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DEVELOPMENT OF DAIRY PRODUCTS TECHNOLOGY WITH APPLICATION LOW-ETHERIFICATED PECTIN PRODUCTS

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The issue relatedto removing heavy and radioactive metals from the body is relevant all over the world. Chemical preparations for removing heavy metals and radionuclides are not effective enough, causing the depletion of trace elements in the body. It is effective to use substances contained in natural foods that do not cause side effects and provide for protective action. These substances include pectin, safe natural detoxifying agents that remove toxins from the body.

When processing fruits and vegetables, pectin remains in the pomace thatis valuable for obtaining competitive products. There are techniques to produce pectin from plant raw materials by using enzymes that are harmless to health. The use of pectin concentrates in combination with dairy raw materials makes it possible to obtain biologically complete products with functional properties.

A concentrate containing 5 % of pectin was used in the study reported in this paper.

Raw materials were studied in terms of important indicators of their quality and safety, to determine their suitability and further use in yogurt technology. The formulations of yogurts have been devised-involving the application of low-esterified beet pectin concentrate, whose degree of etherification is 34.7 % and the complex-forming capacity is 290 mg Pb^{2+}/g. It has been established that the most optimal sample contains pectin in the amount of 0.5 % per milk mass. To preserve the vitamin composition, the yogurts were prepared under the classic pasteurization regime of 72 to 75 °C with a 20 s aging.

In the future, the industrial implementation of the devised technologies and formulations of pectin-containing dairy products could provide the population with products that have functional properties and contribute to the prevention of socially significant diseases

Keywords: beet concentrate, cow's milk, pectin-containing yogurts, pectin, pectin products

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1. Introduction

Given the current rapid development of industry, transport, intensive mining, active chemicalization of agriculture, the environmental conditions of human habitation are deteriorating dramatically: in the air, water, soil. Food contains an excess amount of environmentally harmful substances, including radionuclides, pesticides, heavy metal salts, and others [1, 2].

Thus, there is a clear need to devise a preventive diet designed to prevent the effects on the body of adverse factors of production, the environment, as well as risk factors for disease.

The desire to survive in difficult competition environments mobilizes industrialists to take non-standard decisions that make it possible to increase the range of products manufactured. The most effective concept is the creation of innovative dairy products that have a beneficial effect on the human body. Organoleptic indicators, appearance, consistency, and stability throughout the shelf life play a considerable role in the production of a competitive product. Pectin is often used as a structure-forming agent and a stabilizer of the consistency of various milk desserts, including yogurts. Pectin became especially importantin the period when information about its ability to form complex compounds was acquired. By forming insoluble complexes, pectins are able to remove toxic metals and long-lived (with a half-life of many decades) isotopes of strontium, cesium, etc. In addition to radioprotective and detoxifying properties, clinical studies have shown the capability of pectin to reduce allergic effects associated with the environmental situation, adjust metabolism and digestive function. In this case, low-esterified pectin substances demonstrate the best complex-forming properties. Such substances can improve the effectiveness of certain drugs, reduce their toxic effects on the body, and eliminate some side effects. In terms of its gelling ability, low-esterified pectinis somewhat inferior to pectins from apple and citrus, but, at the same time, has much better complex-forming properties, which is extremely important when making therapeutic and preventive products [3–6].

Thus, the use of low-esterified pectin in the production of dairy products opens wide prospects for the creation of biologically complete, fundamentally new safe foods with pronounced functional properties.

2. Literature review and problem statement

Papers [2, 3] emphasize the need to create functional products that would have a beneficial effect on the human body in fighting unfavorable environmental circumstances. It has been established that the manufacturing of functional products for people, including pectin substances in their formulation, exerts a beneficial effect on the body's resistance against environmental factors. Pollution of the environment by harmful substances (heavy metals, radionuclides) and their further penetration of the human body requires the creation of new products. This entails the creation of food with detoxifying properties through the introduction of pectin substances into their formulations. Pectin substances are able to cleanse the human body of harmful substances, without upsetting its overall balance. Pectin substances can interact with ions of various metals; when the human body is intoxicated with these metals, they are used as an excreting cleanser [1].

The main physiological property of pectin, which predetermines the use of it in the production of dietary foods, is the ability of pectin to bind and excrete from the body heavy metals and radionuclides. The mechanism of pectin related to metal removal is as follows. Getting into the gastrointestinal tract, pectin forms gels. When swollen, the mass of pectin dehydrates the digestive tract and, moving through the intestines, captures toxic substances. In the process of assimilation of food, the demethoxylation of pectin contributes to its transformation into polygalacturonic acid. Polygalacturonic acid is combined with certain heavy metals and radionuclides, resulting in insoluble salts that are not absorbed through the gastrointestinal mucosa and released from the body [7].

It should be emphasized that pectins are natural products and do not have toxic effects on the human body. The main effect of the therapeutic action of pectin is associated with the features of its chemical structure. The polymer chain of polygalacturonic acid, the presence of chemically active free carboxyl groups, and alcoholic hydroxyls contribute to the formation of strong insoluble complexes with polyvalent metals. These complexes, termed chelates, remove heavy metals and nuclides from the body. The literature reports evidence that the influence of pectins increases the antioxidant activity of the blood and liver tissues [8].

It has been established that the modified citrus pectin significantly increased the excretion of lead in the urine in adults [9, 10]; its use for children as a safe and harmless chelator is especially recommended.

The galactose structures on the macromolecule of pectin likely bind the protein complexes on the surface of the cancer cells, which are responsible for "sticking" to healthy tissues, and, thus, hinder the metastasis process. Pectin as a non-toxic immunomodulator is also considered by oncologists [12].

Due to the complex-forming properties, pectins are included in the diet of persons in the environment contaminated with radionuclides, who have contact with heavy metals [13, 14]. It has been established that the most effective at removing radionuclides and heavy metal cations are low-molecular pectins with a degree of etherification not higher than 25 %. The combination of this type of pectin with medicinal herbs has made it possible to create a new type of highly effective therapeutic and preventive products [15].

Pectin has a beneficial effect on cholesterol metabolism, is used in the prevention of atherosclerosis, reduces the amount of lipids and fatty acids in the blood; in vegetable and fruit diets, it is recommended to patients with impaired lipid metabolism (obesity). Lowering cholesterol levels in a person's blood reduces the risk of heart disease [16].

Basically, the pectin supplement gives a positive effect when it is consumed at least 6 g/day. However, on average, the functional level for effective manifestation is between 15 and 20 grams per day; this amount of pectin can reduce cholesterol by 11–12 %. A more impressive decline can be achieved in people with significantly elevated cholesterol levels, where dietary pectin can reduce whey cholesterol by 19 %. In combination with drugs, pectin reduces whey cholesterol by 31 % [17].

One of the most important biologically active properties of pectin-containing products is the complex-forming ability based on the interaction of pectin with heavy and radioactive metal ions. These properties of pectin are the base of the design of food products based on pectin-containing raw materials.

Modern advances in biochemistry, pectin production technology and its products make it possible to create a range of products for preventive, specialized and therapeutic nutrition by forming preset organoleptic, physical-chemical, energy, and therapeutic properties. Such products differ in chemical composition, food, energy and biological value, physical properties, the balance of food compositions, the content of certain nutrients. At the same time, a relevant current area is the creation and comprehensive study of pectin-containing products with different properties: sorption, nutritional, probiotic, etc. [18].

The technology of production of combined powdered pectin-containing concentrates of functional purpose from the pomace of table beetroot and apple has been developed. The resulting concentrates can be used as a basis for the production of functional foods and as an additional ingredient for their enrichment [19]. The best physiological effect of pectin is demonstrated in a hydrated form, in which the unique properties are preserved as much as possible. These products include juices, jams, confits, drinks, marmalade. The most convenient and effective form of use of pectin-containing products for preventive nutrition are drinks that are easily normalized, have a pleasant taste, and can be produced for any group of the population.

As a stabilizer, pectin substances are used in the production of yogurts, mayonnaise, margarine, butter [19]. In the composition of fruit and jelly fillings for dairy products, pectins give the products the necessary rheological properties. In fruit yogurts, pectin substances enhance the taste of the filler used. In drinking yogurt, highly-esterified citrus and apple pectins at low pH values protect milk proteins from denaturation when heat-treated. This contributes to making a product with optimal organoleptic properties without loss of quality in the process of long-term storage. Pectin substances are also used in the production of milk drinks in order to stabilize the consistency and increase their biological value. The use of pectin concentrates in combination with dairy raw materials – whole and skimmed milk, buttermilk, whey – makes it possible to obtain biologically complete products with good organoleptic characteristics and pronounced functional properties.

Pectin and vitamin C increase the degree of iron absorption, contribute to the biological effectiveness of meat compositions [20–22]. Based on the cited studies, a conclusion has been made on the feasibility of using pectins in the formulation of meat and bakery products. In these products, it is advisable to use pectin substances in composition with sources of iron and ascorbic acid, which enhances the therapeutic effect of the product.

The results of studying the effect of green pea pectin on the quality of finished products show the positive effect of pectin on the physical-chemical performance of bakery products. The maximum value of the indicators is achieved by introducing pectin in the amount of 0.3 % to the mass of flour. In products with 0.3 % pectin dosage, compared to control, the specific volume increases by 12.9 %, porosity – by 4.2 %, shape stability– by 12.5 %. Taking into consideration the consumption of pectin for preventive purposes (2 grams per day), 100 grams of developed buns provide for 10 % of the human need for pectin. This allows them to be positioned as functional products [23].

The review of literary sources shows that among the many issues currently facing humanity, one of the first places is taken by the problem of pollution of the environment by various chemicals – products of man-made products, heavy metals. Heavy metals with a wide range of biological effects are among the toxicants most dangerous to human health. One way to solve this problem, caused by pollution and the intake of the excess quantities of heavy metals and radionuclides into the human body, is to create the most consumed pectin-containing dairy products of detoxifying action.

When making pectin-containing functional products, ready-made highly-esterified pectins with high gel-forming ability are used.

The ability of pectins, especially low-esterified, to form low-soluble compounds with metal ions indicates the feasibility of their use in the production of dairy products with pronounced functional properties. One of the sources of low-esterified pectin is beet pomace, which is mainly used as animal feed or disposed of as industrial waste.

Given all the above data, there is a need to create a dairy product, in particular yogurts, using low-esterified beetroot pomace.

3. The aim and objectives of the study

The aim of this study is to devise a yogurt technology using low-esterified beet concentrate.

To accomplish the aim, the following tasks have been set:

– to determine the gel-forming, complex-forming ability, and food safety of pectin concentrate;

– to determine the quality and safety of raw materials;

– to devise formulations and technological modes of yogurt production using low-esterified beet pectin concentrate.

4. The study materials and methods

The objects of this study are cow's milk, a pectin concentrate from sugar beet of the "Avantage" variety, pectin-containing yogurt.

The gel-forming ability is defined by the method described in [24]. The Sosnovsky device measures the strength of a gel by the effort required to break through the gel, 10 mm thick, and is recorded by the indication of the gauge in mm Hgor g/cm^3 (1 mm Hg=1.32 g/cm^3=0.133 kPa).

The complex-forming ability is determined by the selectiveness factor of cation exchange $K_{M^{+}}^{M^{2+}}$, which characterizes the affinity of pectin molecules to bivalent cations [25, 26]. The largest values of selectivity coefficient are demonstrated by elements capable of forming acid-molecular complexes, as the mixed complexes are more stable [27]. For example, $K_{M^{+}}^{M^{2+}}$ for Cu^{2+}(3300), Pb^{2+} (2580) takes higher values than for Ca^{2+} (121) and Sr^{2+} (120).

The complex-forming ability of pectin extracts is determined by the amount of bound lead when treating the solution of pectin extract with a solution of basic lead acetic acid. For industrially produced pectins, the lead binding amount is (mg Pb^{2+} per gram of pectin): beetroot – 192–220, citrus – 67, apple– 58 [25].

The degree of etherification was determined by the method of conductometric titration [26, 28].

The quality of milk was determined by determining the general physical-chemical indicators: titratable acidity, the mass share of fat, NFDM protein, and water, density. We used standard methods to determine the quality indicators of milk.

Since the presence of calcium contributes to an increase in the solubility, viscosity, and rate of gelling of pectin substances with a low degree of etherification [29, 30], it was important to determine the amount of calcium in the raw materials. We determined the amount of calcium in milk by the titrimetric method [31].

The presence of antibiotics was determined by an express method. The MilkSafe™ 4BTSC antibiotic test was used (Chr. Hansen, Denmark). This is an express test for detecting the residues of beta lactam, tetracycline, streptomycin, and chloramphenicol in milk. The viscosity and elasticity of the raw materials were determined by the ViscoStarPlus rotary viscosimeter (Fungilab S. A., Spain) according to Brookfield standard.

The antioxidant activity in the raw materials and products was determined at the device "TsvetYauza-01-AA" (NPO "Himautomatica", RF), based on the amperometry method [32, 33].

The content of carotene was determined by GOST P 54058-2010.

The mass shares of casein and whey protein in milk were determined by the casein and Kjeldahl deposition method, using an automated DK6 combustion furnace (VELPSCIENTIFICA, Italy) and a steam distillation device (VELPSCIENTIFICA, Italy) [34, 35].

To prove the safety of developed products, important are such indicators as the content of heavy metals, pesticides, the number of mesophilic aerobic and optional-anaerobic microorganisms, etc.

Heavy metals content was determined by the method of atomic-absorption spectroscopy (ASS) at the spectrometer with electric atomization "KVANT-X.ETA-T" (NPF "Cortec", RF).

The mass concentration of chloro-organic pesticides (α-, β- and γ-isomers hexachlorocyclohexane (HCCH), heptachlor, 4.4"-dichlordiphenyltrichloroethan (DDT)) was determined by gas-liquid chromatography using the analytical stationary gas chromatographer "Crystallux-4000M" (NPF "Meta-Chrom", RF) with an electronic capture detector and "NetChrom" software (NPF "Meta-Chrom", RF) [39, 40].

The content of aflatoxin B_1 was determined by the method of thin-layer chromatography (TLC). The method is based on the extraction of aflatoxin $B_1$from the sample of the product by chloroform, cleaning the extract from the interfering substances with the help of column chromatography. The mass concentration of aflatoxins is measured by thin-layer chromatography, visually determining the amount of matter in a spot [41].

The number of mesophilic aerobic and facultative anaerobic microorganisms (QMAFAnM) was determined by GOST 32012-2012, GOST 10444.15-94. Bacteria of the group of *E. coli* – GOST 31747-2012. The number of lactic acid bacteria was determined by GOST 33951-2016. Yeast and mold in yogurts were determined by GOST 10444.11-13.

5. Results of studying the quality and safety of raw materials and finished pectin-containing yogurts

5. 1. Determining the gel-forming, complex-forming ability, and the food safety of pectin concentrate made from sugar beet

To assess the quality of pectin concentrate made from sugar beet, variety "Avantage", its gel-forming and complex-forming abilities were determined. Table 1 demonstrates that the degree of etherification was 34.7 %, the complex-forming capacity of pectin-containing concentrate was 290 mg Pb^{2+}/g.

The results of the microbiological study of pectin concentrate from the "Avantage" variety sugar beet are given in Table 2.

Table 1

The gel-forming and complex-forming capacities of pectin concentrate made from the "Avantage" variety sugar beet, %, in terms of absolutely dry mass

No.	Indicator name	Pectin concentrate from the "Avantage" variety sugar beet
1	Esterification degree, %	34.7
2	Complex-forming capacity, mg Pb^{2+}/g	290

Table 2

Safety indicators of pectin concentrate from the "Avantage" variety sugar beet

Indicator name, unit	Research method documentation	Actual results
Microbiological indicators:		
QMAFAnM, CFU/g, not exceeding	GOST 10444.15-94	not detected
Coliform bacteria per 1 g of product	GOST 31747-2012	not detected
Heavy metals, mg/kg:		
lead	AAC method	0.07370.005
cadmium		0.00170.00004
mercury		not detected
arsenic		not detected
Pesticides, mg/kg:		
HCCH (α-, β-, γ-isomers)	GOST 23452-2015	not detected
Heptachlor		not detected
DDT and its metabolites		not detected

The study results show that the resulting product meets the requirements of CU TR 021/2011 Technical Regulations of the Customs Union "On Food Safety" according to all microbiological indicators.

Table 2 gives the results from studying some safety indicators. For the pectin concentrate made from the "Avantage" variety sugar beet, the following safety indicators were determined: the content of toxic elements (lead, cadmium, arsenic, mercury), pesticides. The study results showed their safety and compliance with the requirements set by CU TR 021/2011.

5. 2. Results of determining the quality and safety of raw materials

To make dairy products for functional purposes, it is necessary to select quality and safe raw materials. The quality, safety, and content of biologically valuable substances in the milk from cows in the Almaty oblast regions vary. The content of these substances depends on the breed, habitat, and quality of feed, etc.

Average samples were taken from the samples of milk collected from private farms from sixteen regions. The following regions were chosen: Yenbekshikazakhskiy, Zhambylskiy, Balkhashskiy, Iliyskiy, Panfilovskiy, Kerbulakskiy, Aksuskiy, Alakol'skiy, Yeskel'dinskiy, Karatal'skiy, Kegenskiy, Koksuskiy, Rayymbekskiy, Sarkanskiy, Talgarskiy, Uygurskiy. We studiedthe selected average milk samples for the quality and naturalness in line with GOST P 52054-2003, which sets the requirement for natural cow's milk as a raw material.

Table 3 gives the physical-chemical indicators of the milk from cows in the Almaty oblast.

Table 3

Physical-chemical indicators of milk from cows in Almaty oblast

No.	Sample	Acidity, °T	Fat mass share, %	Protein mass share, %	NFDM mass share, %	Ca content, mg/100 g	Density, kg/m^3
1	Enbekshikazakh region, Esik	16	4.80	1.60	9.06	240	1,026
2	Zhambyl region, Uzun-agash	17	6.25	2.79	8.14	300	1,031
3	Balkhash region, Bakanas	17	6.54	2.88	8.06	220	1,025
4	Ili region, Otegen-batyr	18	3.99	3.35	8.86	300	1,030
5	Panfilov region, Zharkent	16	6.62	2.70	7.38	200	1,026
6	Kerbulak region, Sary-ozek	18	8.66	2.95	8.76	300	2,559
7	Aksu region, Zhansugurov	17	6.53	2.38	8.15	230	1,024
8	Alakol region, Usharal	17	4.91	3.15	8.61	280	1,032
9	Eskeldy region, Karabulak	17	6.67	3.50	7.01	210	1,029
10	Karatal region, Ushtobe	18	8.73	2.98	8.54	270	2,553
11	Kegen region, Kegen	16	6.55	2.81	8.16	210	1,024
12	Koksu region, Balpyk-Bi	18	4.01	3.30	8.76	290	1,031
13	Raiymbek region, Narynkol	15	6.65	2.72	7.35	220	1,027
14	Sarkan region, Sarkan	17	8.76	2.93	8.67	250	2,557
15	Talgar region, Talgar	17	4.23	3.47	8.95	220	1,036
16	Uygur region, Chundzha	18	6.63	2.71	7.33	280	1,025

Dry matter includes all components of milk, determining its common nutritional and technological properties. In this regard, an assessment of the quality of cow's milk for the content of dry matter is particularly important and necessary. The mass proportion of dry matter in the milk of cows from the Almaty oblast ranges from 7.01 to 9.06 %, the difference in the content of nonfat dry milk solids (NFDM) is 2.05 %. At the same time, Table 3 shows that the content of NFDM is the largest in the milk from the Enbekshikazakhsky region, but in terms of the mass share of protein, it demonstrated the lowest indicator.

To assess the naturalness of milk, density is important, which depends directly on its chemical composition. We established significant superiority in terms of fat content in the milk from Sarkan region – 8.76 %, Karatal – 8.73 %, Kerbulak – 8.66 %. As regards the protein content, it was established that in the milk from Eskeldin region, its content is 3.50 %, Talgar region – 3.47 %, Ili region – 3.35 %, Koksu region – 3.30 %, Alakol region – 3.15 %.

Milk acidity is an important indicator of its quality and freshness and is due to the presence of phosphorous-acid and lemon-acid salts in it, the acidic nature of proteins, and carbon dioxide soluble in milk. The titrated acidity of fresh milk should be within 16 and 18 °T. Proteins account for 3–4 °T; carbon dioxide – 1–2 °T. In our studies, the acidity of milk was within the specified limits.

The calcium content was also determined. The milk from Jambyl, Ili, Kerbulak regions demonstrated the largest calcium content of 300 mg/100 g; Koksu region– 290 mg/100 g; Alakol and Uyghur regions – 280 mg/100 g; Karatala region– 270 mg/100 g.

All selected milk samples met the standards of quality milk. We selected the regions to purchase raw materials in order to produce functional dairy products.

The least important indicator of quality in the creation of dairy products are casein and whey protein. Casein, a complex protein, the main component of cow's milk, is the basis for the production of curds and cheese. In the stomach, casein acts like gluten, that is, connects the contents into clots, preventing digestion. Casein promotes long-term muscle saturation with amino acids, so it is recommended by experts as a food additive when creating functional products. Casein is formed from the precursor of case inogen by curdling milk with the help of lactic acid bacteria and, along with egg white, accelerates cell growth. In this regard, the mass proportions of casein and whey protein were identified [34, 35] in the selected milk samples; the results are given in Table 4.

Based on the results of our study, the percentage of casein in the total protein content was calculated. According to casein content, cow's milk from the following regions dominated: Karatal– 83.22 %, Eskeldin– 78.0 %, Kerbulak– 75.80 %, Uyghur – 74.9 %, Ili – 73.35 %,Aksu– 71.42 %.

Another indicator responsible for the preservation of raw materials before processing is bacterial insemination of milk. Therefore, the selected average samples of milk were tested by the express method for insemination; the results are given in Table 5.

According to GOST P 51331-99, cow's milk is used in the production of yogurts that is not lower than class II. It was determined that milk from Balkhash, Alakol, Eskeldinsky, Karatal, Sarkansky, and Uyghur regions belongs to milk class III. All other samples, in terms of bacterial insemination, belonged to milk classes I and II. To reduce the risk of microbiological contamination of the finished product, it was decided to select milk of class I from four regions. Milk samples selected from other areas were suitable for use in other dairy products.

Next, the presence of residues of beta lactam, tetracycline, chloramphenicol, and streptomycin in milk was determined, based on immunochromatography technology on colloidal gold, using the MilkSafe™ 4BTSC tests to determine the antibiotics. The test results are given in Table 6.

Table 4

The content of casein and whey protein in cow's milk from regions of Almaty oblast

No.	Sample	Casein mass share, %	Mass share of whey protein, %	Percentage of casein in total protein content, %	Percentage of whey protein in total protein content, %
1	Enbekshikazakh region, Esik	0.71	0.89	44.19	55.81
2	Zhambyl region, Uzun-agash	1.60	1.07	61.58	38.42
3	Balkhash region, Bakanas	1.81	1.07	62.78	37.22
4	Ili region, Otegenbatyr	2.46	0.89	73.35	26.65
5	Panfilov region, Zharkent	1.63	1.07	60.30	39.70
6	Kerbulak region, Sary-ozek	2.24	0.71	75.80	24.20
7	Aksu region, Zhansugurov	1.70	0.68	71.42	28.57
8	Alakol region, Usharal	1.76	1.39	55.87	44.12
9	Eskeldy region, Karabulak	2.73	0.77	78.0	22.0
10	Karatal region, Ushtobe	2.48	0.5	83.22	16.77
11	Kegen region, Kegen	1.61	1.20	57.29	42.70
12	Koksu region, Balpyk-Bi	2.23	0.49	67.57	32.42
13	Raiymbek region, Narynkol	1.72	1.0	63.23	36.76
14	Sarkan region, Sarkan	1.71	1.22	58.36	41.63
15	Talgar region, Talgar	2.05	1.42	59.07	40.92
16	Uygur region, Chundzha	2.03	0.68	74.90	25.09

Table 5

Determining the bacterial insemination of milk

No.	Sample	Discoloration rate	Number of bacteria per ml of milk	Milk class and estimate
1	Enbekshikazakh region, Esik	1 to 3 hours	to 4 million	II, satisfactory
2	Zhambyl region, Uzun-agash	1 to 3 hours	to 4 million	II, satisfactory
3	Balkhash region, Bakanas	10 min to 1 hour	to 20 million	III, poor
4	Ili region, Otegenbatyr	1 to 3 hours	to 4 million	II, satisfactory
5	Panfilov region, Zharkent	over 3 hours	to 500 thousand	I, good
6	Kerbulak region, Sary-ozek	over 3 hours	to 500 thousand	I, good
7	Aksu region, Zhansugurov	1 to 3 hours	to 4 million	II, satisfactory
8	Alakol region, Usharal	10 min to 1 hour	to 20 million	III, poor
9	Eskeldy region, Karabulak	10 min to 1 hour	to 20 million	III, poor
10	Karatal region, Ushtobe	10 min to 1 hour	to 20 million	III, poor
11	Kegen region, Kegen	over 3 hours	to 500 thousand	I, good
12	Koksu region, Balpyk-Bi	1 to 3 hours	to 4 million	II, satisfactory
13	Raiymbek region, Narynkol	over 3 hours	to 500 thousand	I, good
14	Sarkan region, Sarkan	10 min to 1 hour	to 20 million	III, poor
15	Talgar region, Talgar	1 to 3 hours	to 4 million	II, satisfactory
16	Uygur region, Chundzha	10 min to 1 hour	to 20 million	III, poor

Table 6

Results of determining the presence of antibiotics in cow's milk from regions of the Almaty oblast

No.	Sample	Beta-lactams	Tetracyclines	Streptomycin	Chloramphenicol
1	Enbekshikazakh region, Esik	negative	negative	negative	negative
2	Zhambyl region, Uzun-agash	negative	negative	negative	negative
3	Balkhash region, Bakanas	negative	negative	negative	negative
4	Iliregion, Otegenbatyr	negative	negative	negative	negative
5	Panfilov region, Zharkent	negative	negative	negative	negative
6	Kerbulak region, Sary-ozek	negative	negative	negative	negative
7	Aksu region, Zhansugurov	negative	negative	negative	negative
8	Alakol region, Usharal	negative	negative	negative	negative
9	Eskeldy region, Karabulak	negative	negative	negative	negative
10	Karatal region, Ushtobe	negative	negative	negative	negative
11	Kegen region, Kegen	negative	negative	negative	negative
12	Koksu region, Balpyk-Bi	negative	negative	negative	negative
13	Raiymbek region, Narynkol	negative	negative	negative	negative
14	Sarkan region, Sarkan	negative	negative	negative	negative
15	Talgar region, Talgar	negative	negative	negative	negative
16	Uygur region, Chundzha	negative	negative	negative	negative

Our study has found that all selected milk samples demonstrated a negative result for these types of antibiotics. In other world, milk samples were suitable for use in dairy technology.

5. 3. Devising pectin-containing yogurt technology

A range of pectin-containing yogurts has been developed using low-esterified beet pectin concentrate according to the formulations given in Table 7. A method of full-factor experiment [47] was used to model the formulation of yogurts in terms of the amount of pectin, the organoleptic and quality indicators. The conditions of correctness of the use of statistical modeling methods were checked against statistical criteria. The normal distribution of all the factors involved in the simulation was acquired from software Statistica 10.0.

The addition of low-esterified beet concentrate makes it possible to use the product to detoxify heavy metals from the body. When pectin is added in the amount of 0.5 %, the shelf life of yogurt is increased to 15 days, by stabilizing the acidity of the product and increasing the strength of the milk-protein gel clot. The introduction of pectin to some extent suppressed the biochemical activity of sourdough microflora, the products with the addition of pectin demonstrated a lower titrated acidity than that in control.

The quality and safety indicators of pectin-containing yogurts No. 1–8 were determined, in accordance with the requirements from the technical regulations of the Customs Union 033/2013 "On the safety of milk and dairy products" No. 6, 7 as of 09.10.2013 (Table 8).

Table 7

Formulations of pectin-containing yogurts containing beet pectin concentrate

Ingredient	Formulation							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
Whole milk with a fat mass share of 3.2%, kg	684.4	684.4	684.4	684.4	684.4	684.4	684.4	684.4
Skimmed milk, kg	145.24	145.24	145.24	145.24	145.24	145.24	145.24	145.24
Fruit and berry fillers, kg	96.4	63	79.6	96.4	48.76	64.6	82.16	48
Sugar, kg	24.36	24.36	24.36	24.36	38.6	39.36	38.6	39.36
Beet pectin concentrate, kg (% pectin to milk mass)	49.6 (0.3%)	83 (0.5%)	66.4 (0.4%)	49.6 (0.4%)	83 (0.5%)	66.4 (0.4%)	49.6 (0.3%)	83 (0.5%)
Concentrated culture Yoflex-Harmony 1.0 milk, U	200	200	200	200	200	200	200	200
Yield, without losses, kg	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Table 8

Indicators of the quality and safety of prepared pectin-containing yogurts performulation

Indicator name, unit	Yogurt formulation							
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Physical-chemical indicators:								
viscosity, mPa*s	348	357	344	367	340	345	348	356
elasticity, %	23	25	23	25	22	23	23	24
fat, %	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
protein, %	10	10	10	10	10	10	10	10
carbohydrates, %	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
pH	4.6	4.6	4.7	4.6	4.7	4.6	4.6	4.6
Anti-oxidant content, mg/100 g	18.07±0.1	19.14±0.1	20.31±0.1	21.30±0.1	17.97±0.1	18.99±0.1	19.93±0.1	21.58±0.1
β-carotene, mg/100 g	0.51±0.01	0.93±0.01	1.41±0.01	1.92±0.01	0.33±0.01	0.59±0.01	0.98±0.01	1.23±0.1
Toxic elements, mg/kg:								
arsenic	not detected	not detected	not detected	not detected	not detected	not detected	not detected	not detected
cadmium	not detected	not detected	not detected	0.005±0.0001	not detected	not detected	not detected	0.003±0.0001
lead	not detected	not detected	not detected	not detected	not detected	not detected	not detected	not detected
mercury	not detected	not detected	not detected	not detected	not detected	not detected	not detected	not detected
Pesticides, mg/kg:								
HCCH (α, β, γ – isomers)	not detected	not detected	not detected	not detected	not detected	not detected	not detected	not detected
DDT and its metabolites	not detected	not detected	not detected	not detected	not detected	not detected	not detected	not detected
Myco-toxins, mg/kg:								
aflatoxin B1	not detected	not detected	not detected	not detected	not detected	not detected	not detected	not detected
Microbiological indicators on day 1:								
Lactic acid bacteria, CFU/g	$9.8*10^8$	$7*10^8$	$8.7*10^8$	$11*10^8$	$7.6*10^8$	$8.6*10^8$	$9*10^8$	$9.8*10^8$
Yeast and mold, CFU/g	not detected	not detected	not detected	not detected	not detected	4	5	2
Microbiological indicators on day 15:								
Lactic acid bacteria, CFU/g	$2.3*10^7$	$3.4*10^8$	$5*10^7$	$6.3*10^7$	$3*10^8$	$9*10^7$	$3*10^7$	$5.6*10^8$
Yeast and mold, CFU/g	not detected	not detected	not detected	not detected	not detected	30	38	33

All samples of pectin-containing yogurts were tested for the physical-chemical, microbiological, and safety indicators. The value of the rheological indicators ranged from 340 mPa·sec to 367 mPa·sec, depending on the amount of beet concentrate added and on the type of fruit and berry fillers (raspberry, strawberry, apricot, cherry, peach, cherry, raspberry, apricot).In addition, the type of fillers affected the content of antioxidants and beta carotene, which were detected in yogurts in the amount of 17.9 to 21.5 mg/100 g, from 0.5 to 1.9 mg/100 g, respectively. In terms of safety indicators, they met the required standards. The number of lactic acid bacteria was kept at least $2.3 \cdot 10^7$over 15 days. The largest number of lactic acid bacteria remained in yogurts prepared according to formulations No. 2, 5, 8, which corresponds to 0.5 % of the pectin of beet concentrate per the mass of milk.

The introduction of sufficient amounts of hydrocolloid concentrates, which have the ability to stabilize structural and mechanical characteristics, has improved the moisture-retaining capacity of yogurt in the process of storage. That hasmade it possible, provided microbiological purity, to increase the shelf life during which the consistency of the product is maintained without deterioration of the original quality.

The production of fruit and berry yogurt with 2.5 % of fat includes the acceptance and evaluation of the quality of cow's milk, collected to be no lower than grade 2 by GOST P 51331-99, with acidity not exceeding 19 °T. The whole milk with a mass share of fat of 3.2 % is supplemented with skimmed milk. Milk is pasteurized and then cooled. The technological scheme of pectin-containing yogurt is shown in Fig. 1.

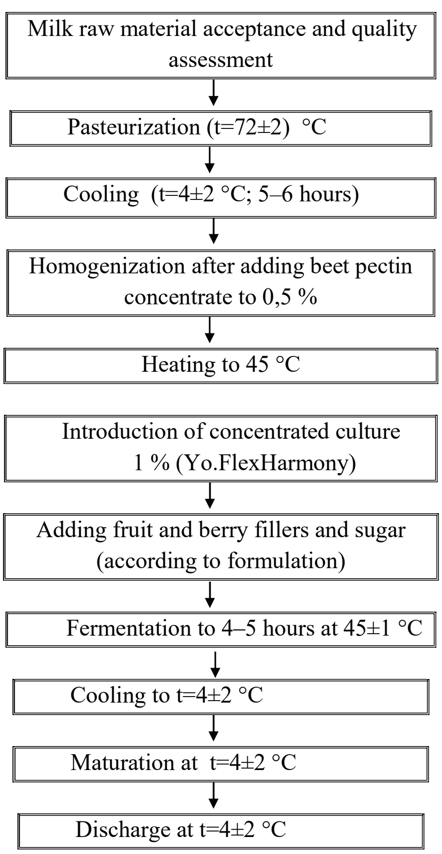

Fig. 1. Technological scheme of pectin-containing yogurt production

The prepared milk is supplemented with beet pectin concentrate at the predefined calculation (0.5 % of pectin to the mass of milk); the mixture is homogenized and heated to a temperature of 45 °C. Next, the YoFlex Harmony 1.0 sourdough is added. It includes thermophilic lactic acid streptococcus and lactobacillus: Lactococcus thermophilus, Lactococcus delbrueckii subsp.bulgaricus, as well as Lactobacillus delbrueckii subsp. lactis, in different combinations. To expand the range and reduce the amount of added sugar (according to the formulation), fruit and berry fillers are introduced. The finished mixture is fermented for up to 4–5 hours at 45±1 °C. After fermentation, the yogurt is cooled and stirred to ensure the smoothness of the clot, then it is packaged.

6. Discussion of results of studying the impact of low-esterifiedpectin on the quality of yogurts

Our research has made it possible to justify the sequence and parameters of technological operations in the production of pectin-containing yogurts using low-esterified beet pectin concentrate.

Milk studies have been conducted on important qualitative indicators and safety indicators, to determine its suitability and further use in the technology of yogurts and other dairy products.

When studying the quality of the raw materials (Table 3), the mass share of dry matter in the examined milk samples ranged from 7.01 to 9.06 %, the difference in the content of NFDM is 2.05 %. The largest fat content was demonstrated by milk from Sarkan, Karatal, Kerbulak regions, from 8.66 to 8.76 %. The high protein content was found in the samples of milk from Eskeldin, Talgar, Ili, Coksusk, Alakol regions compared to other areas, from 3.15 to 3.5 %, respectively.

Gel-forming and other properties of pectins depend on the mass proportion of pectin substances and calcium ions in foods. A prerequisite for the properties of pectin in the product is the presence of a minimum of 50 mg of calcium ions per 0.5 g of pectin substances [26, 30]. In the milk studied, the high calcium content, ranging from 270 to 300 mg/100 g, was found in the samples from Jambyl, Ili, Kerbulak, Coksusk, Alakol, Uyghur, Karatal regions.

MilkSafe™ 4BTSC antibiotic tests were used to determine the presence of beta lactam, tetracycline, chloramphenicol, and streptomycin in milk (Table 6), based on the technology of immunochromatography on colloidal gold. It was established that all the samples of milk selected demonstrated a negative result for these types of antibiotics.

Thus, our study into the quality of milk has shown that milk from Panfilovsk, Kerbulak, Kegen, Raimbek regions can be used to make yogurts. The remaining milk samples from other areas were suitable for use in other dairy products. All selected milk samples met the standards of quality milk. Regions were selected to purchase raw materials in order to produce functional dairy products.

We have devised formulations (Tables 7, 8) for pectin-containing yogurts using low-esterified beet pectin concentrate (etherification degree, 34.7 %, complex-forming capacity, 290 mg Pb^{2+}/g). It has been established that in terms of all quality indicators the most optimal is a sample with a pectin concentrate content at the rate of 0.5 %of pectin per milk mass.

Based on the research, a technological scheme (Fig. 1) for the production of fruit-berry yogurt with a 2.5 % fat content was prepared, involving the introduction of beet pectin concentrate.

The production technology scheme includes the acceptance and evaluation of the quality of cow's milk; pasteurization of milk; cooling; introduction of beet pectin concentrate; homogenization; heating to a temperature of 45 °C. YoFlexHarmony 1.0 starter cultures are added to the finished mixture with pectin concentrate thermophilic lactic acid streptococci and lactobacilli. The use of fruit and berry fillers makes it possible to expand the range of yogurts and reduce the amount of sugar added in line with a formulation. The mixture is fermented for up to 4–5 hours at 45±1 °C, followed by cooling and stirring the clot. Finished yogurt with the addition of beetroot pectin concentrate is sent to packaging.

The formulations were devised considering that they should be classified as functional products, therefore, the content of the functional ingredient, in this case, pectin, should be between 10 and 50 % of the daily physiological intake [48]. The daily intake of pectin for preventive nutrition is 2–4 grams [49]. Adding 0.5 %of pectin makes it possible to apply this technology of yogurts in a functional diet.

The technology of dairy products, beverages, including yogurts, mostly involved ready-made commercially available pectins and pectin-based products. As an alternative source of soluble dietary fiber for enriching yogurt and producing a functional product with potential health effects, finished commercially available high-esterified citrus pectin, apple pectin, and others are used [50–52]. The extracted beetroot pomace pectin is applied in some foods, such as tomato ketchup sauce, as a thickener or an agent that enhances viscosity. However, it is not able to form dense gels in food compared to commercially available citrus pectin, so it is mainly used for fodder purposes [53]. In the complex of water and oils, they had a smaller size of oil droplets and improved stability when stored in an acidic environment. The decomposition of β-carotene in emulsion during storage was more obviously slowed down when beetroot pectin was added. It has been shown [16, 54] that pectins high in methoxy group have a high ability to bind water, and low-methoxy-group pectin has radio-protective properties. In this regard, the use of low-esterified pectin from beetroot pomace makes it possible to attribute the yogurts prepared according to the proposed technology to specialized dairy drinks.

For the full pattern of proving the functionality of the devised products, it is necessary to conduct preclinical tests, which would make it possible to fully reveal the detoxifying, functional properties of yogurts with the addition of beet pectin.

7. Conclusions

1. Our experimental study has identified the gel-forming, complex-forming abilities of pectin concentrate made from the "Avantage" variety sugar beet. It was established that the degree of esterification of pectin-containing beet concentrate was 34.7 %, its complex-forming capacity – 290 mg/Pb^{2+}/g, which allows it to be used as a corrector of heavy metals.

2. The quality and safety of the raw materials were determined. Our study has found that all selected milk samples had a negative result in terms of the antibiotics beta lactam, tetracycline, chloramphenicol, and streptomycin. The mass share of dry matter in the milk samples was between 7.01 and 9.06 %, the difference in the content of NFDM – 2.05 %. The titrated acidity ranged between 16 and 18 °T, which corresponded to the required quality of milk. As a result, milk samples from four regions were selected for use in yogurt production technology.

3. The study reported in this paper has made it possible to justify the sequence and parameters of technological operations in the production of pectin-containing yogurts using low-esterified beet pectin concentrate. The optimal formulations forpectin-containing yogurts with low-esterified beet pectin concentrate with a content of 0.5 % to milk mass have been devised. The resulting products comply with the requirements set by CU TR 021/2011 Technical regulations of the Customs Union on Food Safety. The shelf life of pectin-containing yogurts has been extended to 15 days.

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