Studii şi Cercetări Ştiinţifice
Chimie şi Inginerie Chimică, Biotehnologii, Industrie Alimentară

2022, **23** (1), pp. 073 – 081

Scientific Study & Research
Chemistry & Chemical Engineering, Biotechnology, Food Industry

ISSN 1582-540X

ORIGINAL RESEARCH PAPER

ENRICHED FERMENTED DAIRY PRODUCT: FUNCTIONAL CHARACTERISTICS AND TECHNOLOGY

Natalya I. Mosolova[1], Vera V. Kryuchkova[1,2], Svetlana N. Belik[3], Ivan F. Gorlov[1,4], Marina I. Slozhenkina[1,4], Anastasia E. Serkova[4*]

[1] Volga Region Research Institute of Production and Processing of Meat and Dairy Products, 400131, 6 Rokossovsky str., Volgograd, Russia
[2] Skolkovo Innovation Center, 143026, bld. 1, 42 Bolshoi blvd., Moscow, Russia
[3] Rostov State Medical University, 344022, 29 Nahichevansky av., Rostov-on-Don, Russia
[4] Volgograd State Technical University, 400005, 28 Lenin av., Volgograd, Russia

* Corresponding author: serkova.anastasiya@gmail.com

Received: December, 02, 2019
Accepted: March, 25, 2022

Abstract: The authors have developed a technology for a 3.2 % fat fermented dairy product enriched with Jerusalem artichoke powder and red currant juice. High sensory indicators have been established, and taste characteristics of the product have been determined. The assessment of the nutritional value of the developed product has revealed an increase in the weight fraction of protein by 0.2 % and carbohydrates by 1.5 %, including nutrients by 123.28 ± 0.11 mg/100 g of product and dietary fiber by 161.36 ± 0.14 mg/100 g of product. The acid production efficiency of the enriched fermented dairy product increased, which resulted in reducing the fermentation time of the developed product by 1 hour in comparison with the traditional one. The developed product is microbiologically safe. Lactic acid microorganisms in the enriched product considerably exceeded the control values, which proved its pre- and probiotic properties.

Keywords: *fermented dairy product, Jerusalem artichoke, microbiological points, nutritional value, red currant*

INTRODUCTION

Actual nutrition of Russians is noted for a high calorie diet with an excess of fats and carbohydrates, as well as vitamin and mineral deficiency [1]. In 2017, dietary calories of an average Russian reached 2675 kcal or more per day, while a guideline daily amount being 1500-2500 kcal, which under conditions of physical inactivity contributes to an increase in the number of obese people in all age categories. Currently, up to 55 % of men, up to 60 % of women and every fourth child suffer from varying degrees of obesity [2].

A policy challenge for the food industry is to create functional food products that ensure the appropriate functioning of vital organs and systems of the human body and contribute to the body's overall resistance to adverse environmental factors [3]. Due to the annually increasing load of harmful environmental factors and the need to increase the natural resistance of the human body, such as Jerusalem artichoke powder (AP) and red currant juice (RC) to enrich the dairy product.

Jerusalem artichoke (*Helianthus tuberous*) is a species of perennial herbaceous tuberous plants of the family *Compositae*, genus *Helianthus*. In tubers, the dry matter content ranges in 19-30 % and nitrogenous substances vary from 4.3 to 11.0 %. Jerusalem artichoke surpasses cereal grain with respect to the essential amino acids balance. The tubers contain vitamin B_1 (thiamine), B_2 (riboflavin), B_7 (vitamin *H* or biotin), *PP* (nicotinic acid) and vitamin *C* (ascorbic acid) [4]. Jerusalem artichoke tubers contain about 77 % of inulin carbohydrate that during storage turns into fructose and makes the root crop quite sweet in taste [5]. Inulin specifically stimulates the beneficial intestinal bacteria to grow and inhibits or weakens the uncontrolled growth of potentially pathogenic and harmful microorganisms [6, 7]. Due to its unique composition, Jerusalem artichoke has a wide range of physiological activity and preventive effects [8].

Daily consumption of a fermented milk drink enriched with Jerusalem artichoke in amount of 200 g for 18 days leads to a 3-fold decrease in *Helicobacter pylori* in feces and hematocrit normalization, which indicates a decrease in the activity of granulocytes and monocytes and retardation of oxidative reactions [9]. Jerusalem artichoke powder in diets improves the profile of fatty acids, *i.e.*, increases the PUFA proportion and decreases the ω-6 / ω-3 ratio, and reduces the concentration of total lipids and cholesterol in blood [10]. The basis of the carbohydrate complex of Jerusalem artichoke is composed of fructose and its polymers of varying degrees of complexity. Their highest homolog is inulin that, added to mice's high fat diet, decreases the body weight, increases activity of glutathione peroxidase in the liver, normalizes the malonic aldehyde, and considerably reduces the level of advanced glycation endproducts – main markers of chronic pathologies and aging [11]. Being a prebiotic, inulin significantly improves the microbial profile in all parts of the intestine and reduces intestinal pathogens [12].

Red currant is the source of valuable essential components, primarily polyphenolic compounds. The main P-active substances are flavonoids, including catechins, anthocyanins, and leukoanthocyanins contained in the berries under study [13]. Berry catechins determine the taste of berries and products of their processing; anthocyanins determine an attractive color [14]. Polyphenolic compounds of red currant are natural food oxidation inhibitors in organic substances, exhibit pronounced antioxidant activity in reaction with 2,2'-diphenyl-1-picrylhydrazyl stable radical and have a high antioxidant capacity [15]. Flavonoids can inhibit regulatory enzymes or transcription factors that are important to control inflammatory mediators. Flavonoids are powerful geroprotectors with antifibrotic potential [16]. Phenolic compounds can inhibit the proliferation of cancer cells through the apoptosis activation [17]. Other RC components are sugars—mainly glucose and fructose, organic acids (malic, citric and succinic), pectin substances (protopectin 1.74 mg/100 g and soluble pectin 1.27 mg/100 g), and ascorbic acid up to 83 mg/100 g [18].

We assume that the developed enriched product will have a number of advantages over a traditional fermented milk product, since on the one hand, the probiotic composition of the fermented milk base, including *Streptococcus thermophilus*; *Lactococcus lactis*; *Lactobacillus helveticus*; *Propionibacterium freudenreichii* subsp. *shermania*; *Lactobacillus acidophilus*) will inhibit the growth of pathogens due to the formation of low-molecular metabolites of the saccharolytic microflora (short-chain fatty acids (FFA) - propionic, butyric, acetic, formic, lactic, etc.), lactate, bacteriocins and other antimicrobial compounds, as well as compete with undesirable microorganisms for adhesion sites on the intestinal epithelium and for nutrients [19, 20]. On the other hand, *Jerusalem artichoke* mono- and oligosaccharides, such as D-fructose, D-lactose, D-galactose, D-sucrose, D-glucose and inulin, being a nutrient substrate for the growth of probiotics producing SCS, will thereby enhance the biological effects of probiotics. On the third hand, the normal intestinal microbiota plays a key role in increasing the bioavailability and, consequently, the biological activity of phenolic metabolites, especially after eating a meal containing high-molecular polyphenols [21, 22]. In addition, recent studies have shown that plant polyphenols can act as a prebiotic metabolite to modulate the microbial composition of the intestine mainly by inhibiting pathogenic bacteria and stimulating the growth of beneficial bacteria. [23, 24].

Thus, the combined use of probiotics, prebiotics and plant polyphenols in synbiotic compositions can be an effective approach in maintaining the balance of the intestinal microbiome and the metabolites produced by it, and can also contribute to the maximum realization of a variety of potentially beneficial effects of the enriching components listed above for human health the purpose of the study was to develop a fermented milk product enriched with Jerusalem artichoke powder and red currant juice and the study of its functional characteristics

MATERIALS AND METHODS

The object of the research was a fermented dairy product added with Jerusalem artichoke powder and red currant juice (Prototype), and a Control sample - fermented dairy product that was produced according to a similar technology but did not contain any additives. The main methods of research of fermented milk products: organoleptic indicators by sensory method according to GOST R ISO 22935-2-2011; titratable acidity by titrimetric method according to GOST R ISO 2446-2011; fat mass fraction by acid method according to GOST R ISO 2446-2011; protein mass fraction by formative titration according to GOST R 53951-2010; determination of the mass fraction of pectin substances by titrimetric method according to GOST 29059-91; determination of the mass fraction of dietary fibre by the enzymatic gravimetric method according to GOST

R 54014-2010; determination of the number of lactic acid bacteria by microbiological method according to GOST 32901-2014; *Staphylococcus aureus* according to GOST 30347-2016, bacteria of the genus *Salmonella* according to GOST 31659-2012 (ISO 6579:2002), bacteria of the *Escherichia coli* group according to GOST 32901-2014, yeast and mould fungi according to GOST 33566-2015; calculation of energy value is carried out taking into account the coefficients of caloric content and fat, protein and carbohydrates.

Statistical analysis

Statistical data were processed using the Statistical program (Statistica, version 6.0 (Dell, USA). The data are presented as averages. The differences between the samples were assessed using unpaired t-test. Correlation analysis with the pair correlation coefficient calculated was used to establish the dependence between parameters. The significance of differences was determined by the Student's t-test. The level was considered significant at $p \leq 0.05$. The study was repeated three times.

RESULTS AND DISCUSSION

After a series of preliminary studies, the formulation of the fermented dairy product enriched with Jerusalem artichoke powder and red currant juice, with fat weight fraction of 3.2 % was calculated and is presented in Table 1.

Table 1. *Formulation of fortified fermented dairy product (per 1000 kg of mixture, excluding losses)*

Raw material	Raw material consumption [kg]
Cow's milk (fat weight fraction 3.6 %)	817.7
Skim milk (fat weight fraction 0.0 5%)	102.2
Jerusalem artichoke powder (5%)	50.0
Red currant juice (3%)	30.0
Direct DVS starter culture	0.1
Total	1000.0

The product was developed by the reservoir method that allowed us to save the maximum amount of nutrients and stop ripening at the time of the greatest growth of beneficial microflora, which increased useful properties of the dairy product and preserved its taste and aroma.
The technology of production of liquid fermented milk product includes the following technological operations: normalization of natural milk by fat by the method of fat balance with the addition of an estimated amount of skimmed milk; pasteurization at a temperature of 90 - 95 °C with exposure for 2 - 3 seconds; cooling to a temperature of 40 ± 2 °C; fermentation with a direct application starter for fermented milk drinks DVS, in the composition which includes the following types of bacteria: *Streptococcus thermophilus; Lactococcus lactis; Lactobacillus helveticus; Propionibacterium freudenreichii subsp. shermanii; Lactobacillus acidophilus*); stirring for 15 minutes and

fermentation at a temperature of t = 40 ± 2 ℃ for 5 hours until the titrated acidity reaches 65 - 70 °T; cooling to a temperature of t = 20 ± 2 °C. According to GOST 32923-2014, the predicted acidity for fermented milk products should vary between 80 - 120 °T, for this it is advisable to start cooling the resulting clot, which has reached a titratable acidity of 65 - 70 °T, in order to prevent deterioration of the consistency of the product during storage and to ensure a stable composition of the microflora of the fermented milk product. *Jerusalem artichoke* powder, pre-treated with hot milk at a temperature of 65 ± 2 ℃ and cooled to 20 ± 2 °C, and red currant juice, pasteurized at a temperature of 65 ± 2 °C, are added to the fermented and cooled fermented milk product for 25 minutes and cooled to a temperature of 12 ± 2 °C, thoroughly mixed to achieve their uniform distribution throughout the mass and packaged in consumer containers, samples are taken for a comprehensive quality assessment. The finished product is sent to the refrigerator (storage temperature 4 ± 2 °C).

Jerusalem artichoke powder in an amount of 5.0 % was pre-steamed with 65 ± 2 °C hot milk and cooled to a temperature of 20 ± 2 °C. Then, red currant juice was added in an amount of 3 %, pasteurized at a temperature of 65 ± 2 °C for 25 min and cooled to a temperature of 12 ± 2 °C. All components were mixed to achieve their uniform distribution throughout the mass. The fermented product was packaged into retail packaging. The quality of the finished product was assessed; sensory characteristics, nutritional and energy values, physico-chemical indicators and microbiological points were examined.

To determine appearance, consistency, smell, taste, and color, a sensory evaluation of a control sample and prototype was conducted. For clarity, the samples got sensory scores. The results of the study are presented in Table 2.

Table 2. *Sensory characteristics of fermented dairy products*

Characteristic	**Control sample (fermented milk drink)**	**Prototype (enriched fermented milk drink)**
Appearance and consistency	Dense, uniform stirred consistency	Dense, uniform stirred consistency with single Jerusalem artichoke powder interspersed
Taste and smell	Pure, fermented	Pure fermented, slightly sweet with a pleasant milky-vegetable flavor and aroma
Color	Milky white, uniform throughout the mass	Pinkish-cream, with a slight sediment of dark particles, due to the Jerusalem artichoke powder introduced
Sensory score	4.4	4.8

The sensory assessment showed that the Prototype of the enriched fermented dairy product prevailed over the Control sample in all respects. A distinctive feature of the enriched fermented dairy product was sweetish taste with a milky plant flavor and aroma and a pinkish-cream color. Due to the high sensory assessment and expected attractiveness to the consumer, the prototype received more points than the control sample by 0.4.

Nutritional value of products largely depends on their chemical composition, so we examined the samples of the fermented dairy products with respect to possible changes in the indicators caused by enriching phytocomponents. The results of the study are presented in Table 3.

Table 3. *Nutritional and energy value of fermented dairy samples, per 100 g of product*

Parameter	Control sample (fermented milk drink)	Prototype (enriched fermented milk drink)
Weight fraction of fat [g]	3.2±0.10*	3.2±0.13*
Weight fraction of protein [g]	3.0±0.15*	3.2±0.16*
Weight fraction of carbohydrates [g] incl.	4.2±0.14*	5.7±0.09*
- pectin substances [mg]	-	123.28±0.11*
- dietary fiber [mg]	-	161.36±0.14*
Energy value [kcal]	57.6	64.4

* P < 0,05

According to the results of the assessment of nutritional and energy value, it was found that the enrichment of a fermented milk product with vegetable ingredients increased its nutritional value by increasing the amount of carbohydrates, including plant polysaccharides (pectin and dietary fiber), which promotes the growth of lactic acid bacteria in the enriched product and positively affects the human body as a prebiotic. Low energy value implies the possibility of using the product in dietary nutrition.

The study of the influence of functional ingredients on the acid production during fermentation in milk product showed that the increase in titratable acidity in an enriched product (EP) was faster than in a traditional product (TP). The efficiency of acid formation is shown in Figure 1.

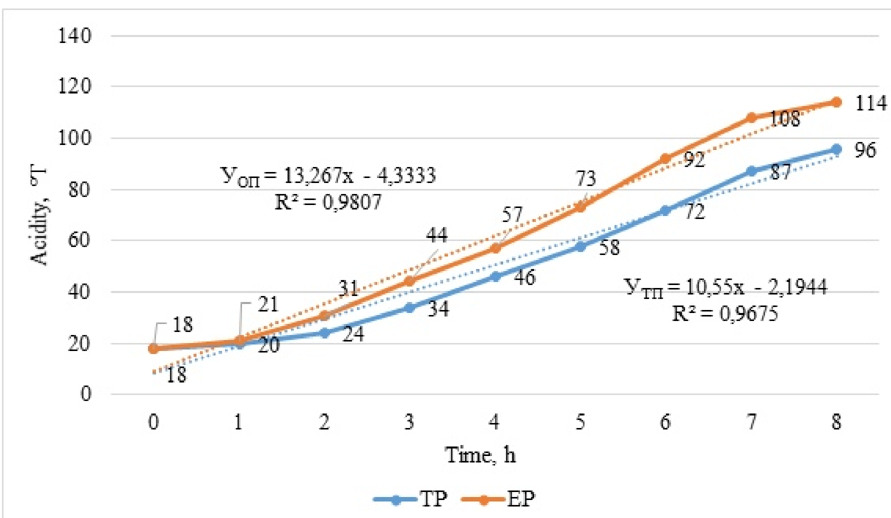

Figure 1. *Efficiency of acid production. TP is the traditional product; and EP is the enriched product*

Due to the functional ingredients – *Jerusalem artichoke* powder and red currant juice – in the enriched fermented dairy product, soft curd milk and titratable acidity of 65 - 70 °T were obtained in 5 hours, *i.e*. more efficiently, than in the traditional fermented milk product, where fermentation took 6 hours. Therefore, the fermentation process in the fortified fermented dairy product was reduced by 1 hour in comparison with the traditional one, which made it possible to save heat and energy resources of the enterprise and consider the technology resource-saving.
The safety of food and food raw materials is one of the most important factors affecting human health. Microbiological points of the fermented dairy products - traditional (without fillers) and enriched (with Jerusalem artichoke powder and red currant juice) were evaluated. The results are presented in Table 4.

Table 4. *Microbiological points of dairy products*

Indicator		TRCU 033 / 2013 indicator value	Actual value	
			Control sample (fermented milk drink)	**Prototype (enriched fermented milk drink)**
Lactic acid microorganisms [CFU·cm^{-3} (g)], not less than (end-of-shelf-life specification)		1×10^7	1.6×10^7	6×10^7
Product weight [cm^3 (g)], which does not allow	*Coliform bacterias*	0.1	N/D	N/D
	Staphylococcus aureus	1.0		
	Pathogenic (incl. *Salmonella*)	25		
Yeast [CFU·cm^{-3} (g)], not more than		50	15	25
Mold [CFU·cm^{-3} (g)], not more than		50	20	30

Due to the presence of pectin substances and dietary fibers in the enriched product, the number of lactic acid bacteria increased from 1.6×10^7 to 6×10^7 CFU·cm^{-3}, which gives it probiotic properties. The microbiological study showed that lactic acid microorganisms in the enriched product considerably exceeded both standard indicators and values in the traditional fermented milk product, thereby proved its pre- and probiotic properties and indicated high functional activity.
The yeast and mold cells values did not exceed the safety norms for milk and dairy products in the Technical Regulation of the Customs Union. No pathogens, such as *Escherichia coli bacteria, Staphylococcus aureus* and *Salmonella bacteria*, were detected in the fermented milk samples.

CONCLUSIONS

The developed technology of the enriched fermented milk product is resource-saving, the resulting drink has high quality indicators: organoleptic, physico-chemical and microbiological. The results of the study of microbiological indicators indicate that the number of lactic acid microorganisms in the enriched product significantly exceeds both the normalized indicators and the values in the traditional fermented milk product, which proves its pre- and probiotic properties and indicates high functional activity in the consumer's diet. Thus, the production of a fermented milk product of the proposed composition will expand the range of functional products on the Russian market.

ASKNOWLEGMENTS

The research was carried out under a grant RSF 22-26-00138, VRIIMMP.

REFERENCES

1. Pastushkov, E.V., Mysakov, D.S., Chugunova, O.V.: Some aspects of the factors of nutrition and human health, *Health and millennium education*, **2016**, **18** (4), 67-72;
2. Fedotova, G.V., Khramova, V.N., Mosolova, N.I., Surkova, S.A.: Promotion of a healthy diet and maintaining energy balance, *Agricultural and Food Innovations*, **2018**, **4** (4), 76-83;
3. Gorlov, I.F., Mosolova, N.I., Zlobina, E.Yu .: New biologically active substances for environmental safety and improving the milk quality, *Food Industry*, **2012**, **12**, 32-34;
4. Shatilova, T.I., Sokolova, O.S., Belopukhov, S.L., Semko, V.T., Vitol, I.S., Karpilenko G.P., Shaikhiev I.G.: Obtaining promising functional ingredients from artichoke in biotechnological industries. 1. Inulin, *Herald of Kazan Technological University*, **2015**, **16**, 301-303;
5. Nazarenko, M.N., Barkhatova, T.V., Kozhukhova, M.A., Khripko, I.A., Burlakova, E.V.: Inulin change in Jerusalem artichoke tubers during storage, *Scientific Journal of Kuban State Agrarian University*, **2013**, **94**, 360-384;
6. Roberfroid, M.: Prebiotics: the concept revisited, *The Journal of nutrition*, **2007**, **137** (3), 830-837;
7. Roberfroid, M. et al.; Prebiotic effects: metabolic and health benefits, *British Journal of Nutrition*, **2010**, **104** (2), 1-63;
8. Karomatov, I.D., Istamova, F.M.: Medicinal plant tuberous sunflower, Jerusalem artichoke and earth apple, *Biology and integrative medicine*, **2017**, **5**, 115-125;
9. Liubchenko, P.N., Skobeleva, N.V., Shirokova, E.B., Zubova, Iu.E., Suchkov, S.V., Donskaia, G.A.: The use of fermented milk drink with topinambur for the treatment of Helicobacter infection in the liquidators of Chernobyl nuclear power plant accident, *Vopr Pitan*, **2003**, **72** (3), 29-31;
10. Grela, E.R., Sobolewska, S., Roziński, T.: Effect of inulin extracts or inulin-containing plant supplement on blood lipid indices and fatty acid profile in fattener tissues, *Polish Journal of Veterinary Sciences*, **2014**, **17** (1), 93-98;
11. Zhu, Z., Huang, Y., Luo, X., Wu, Q., He, J., Li, S., Barba, F.J.: Modulation of lipid metabolism and colonic microbial diversity of high-fat-diet C57BL/6 mice by inulin with different chain lengths, *Food Research International*, **2019**, **123**, 355-363;
12. Boonanuntanasarn, S., Tiengtam. N., Pitaksong, T., Piromyou, P., Teaumroong, N.: Effects of dietary inulin and Jerusalem artichoke (Helianthus tuberosus) on intestinal microbiota community and morphology of Nile tilapia (Oreochromis niloticus) fingerlings, *Aquaculture Nutrition*, **2018**, **24**, 712-722;
13. Bzhetseva, N.R.: Biochemical composition of currant fruits, *New Technologies*, **2017**, **2**, 90-98;
14. Golub, O.V., Stepanova, E.I., Tyapkina, E.V.: Nutritional value and quality of redcurrant berries, *Food Engineering and Technology*, **2017**, **1**, 105-110;
15. Puganen, A., Kallio, H.P., Schaich, K.M., Suomela, J.P., Yang, B.: Red/Green Currant and Sea Buckthorn Berry Press Residues as Potential Sources of Antioxidants for Food Use, *Journal of Agricultural and Food Chemistry*, **2018**, **66** (13), 3426-3434;
16. Maleki, S.J., Crespo, J.F., Cabanillas, B.: Anti-inflammatory effects of flavonoids, *Food Chemistry*, **2019**, **299**, 125-124;

17. Rao, S., Chinkwo, K., Santhakumar, A., Johnson, S., Blanchard, C.: Apoptosis Induction Pathway in Human Colorectal Cancer Cell Line SW480 Exposed to Cereal Phenolic Extracts, *Molecules*, **2019**, **24** (13), 2465;
18. Makarkina, M.A., Golyaeva, O.D.: Selection of red currant Ribes rubrum L. for improved chemical composition of berries, *Agricultural Biology*, **2013**, **3**, 18-27;
19. Evdokimova, S.A., Nokhaeva, V.S., Karetkin, B.A., Guseva, E.V., Khabibulina, N.V., Kornienko, M.A., Grosheva, V.D., Menshutina, N.V., Shakir, I.V., Panfilov, V.I.: A Study on the Synbiotic Composition of Bifidobacterium bifidum and Fructans from Arctium lappa Roots and Helianthus tuberosus Tubers against Staphylococcus aureus, *Microorganisms*, **2021**, **9** (5), 930, doi: 10.3390/microorganisms9050930;
20. Ozdal, T., Sela, D.A., Xiao, J., Boyacioglu, D., Chen, F., Capanoglu, E.: The Reciprocal Interactions between Polyphenols and Gut Microbiota and Effects on Bioaccessibility, *Nutrients*, **2016**, **8** (2), 78, doi: 10.3390/nu8020078;
21. Dueñas, M., Muñoz-González, I., Cueva, C., Jiménez-Girón, A., Sánchez-Patán, F., Santos-Buelga, C., Moreno-Arribas, M.V., Bartolomé, B.: A survey of modulation of gut microbiota by dietary polyphenols, *Biomed Research International*, **2015**, 850902, doi: 10.1155/2015/850902;
22. Kryuchkova, V.V., Gorlov, I.F., Belik, S.N., Kamlatsky, A.S.: Vegetable ingredients in functional fermented milk products, *IOP Conference Series Earth and Environmental Science*, **2020**, **548** (8), 082092;
23. Slozhenkina, M.I., Gorlov, I.F., Kryuchkova, V.V., Evlushin, D.S., Tkachev, S.A.: Development of drinking yogurt enriched with magnesium, *Food industry*, **2020**, **5** (4), 18-25;
24. Kryuchkova, V.V., Gorlov, I.F., Slozhenkina, M.I., Lomonova, N.V., Belik, S.N.: Functional curd product of increased biological value, *IOP Conference Series: Earth and Environmental Science*, **2021**, C. 32073.