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Fermented buttermilk drinks fortified by plant raw materials

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Abstract:
The research featured fortified fermented drinks from pasteurized buttermilk with such natural additives as Jerusalem artichoke syrup and beetroot dietary fiber.

The optimal symbiotic culture included *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*: it provided rapid fermentation and a creamy, homogeneous structure with delta pH time = 3.5 h. Jerusalem artichoke syrup was added in amounts of 3, 6, and 9%. Its optimal share proved to be 6% by the weight of the finished product. Beet dietary fiber was added in amounts of 2, 4, and 6%, where the optimal amount was 4%. A higher percentage affected the consistency of the finished product but not its clotting or taste. The experimental drinks were produced by the tank method and fermented at 42 ± 2°C until dense clotting and titratable acidity = 72 ± 2°T. The finished product was stored at 4 ± 2°C. The shelf-life was 12 days for the sample with Jerusalem artichoke syrup and 14 days for the drink fortified with beetroot fiber. The physical and chemical indicators showed that the energy value of the fortified fermented buttermilk drinks was by 45.3% lower compared to conventional fermented dairy drinks.

As a result of research, it has been established that the use of plant components, namely Jerusalem artichoke syrup and beet dietary fiber in the production technology of fermented milk drink from buttermilk makes it possible to obtain a finished product with improved consumer properties.

Keywords: Starter cultures, fermented drinks, buttermilk, plant components, quality indicators, shelf-life

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INTRODUCTION

Healthy diet, food safety, and hygiene have become the main lifestyle concepts as the constantly improving living standards and industrial technologies increase people's health awareness [1–4]. Obesity and cardiovascular diseases are associated with foods that are high in cholesterol and saturated fatty acids. Therefore, plant proteins have good potential regarding healthy nutrition [5–7].

As a result, the food industry gradually turns to plant raw materials [8–11]. For instance, secondary dairy raw materials represent a promising direction. Processing enterprises often use them irrationally. However, secondary dairy raw materials can become part of functional foods if fortified with renewable plant raw materials of high nutritional value [12–14].

The Far Eastern region boasts a wide variety of plants with functional and physiological components. As part of human diet, they can increase nonspecific resistance to stress and adverse environmental conditions [15, 16].

Buttermilk is a by-product of butter production. It contains all main components of milk, i.e., protein, lactose, milk fat, and minerals. In addition, it also contains vitamins and phospholipids, not to mention macro- and microelements. Buttermilk has an overall beneficial effect on human body. As its calorie content is very small, it can be classified as a dietary drink. However, buttermilk gives so much strength and vigor that it is sometimes regarded as an energy drink. Technological properties of buttermilk depend on its composition and physicochemical parameters [17, 18]. Its physical indicators are similar to those of skimmed milk [19]. The acidity of buttermilk depends on the production method and the type of butter produced. If the buttermilk was obtained by the churning method as a by-product of sweet cream butter, its titratable acidity ranges between 18 and 20°T while its pH is 6.53–6.59. If the buttermilk came from butter processed by high-fat cream conversion, its titratable acidity and active acidity are 17–18°T and pH 6.52–6.60, respectively.

The market of buttermilk drinks is growing quite rapidly, following the changes in consumption culture. The main market segments have already been occupied; yet, they demonstrate some prospective niches, e.g., fermented milk or buttermilk-based diet drinks.

In the near future, consumers will turn to high-quality products that fortified with functional natural ingredients and contain neither artificial dyes nor preservatives [20–22].

The most probable food plant components for buttermilk drinks are some popular plant additives, e.g., Jerusalem artichoke syrup and beetroot dietary fiber. These plant additives have a natural taste and render the finished product a beautiful color or pleasant aroma [23, 24].

Jerusalem artichoke syrup is a natural sweetener that has a consumer-appealing taste and meets the most rigorous scientific requirements for a healthy diet. Jerusalem artichoke syrup has a low glycemic index of 15: for comparison, the glycemic index of white sugar is 70. Therefore, even patients with diabetes may consume it in moderate quantities, both as a sweetener and for therapeutic and prophylactic purposes. Table 1 illustrates the main properties of Jerusalem artichoke syrup.

Jerusalem artichoke tuber syrup is a highly concentrated natural and environmentally friendly plant extract with physiologically active components. It contains at least 70% solids and more than 60% biologically active reducing substances. Unfiltered syrup is thick and has a sweet caramel flavor. Jerusalem artichoke tuber syrup contains vitamins B_1, B_2, C, PP, pectin, and probiotic inulin. Due to its sweet caramel flavor, Jerusalem artichoke tuber syrup can serve as a healthy natural sugar substitute with a low glycemic index.

Dietary fiber is currently one of the most common ingredients in functional foods. Dietary fiber comes from products of plant origin. It undergoes fermentation in the upper gastrointestinal tract and acts as a prebiotic for healthy intestinal microflora. When regularly consumed, dietary fiber has a beneficial biological effect on people of all ages.

If consumed regularly, beetroot dietary fiber prevents dysfunction of the gastrointestinal tract, as well as various pathological processes. It helps the body to get rid of nitrates and nitrites, bile acids, cholesterol, peroxide compounds, toxic elements, pesticides, radionuclides, and waste. Beetroot dietary fiber normalizes intestinal motility, accelerates intestinal transit, removes pathogenic microflora, and regulates metabolism. It reduces cholesterol, glucose, and urea in the blood while maintaining the antitoxic liver function. In addition, it optimizes fermentation processes in the intestines, as well as prevents cholelithiasis and diabetes. A comparative analysis of beetroot fiber proved that it is superior to all food additives on domestic market. Beetroot fiber demonstrated high protective, sorption, and mass transfer indicators, as well as good potential for preventing gastrointestinal and cardiovascular diseases [25–27].

Dietary fiber is part of a wide range of products with increased biological value, including functional foods.

Table 2 clearly demonstrates that beetroot fiber is a promising food component.

The research objective was to study the effect of plant components on the quality of fermented milk drinks from secondary dairy raw materials.

We rationalized the possibility of using Jerusalem artichoke syrup and beetroot dietary fiber as functional components in the production of fermented buttermilk drinks. Then, we selected the optimal amount of plant components to render the final product functional properties. Finally, we studied the physicochemical and microbiological indicators of the obtained fermented drinks.

STUDY OBJECTS AND METHODS

The research featured buttermilk, Jerusalem artichoke syrup, beetroot dietary fiber, and starter microorganisms that came in two versions: 1) *Streptococcus thermophilus* (strain No. CNCM I-2980) + *Lactobacillus delbrueckii* subsp. *bulgaricus* and 2) *S. thermophilus* + *L. delbrueckii* subsp. *bulgaricus*. They were lyophilized milk cultures intended for direct addition to the milk base.

The experimental samples were fermented milk drinks with Jerusalem artichoke syrup in amounts of 3, 6 and 9% and fermented drinks with beet dietary fiber in amounts of 2, 4 and 6%. The control sample was a fermented milk drink without plant components.

Table 1 Jerusalem artichoke syrup

Indicator	Content per 100 g
Mass fraction of carbohydrates, %	69.5
Energy value, kcal	254.0

Table 2 Main indicators of bleached beet fibers

Indicator	Value
Mass fraction of fiber, %	23.0–28.0
Mass fraction of lignin, %	7.0–9.0
Mass fraction of pectin substances, %, including:	
water-soluble pectin substances	10.0–12.0
water-insoluble protopectin	8.0–10.0
Protein, %	7.0–8.0
Mass fraction of minerals, % (K – 0.2%; N_3 – 0.4%; Ca – 0.8%; Mg – 0.4%; P – 0.25%)	3.5–5.0
Moisture-binding coefficient	5.0–5.5
Fat-binding coefficient	1.4–1.5
Color change during mass during hydration	does not change color
pH of water extract	4.3–4.6
Flavor	absent
Taste, aftertaste	sourish
Average fraction size, mm	0.120
Energy value, kcal/100 g	55.0–60.0

In this research, we analyzed the chemical composition, biological value and safety indicators of Jerusalem artichoke syrup and beet fibers as well as the nutritional and energy value of fermented milk drinks based on these plant components. The shelf-life of the finished products was determined using microbiological indicators and sensory assessment.

The research involved standard methods. The sensory, physicochemical, and microbiological methods made it possible to assess the quality of raw materials and product samples. The experiment took into account the chemical composition, physical properties, and microbiological indicators of the plant components.

The synergistic properties of clotting were determined by the amount of whey released by 10 cm^3 of a crushed clot during centrifugation at 1000 rpm for 5 min.

We used the formula below to calculate the energy value for 100 g of product based on the coefficients of nutrient absorption:

$$\text{Energy value} = P\times4.0 + F\times9.0 + C\times4.0$$

where P, F, and C mean proteins, fats, and carbohydrates, respectively, contained in g/100 g of the product.

The review of related publications included scientific articles, technical literature, and patent information on fermented milk production.

RESULTS AND DISCUSSION

We studied the acid-forming ability of various starters on Sample 1, which included *Streptococcus thermophilus* (strain No. CNCM I-2980) and *Lactobacillus delbrueckii* subsp. *bulgaricus*, and Sample 2 with *S. hermophilus* and *L. delbrueckii* subsp. *bulgaricus*. The microbial strains were to give the product a pure fermented milk taste and good texture, as well as to facilitate acid formation. The ripening took place on heat-treated buttermilk. The buttermilk was heated at 95 ± 2°C for 15–20 s. After that, it was normalized to 10% solids and pH 6.60. Since the cultures had been stored at subzero temperatures, the bags were kept at room temperature for 50 min before opening. Before use, we made sure that the culture maintained its powder form. Before adding it to the milk base, we treated the starter with chlorinated water. The temperature of the mix was 42 ± 2°C, i.e., 104–111.2°F. After 30 min of stirring, the samples were fermented at 42 ± 2°C for 6 h. The acidity accumulation was tested every hour (Table 3).

Table 3 Acidity accumulation in activated starter cultures

Time, h	pH	
	Sample 1	Sample 2
1	6.42 ± 0.15	6.53 ± 0.10
2	5.56 ± 0.15	5.97 ± 0.15
3	5.28 ± 0.10	5.74 ± 0.15
4	5.07 ± 0.10	5.50 ± 0.10
5	4.86 ± 0.10	5.31 ± 0.10
6	4.68 ± 0.15	4.86 ± 0.10

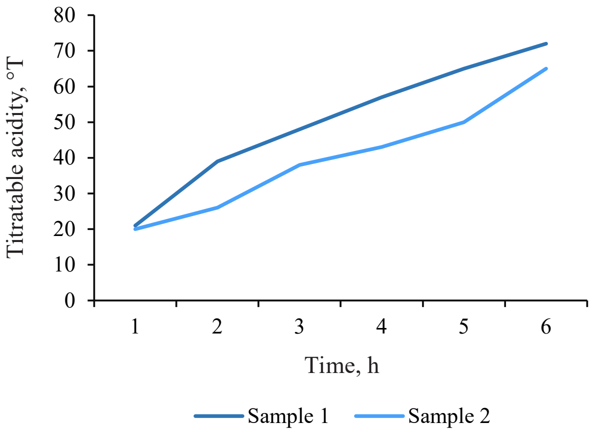

Figure 1 Intensity of acid formation in activated starter cultures

Figure 1 shows the effect of ripening time on the intensity of acid formation.

Both starter samples increased the titratable acidity in the fermented milk; however, the process proceeded more smoothly in Sample 1. During the entire fermentation period, the samples had a different titratable acidity increase rate. Sample 1 proved to be more efficient because it demonstrated the highest ripening speed and reached the pH delta of 1.35 in 3.5 h. In addition, Sample 1 had a better texture and superior sensory profile. Therefore, we selected the symbiotic starter with *S. thermophilus* (strain No. CNCM I-2980) and *L. delbrueckii* subsp. *bulgaricus* for further research.

The amount of plant components in the formulation is known to affect the sensory properties of buttermilk drinks. We chose the optimal share of Jerusalem artichoke syrup, which amounted for 6%.

To evaluate the quality of the finished product, we used sensory indicators based on sight, smell, touch, and taste. The assessment was carried out by panelists and took place in the following order: appearance, consistency, taste, flavor, and color. Table 4 structures the sensory properties of buttermilk drink samples with different contents of Jerusalem artichoke syrup. A sample without Jerusalem artichoke syrup served as control.

The sample with 6% Jerusalem artichoke syrup demonstrated the best sensory characteristics.

To identify the optimal share of beetroot dietary fibers, we studied the synergetic properties of resulting clots. Dietary fibers were added in amounts of 2, 4, and 6%; a sample of fermented buttermilk drink without beetroot dietary fiber served as control (Table 5).

The water-holding capacity increased together with the mass fraction of beetroot dietary fiber in the samples, while the amount of whey released decreased.

We presumed that the increase in the content of beetroot dietary fiber had no effect on the taste of the finished product but changed its consistency. As a result, we added 4% of beetroot fiber by the weight of the finished product, since this amount of beet dietary fiber gave the best consistency to the product.

Table 4 Sensory profile of fermented buttermilk drink fortified with Jerusalem artichoke syrup

Indicator	Fermented buttermilk drink (control)	Fermented buttermilk drink with Jerusalem artichoke syrup in the amount of:		
		3%	6%	9%
Appearance	Homogeneous, moderately viscous	Smooth surface, no stratification	Smooth surface, no stratification	Smooth surface, no stratification
Consistency	Homogeneous, with crushed clots	Homogeneous, with crushed clots, no visible lumps	Homogeneous, with crushed clots, no visible lumps	Homogeneous, with crushed clots, no visible lumps
Taste and flavor	Pure, fermented milk, no atypical tastes or odors	Pure sour milk taste, and flavor	Moderately sweet taste, pure sour milk flavor	Sweet taste, pure sour milk flavor
Color	Milky white	Milky white and uniform	Milky creamy and uniform	Milky creamy and uniform

Table 5 Synergetic clotting properties in fermented buttermilk drink with beetroot dietary fiber

Centrifugation time, min	Whey released, mL			
	Control	Content of beetroot dietary fiber		
		2%	4%	6%
5	5.0	4.95	4.90	4.85
10	6.4	6.3	6.0	5.6
15	6.9	6.1	5.9	5.6
20	7.4	6.9	6.5	6.2
25	7.6	7.1	6.7	6.3
30	7.7	7.3	6.9	6.3

Fermented milk drinks can be produced by thermostatic or tank methods. In this research, we applied the tank method. The buttermilk was pasteurized at 95 ± 2°C for 15–20 s and cooled to the fermentation temperature of 42 ± 2°C.

Figure 2 illustrates the technological scheme for fermented buttermilk drinks.

The thermostatic method required plant components to be added cooled down to the ripening temperature. With periodic stirring, the fermented mix was immediately poured into consumer containers and sent to a thermostatic chamber for fermentation. The ripening process ended when the clotting was sufficient and the acidity rose to 72 ± 2°T. Then, the product immediately was moved to a refrigerator for cooling and storage.

Shelf-life characterizes the stability of products during storage. During storage at 4 ± 2°C, we measured the changes in sensory properties, microbiological indicators, and titratable acidity (Table 6).

We counted probiotic microorganisms during 21 days with an interval of three days. On storage day 14, the probiotic microbial count in the experimental samples was higher than in the control sample (3×10^6 CFU/cm^3): 1×10^8 CFU/cm^3 in the sample with Jerusalem artichoke syrup and 3×10^8 CFU/cm^3 in the sample with beetroot fiber.

On storage day 21, the count of lactic acid microorganisms decreased to 2×10^6 CFU/cm^3 in the experimental sample with Jerusalem artichoke syrup and to 3×10^6 CFU/cm^3 in the sample with beetroot fiber. In the control sample, it dropped down to 1×10^4 CFU/cm^3. The results obtained violated the standards mentioned in Technical Regulations of the Customs Union TR CU 033/2013 regarding the amount of probiotic microflora in this type of product.

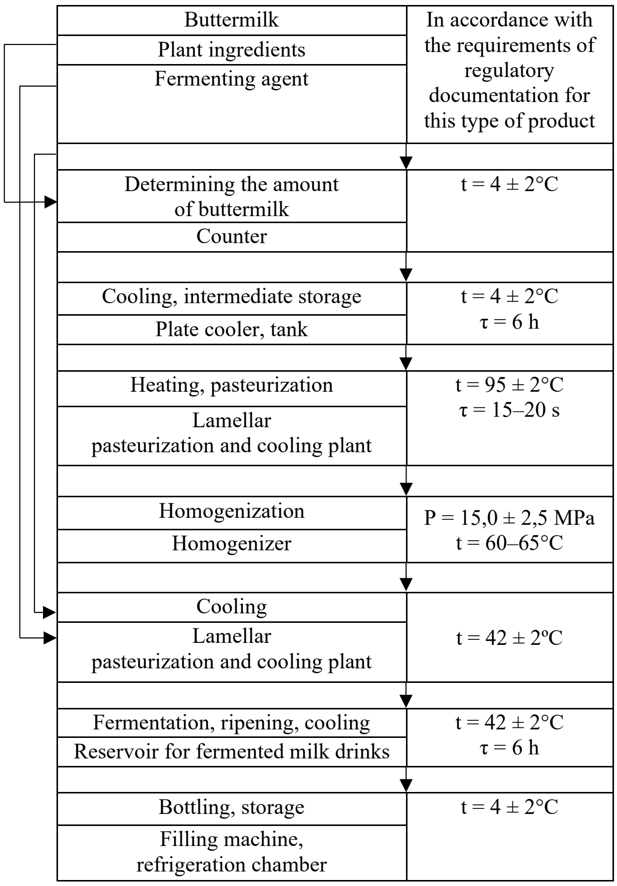

Figure 2 Technological scheme for fermented buttermilk drinks

Table 6 Microbiological parameters of fermented buttermilk drinks during storage

Storage time, h	Microbial count, CFU/cm^3		
	Control	Fermented buttermilk drink with Jerusalem artichoke syrup	Fermented buttermilk drink with beetroot fiber
1	4×10^7	5×10^8	7×10^8
4	4×10^7	4×10^8	6×10^8
7	1×10^7	3×10^8	5×10^8
11	6×10^7	2×10^8	4×10^8
14	3×10^6	1×10^8	3×10^8
17	1×10^5	3×10^7	2×10^7
21	1×10^4	2×10^6	3×10^6

Table 7 Chemical composition: buttermilk drinks with Jerusalem artichoke syrup and beetroot fiber vs. industrially produced yogurt

Mass fraction, %	Control	Fermented buttermilk drink with Jerusalem artichoke syrup	Fermented buttermilk drink with beetroot dietary fiber
Fat	2.5	0.5	0.5
Carbohydrates	4.7	8.2	4.8
Protein	3.2	3.2	3.4
Dry skimmed milk residue	9.5	13.0	9.8
Dietary fiber	–	–	4.0

The titratable acidity of the samples met the requirements for this category of fermented milk products and ranged from 75 to 100°T. During the entire period of observation, the acidity in both samples did not exceed the standard values.

The experimental samples also showed sensory stability and good preservation during the entire storage period.

On storage day 17, the sample with beetroot fiber demonstrated signs of deterioration in appearance and consistency. In the sample with Jerusalem artichoke syrup, these processes became visible on storage day 14. In addition, ≥ 3% whey got separated, and the samples started to emit a flavor not typical of fermented milk drinks.

Therefore, dietary fiber in the fermented buttermilk product improved its sensory profile and stabilized its consistency during storage.

The shelf-life of the fermented buttermilk drink with Jerusalem artichoke syrup was defined as 12 days at 4 ± 2°C, and that of the drink with beetroot fiber was 14 days.

We relied on the content of proteins, fats, calcium, phosphorus, vitamins A, B-carotene, and B_2 to define the nutritional value of fermented buttermilk products. However, the nutritional value of fermented milk products mainly depends on the content of microorganisms and their metabolic products that inhibit putrefactive bacteria in the human gastrointestinal tract. It also includes lactic acid, which reduces the pH of the medium. Lactic acid products are digested thrice as fast as milk.

Fermented milk products are popular in clinical nutrition to improve gastric secretion and normalize intestinal motility in the treatment of colitis and gastritis. Lactic acid that enters the intestine with lactic acid products is neutralized, but lactic acid microorganisms endure and ferment food residues to create an acidic environment that kills putrefactive microorganisms.

Fermented milk drinks have a characteristic taste and consistency that meet the taste habits of the population. They differ in the microflora of fermentation starters. Table 7 compares the chemical composition of the experimental functional fermented buttermilk drinks with that of industrially produced yogurt.

Below is the formula we used to calculate the energy value of yogurt:

$$\text{Energy value} = 3.2\times4.0 + 0.5\times9.0 + 4.7\times4.0 = 36.10 \text{ kcal}$$
$$36.10 \text{ kcal}\times4.184 = 151.04 \text{ kJ}$$

The resulting energy value, or calorie content, of yogurt was 36.10 kcal/151.04 kJ.

The energy value of the fermented buttermilk drink with Jerusalem artichoke syrup was calculated as follows:

$$\text{Energy value} = 3.2\times4.0 + 0.5\times9.0 + 8.2\times4.0 = 50.10 \text{ kcal}$$
$$50.10 \text{ kcal}\times4.184 = 209.62 \text{ kJ}$$

The resulting energy value, or calorie content, of the buttermilk drink with Jerusalem artichoke syrup equaled 50.10 kcal/209.62 kJ.

We used the following formula to calculate the energy value of the buttermilk drink with beetroot fiber:

$$\text{Energy value} = 3.4\times4.0 + 0.5\times9.0 + 4.8\times4.0 = 37.30 \text{ kcal}$$
$$37.30 \text{ kcal}\times4.184 = 156.06 \text{ kJ}$$

The resulting energy value, or calorie content, of the fermented buttermilk drink with beetroot dietary fiber appeared to be 37.30 kcal/156.06 kJ.

Compared to a traditional yogurt, the fermented milk drinks based on buttermilk and Jerusalem artichoke syrup had low fat content, the same protein level and higher percentage of carbohydrates, while the milk drinks made from buttermilk with beet dietary fiber contained lower fat content, as well as relatively equal levels of protein and carbohydrates. In addition, the fermented milk drink with beet dietary fiber contained insoluble dietary fiber, which has a positive effect on the digestive system of the human body. The results obtained allow us to consider the developed products as low-calorie containing various nutritional factors.

The mass fraction of carbohydrates in the fermented buttermilk drink with Jerusalem artichoke syrup increased by 74.47% compared to the control sample. Jerusalem artichoke syrup contains such carbohydrates as inulin and fructose. As a result, sweetened fermented buttermilk products can be included in diabetic diets.

Table 8 shows the recipes for the developed fermented milk drinks made from buttermilk with plant ingredients based on 1 ton of the finished product. The recipes were selected based on the results of organoleptic studies.

Thus, Jerusalem artichoke syrup and beetroot dietary fiber improved the quality of fermented drinks from secondary milk raw materials and elevated them to the status of functional products. The amount of plant components in the formulation affected the sensory indicators of the buttermilk drinks. The optimal shares obtained were based on the sensory assessment.

Table 8 Developed recipes for fermented milk drinks made from buttermilk with plant ingredients

Components, kg	Fermented buttermilk drink with Jerusalem artichoke syrup	Fermented buttermilk drink with beetroot dietary fiber
Buttermilk	939.90	959.90
Sourdough (*Streptococcus thermophilus* (strain No. CNCM I-2980) and *Lactobacillus delbrueckii* subsp. *bulgaricus*)	0.10	0.10
Jerusalem artichoke syrup	60.00	–
Beet dietary fiber	–	40.00
Total	1000.00	1000.00

Drinks from secondary dairy raw materials allow for sustainable production; Jerusalem artichoke syrup and beetroot dietary fiber improve the sensory profile and consumer properties of finished products, making them functional. The results obtained were consistent with previous R&D publications on functional dairy products.

The data obtained correlate with the results of previous studies, while supplementing them with new information about the composition of products based on secondary dairy raw materials in the form of buttermilk and plant components.

CONCLUSION

The research rationalized the use of Jerusalem artichoke syrup and beetroot dietary fiber as functional additives. Beetroot dietary fiber had no effect on clotting and taste but changed the consistency of the final product.

The use of Jerusalem artichoke syrup allows you to obtain a fermented milk drink from buttermilk with a uniform consistency, a pleasant sweetish taste and a light creamy tint. Due to the unique chemical composition of Jerusalem artichoke syrup and the beneficial properties of dietary fiber, the developed fermented milk drinks will have a functional effect on the human body when consumed daily in the diet.

A selected starter consisting of *Streptococcus thermophilus* (strain No. CNCM I-2980) and *Lactobacillus delbrueckii* subsp. *bulgaricus* can let intensify the technological process due to the rapid increase in titratable acidity with the formation of a dense clot.

The shelf-life of the experimental drinks at 4 ± 2°C was 12 days for the drink with Jerusalem artichoke syrup and 14 days for the drink with beetroot dietary fiber.

Buttermilk drinks can save raw milk resources and reduce the cost of the finished product because dairy by-products are cheap. In addition, they allow expanding the range of competitive products with high-quality sensory profiles and increased biological values.

CONTRIBUTION

All the authors were equally involved in the manuscript and are equally responsible for any potential plagiarism.

CONFLICT OF INTEREST

The authors declared no conflict of interests regarding the publication of this article.

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