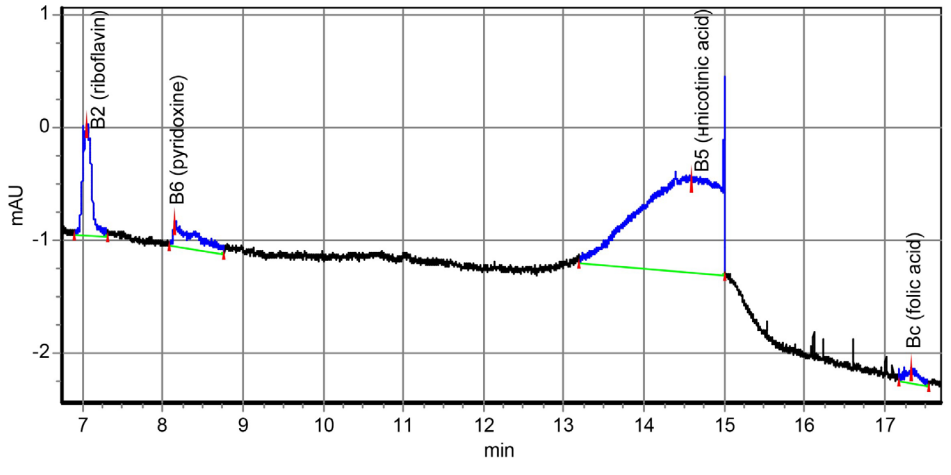
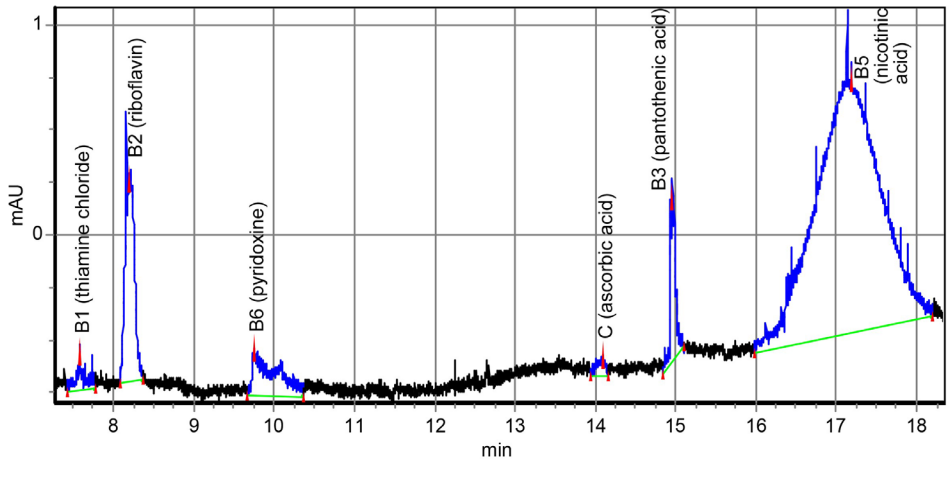


Fig. 6. Mineral composition of the ayran product with an aqueous extract from fresh and dried corn silk: *a*, *b* — fermented milk product ayran (control); *c*, *d* — fermented milk product ayran with an aqueous extract from fresh corn silk; *e*, *f* — fermented milk product ayran with an aqueous extract from dried corn silk

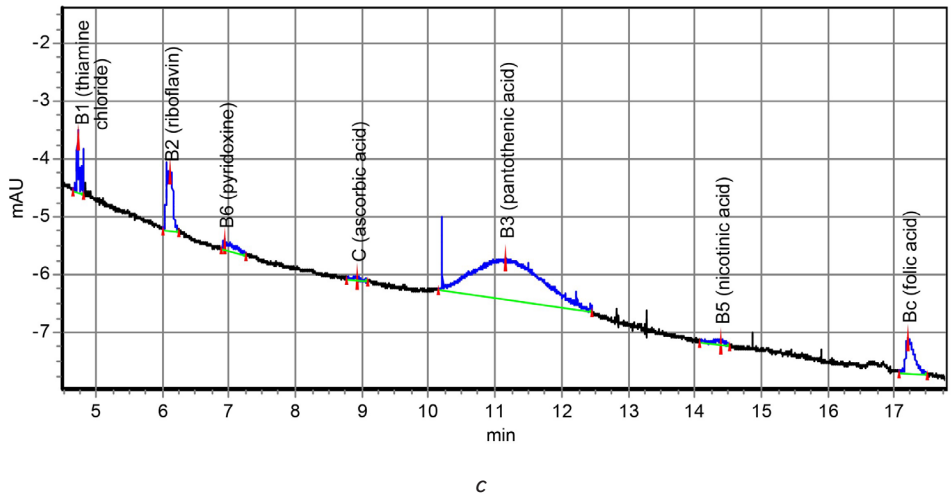
CS contains a significant amount of vitamin-based compounds: B vitamins (especially B2, B5, and B6), ascorbic acid (Fig. 7).



a



b



c

Fig. 7. Vitamin composition of the ayran product:
a — fermented milk product ayran (control);
b — fermented milk product ayran with aqueous extract from fresh corn silk;
c — fermented milk product ayran with aqueous extract from dried corn silk

The results of our studies, summarized in Fig. 7 and Table 3, indicate a significant content of B vitamins (especially B1, B2, B3, B5, and B6) and C in ayran products with aqueous extract of fresh corn silk. Ayran products with aqueous extract of dried corn silk only contain vitamins B2, B5, and B6.

5. 5. Results of assessing the energy value and antioxidant activity of the fortified product of the ayran type

Among the biologically active substances contained in corn silk (CS) extracts, polyphenolic compounds with pronounced antioxidant properties are of particular interest. Within the framework of our study, the content of phenolic compounds and antioxidant activity in ayran samples fortified with aqueous extracts of CS were assessed in comparison with the control sample (Table 4).

Antioxidant activity of food products is an important functional indicator, given its role in protecting the body from oxidative stress caused by adverse external factors (UV radiation, environmental pollution, pathogens) and internal conditions (stress, poor nutrition, smoking). Under the influence of antioxidants, chain reactions of lipid peroxidation are interrupted, which helps protect cellular structures and prevents the development of a number of pathological processes [22].

A comparative analysis revealed that a sample of ayran fortified with an aqueous extract from fresh CS has the highest antioxidant activity both in terms of the level of water- and fat-soluble antioxidants and in terms of the content of polyphenols and flavonoids. These indicators significantly exceed both the values in the control sample and in the sample with an extract from dried CS. Our results indicate a higher biological value of the product with an extract from fresh CS, which may be associated with the features of the method of its production (ultrasonic

treatment). At this stage of the study, the energy value of the fermented milk product of the ayran type, fortified with plant extracts, was assessed. Table 5 gives chemical composition of the fermented milk product ayran.

The results of the chemical composition analysis reveal that the addition of aqueous extract of corn silk (CS) has a significant effect on the nutritional value of ayran. In particular, the highest protein content was recorded in the sample with the extract of fresh CS – 3.58 ± 0.02%, which exceeds the same indicator in the control sample (3.24 ± 0.01%) and in the sample with the extract of dried CS (3.35 ± 0.01%).

Table 4

Antioxidant and phenol content in the ayran product

Name of indicators, units of measurement	Actual results		
	fermented milk product ayran (control)	fermented milk product ayran with aqueous extract from fresh corn silk	fermented milk product ayran with an aqueous extract from dried corn silk
Water-soluble antioxidants, mg/g	0.29 ± 0.064	0.34 ± 0.0058	0.32 ± 0.0014
Fat-soluble antioxidants, mg/g	0.02 ± 0.0002	0.10 ± 0.002	0.04 ± 0.0004
Phenol content, mg/g	0.055 ± 0.0002	0.068 ± 0.0003	0.065 ± 0.0003
Polyphenol content, mg/g	0.18 ± 0.002	0.22 ± 0.001	0.21 ± 0.001
Flavonoid content, mg/g	0.054 ± 0.0003	0.066 ± 0.0003	0.063 ± 0.0003

Table 5

Chemical composition of fermented milk product ayran

No.	Name of indicators, units of measurement	Actual results		
		fermented milk product ayran (control)	fermented milk product ayran with aqueous extract from fresh corn silk	fermented milk product ayran with an aqueous extract from dried corn silk
1	Protein content, %	3.24 ± 0.01	3.58 ± 0.02	3.35 ± 0.01
2	Fat content, %	4.7 ± 0.02	3.8 ± 0.02	3.3 ± 0.02
3	Carbohydrate content, %	4.99 ± 0.33	5.63 ± 0.03	5.63 ± 0.03
4	Energy value, kcal	72.96	72.50	68.27

Despite the decrease in the fat content in the fortified samples, the total carbohydrate content increased, which contributed to the preservation of the organoleptic characteristics and textural properties. Ayran with an extract of fresh CS can be considered a balanced source of proteins, fats, and carbohydrates, with improved functional properties.

From a physiological point of view, the inclusion of corn silk extract in the product helps normalize digestion, maintain the functioning of internal organs, and improve the functions of vital body systems.

It should be noted that one of the current trends in the development of food products is the reduction of their energy value. The use of plant extracts has made it possible to achieve this effect: in the sample with an extract from dried CS, the energy value was only 68.27 kcal, which is lower compared to the control product (72.96 kcal). Thus, the use of plant raw materials in the creation of functional fermented milk products contributes to the formation of a healthier diet and meets modern requirements for preventive dietetics.

6. Discussion of results based on the study of adding corn silk (CS) extracts to the national fermented milk product ayran

The nutritional value of corn silk (Fig. 2) is truly undeniable and characterizes fresh and dried corn silk as a highly valuable food by-product with low energy value. When processing corn silk, there was a high probability of obtaining extracts with biologically active substances, and by extracting the maximum amount of useful components from them, it is possible to obtain innovative products with functional properties (Table 1). It was found that the extract of fresh and dried CS has a diverse spectrum of FAS. It is represented by phenolic compounds (flavonoids, polyphenols, tannins), water- and fat-soluble vitamins, minerals. This allows them to be used as a source of nutrients, as well as to expand the range of products; it correlates with the data obtained as a result of analysis of the composition of the ayran product (Table 4). From this it can be concluded that the allocated secondary resources can be considered as a source of extraction of biologically valuable substances with antioxidant properties.

Table 4 gives data indicating that fortification of the fermented milk product "ayran" with an aqueous extract of corn silk (obtained from fresh and dried raw materials) leads to a significant increase in the concentration of polyphenolic compounds and flavonoids. This effect correlates with the enhancement of the antioxidant properties of the product, due to the presence of the extract of corn silk.

One of the key qualities of corn silk is the presence of dietary fiber, a very important component of a balanced healthy diet that helps improve the quality and duration of life (Fig. 2). These results are consistent with studies reported in [16], indicating that certain plant extracts can enhance the growth of beneficial bacteria during fermentation.

One of the priority areas of development of food production is the creation of products with reduced energy value (Table 5). This is possible due to the addition of aqueous extracts of corn silk, which is the main vector for the use of raw materials of plant origin. From this we can conclude that the optimal amount of inclusion of fortified extracts from corn silk in the technology of the national ayran product expands the range of standard food products. The functional properties of ayran allow it to participate in therapeutic and preventive activities to improve and maintain public health.

Due to the fortification of the composition of the experimental sample (Table 4), the content of antioxidant substances (flavonoids) in the product increased. The obtained results are confirmed by studies [23, 24], according to which fortification of fermented milk products with CS and plant extracts can lead to an increase in the content of antioxidant substances, such as water- and fat-soluble, and polyphenols, flavonoids in the final product. These results are consis-

tent with studies indicating that when a certain balance is achieved between substances of antioxidant and prooxidant nature, it is possible to obtain a result in the form of a product with pronounced functional properties and the predefined shelf life.

When using plant additives together with animal raw materials, mutual enrichment is ensured and the assimilation of the final protein product is increased by 1.5–2 times, due to the content of vitamins and macro-microelement composition, which helps improve the work of metabolism (Tables 2, 3, Fig. 5, 6). This result, taking into account the beneficial properties of corn silk, makes it important to use it to supplement the range with improved functional properties, and to ensure the development of the fortified national fermented milk product ayran.

The viscosity of the ayran product with an aqueous extract of fresh and dried corn silk is 0.0146 Pa·s and 0.0184 Pa·s, respectively, and is greater than the control (0.098). An aqueous extract of corn silk improves the bond between water and changes the consistency of ayran.

According to the results reported in [25], an aqueous extract of fresh corn silk can serve as an additional source of B vitamins during the fermentation of fermented milk products. Thus, in the prototype of the developed fermented milk product ayran with CS extract, such vitamins of group B as pyridoxine, riboflavin, nicotinic acid were synthesized (Fig. 7, Table 3).

Just as in the experimental sample of the fermented milk product, a high content of vital minerals was found: sodium – 35.6%, magnesium – 95.5%, phosphorus – 48.8%, and calcium – 68.3% more than in the control sample. Unlike [26], in which, when fortifying the fermented milk product with a combined extract, trace elements magnesium and copper were found, our result summarized in the table allows for an increase in the content of antioxidant substances in the fermented milk drink. This becomes possible due to the vitamin and mineral composition of ayran with CS extracts.

The increase in protein content has a linear effect on the amino acid profile of the studied fermented milk products. As can be seen from Table 2, the increase in essential amino acids such as isoleucine + leucine by 0.98%, phenylalanine by 10%, histidine – 6.47%, lysine – 2.1%, and valine – 13.36%, arginine – 13.0%, tyrosine – 12.7%, methionine – 15.67%, proline – 18.28%, serine – 4.9%, alanine by 6.7%, glycine by 3.8% suggests that processed products can provide better support for muscle growth, tissue repair, cognitive function, and immune health. For a functional product, 15% of the daily intake level of amino acid is necessary. In the proposed product, it is 13.2%. According to our data, it can be argued that corn silk significantly improves the amino acid profile of the product. These changes indicate that the developed products can be sold as improved, functional foods. This statement leads to another in-depth study of the researched fermented milk products.

The limitations of our study include the lack of data on the preservation of fermented milk products ayran fortified with CS extracts. However, this can be fixed. Further studies will be aimed at determining the microbiological indicators, safety indicators, and shelf life of the fermented milk product ayran fortified with CS extracts.

The lack of analysis of the fatty acid composition is a disadvantage of this study. However, this was due to the fact that determining the fatty acid composition was not the purpose of our study.

Future research should focus on exploring the potential of CS extract to improve new types of fermented milk products. It is expected to make a significant contribution to the development of functional foods with improved properties.

7. Conclusions

1. The extraction method and the choice of solvent exert a significant impact on the quality and quantity of the extract obtained from corn silk. Ultrasonic extraction, in particular, stands out as the most effective technique. When using water as an extractant in a ratio of 1:20 to raw materials, ultrasound significantly accelerates the swelling of the silk and promotes the release of valuable substances from the cells, ensuring their transition to an aqueous solution.

Aqueous extraction is the most effective for extracting useful substances from corn silk (CS). It makes it possible to obtain a wider range of compounds, including those that cannot be isolated from fresh or dried silk directly. The content of flavonoids in the aqueous extract of CS varies within 0.36–0.5% and depends on the choice of extractant.

The nutritional value of corn silk, characterized by low energy content and high content of biologically active substances, makes it a promising secondary resource. The content of total phenolic substances is 16.78 mg/g. Extraction from corn silk yields a wide range of phytochemicals (PhCs), including phenolic compounds (flavonoids, polyphenols, tannins), water- and fat-soluble vitamins, as well as minerals. This composition makes it possible to use the extracts as a source of nutrients and for the development of functional foods with antioxidant activity.

2. Ayran was prepared using 2% KF40 starter culture (Micromilk) and was fortified with aqueous extract of corn silk (raw material to extractant ratio 1:20) obtained using ultrasonic treatment (40 kHz, 50°C, 70 W/cm^2, 60 minutes). After filtering and settling the extract, it was added to ayran, which was fermented for 10 hours to an acidity of 75°T and then matured for 12 hours at 6–10°C. The extract from fresh corn silk obtained using ultrasonic extraction showed better technological properties and organoleptic characteristics compared to extract from dried corn silk prepared in the conventional way. This makes it the preferred choice for use in the production of fortified ayran.

3. A linear increase in the protein content in fermented milk products directly affects their amino acid profile, making them more valuable. Increasing the protein level by 0.34% leads to a significant (0.61%) increase in the content of a number of essential amino acids (isoleucine+leucine, phenylalanine, histidine, lysine, valine) and other important amino acids (arginine, tyrosine, methionine, proline, serine, alanine, glycine). Such an improved amino acid composition suggests that these products may provide more pronounced support for muscle growth, tissue repair, cognitive functions, and the immune system. Although the amino acid content (13.2%) is slightly below the criteria for a functional product (15% of the daily value), the use of corn silk significantly improves the amino acid profile. This allows us to position the developed product as improved and potentially functional, which requires further study of its properties.

4. Due to the high content of B vitamins, corn silk extract is promising for the production of the fermented milk drink "Ayran". This opens up opportunities for the development of the production of healthy and nutritious fermented milk

products fortified with vitamins and minerals. Our studies have shown that "Ayran" with the addition of aqueous extract of corn silk contains a significant amount of vitamins (mg/100 g): B2 by 0.015, B5 by 0.315, B6 by 0.13. The mineral composition of ayran was modified by adding aqueous extract of corn silk B1. That led to an increase in the concentration of the following mineral elements (in %): Na – 4.77, Mg – 1.21, P – 10.90, K – 18.08, Ca – 10.68, Cl – 11.25, S – 0.71.

5. The inclusion of plant concentrates and plant extracts in fermented milk products could significantly increase their antioxidant activity. This is achieved by increasing the content of various antioxidants, such as water- and fat-soluble compounds, polyphenols, and flavonoids. According to research, this approach makes it possible to create a product with an optimal balance of antioxidant and prooxidant substances, which provides it with pronounced functional properties and increases the shelf life. The addition of an aqueous extract of corn silk (CS) significantly improves the nutritional value of ayran. In particular, the highest protein content was recorded in the sample with an extract from fresh CS – 3.58 ± 0.02%, which exceeds a similar indicator in the control sample (3.24 ± 0.01%) and in the sample with an extract from dried CS (3.35 ± 0.01%).

Despite the reduction in fat content by 0.9%, the total amount of carbohydrates increased by 0.64%, which had a positive effect on the taste and texture of the product. Ayran with CS B1 can be considered a balanced and functional product. In addition, the CS extract helps normalize digestion and improve the functioning of the body. The use of the CS B2 extract has made it possible to reduce the caloric content of ayran, which corresponds to modern trends in healthy eating.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

All data are available, either in numerical or graphical form, in the main text of the manuscript.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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