

UDC: 637.146.34:635.07-026.656:604

DEVELOPMENT OF HEALTHY SOUR-MILK BEVERAGES WITH THE USE OF NATURAL PLANT NANOADDITIVES

DOI: <https://doi.org/10.15673/fst.v13i4.1566>

Article history

Received 05.06.2019
Reviewed 27.06.2019
Revised 24.09.2019
Approved 03.12.2019

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Cite as Vancouver style citation

Pavlyuk R, Pogarskaya V, Balabai K, Kravchuk T, Pogarskiy A. Development of healthy sour-milk beverages with the use of natural nanoadditives. Food science and technology. 2019; 13(4):127-137. DOI: <https://doi.org/10.15673/fst.v13i4.1566>

Цитування згідно ДСТУ 8302:2015

Development of healthy sour-milk beverages with the use of natural nanoadditives / Pavlyuk R. et al. // Food science and technology. 2019. Vol. 13, Issue 4. P. 127-137 DOI: <https://doi.org/10.15673/fst.v13i4.1566>

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Introduction. Formulation of the problem

Today, one of the priority areas in healthy nutrition throughout the world is development of functional health-improving products [1-3]. Special attention is paid to combined sour-milk and plant products that are in demand in different countries [4,5]. Low-calorie milk-herbal beverages, in particular bio-yoghurts with fruit and vegetable flavour enhancers, prebiotics, whey, etc. are especially preferred [6]. However, different food

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Abstract. The technology of healthy products (bio-yoghurts with unique characteristics) has been developed. Unlike other beverages, the new products have a high content of natural biologically active substances – phytochemicals of fruits and vegetables (carrots, unpeeled lemons, apples, Jerusalem artichokes), in particular, β -carotene, phenolic compounds, tannins, ascorbic acid, which have high antioxidant and immunomodulating properties. Besides, the new products are high in prebiotic substances – soluble pectic substances, cellulose, inulin, and proteins. The latter act in bio-yoghurts as natural thickeners and structure-formers, which makes it unnecessary to use food additives and synthetic ingredients when manufacturing bio-yoghurts. The innovative feature of bio-yoghurt production technologies is the use of nanosized cryogenic additives from fruit and vegetable raw materials. These additives contain a record mass fraction of biologically active substances (BAS) – 2.5–4.5 times as much as in the original fresh raw materials. Their production is based on a complex cryogenic action upon the raw materials, with the use of liquid and gaseous nitrogen (shock freezing), and cryodestruction into finely dispersed particles. When used in the manufacture of bio-yoghurts, these cryoadditives enrich them with natural BAS, act as structure-formers, texture-stabilisers, and colourants. Phytoextracts from natural spices and medicinal plants (echinacea, coriander, melilot, oregano) have also been included in the recipes and technology of the new-developed bio-yoghurts to enrich them with BAS and extend their shelf life. As the basis to produce sour-milk bio-yoghurts, whey was used. The new types of bio-yoghurts exceed other known types by the BAS content and have twice as long shelf life in comparison with the control samples. The technological modes of bio-yoghurt production have been tested on test-bench semi-industrial equipment. It has been recommended to introduce the new yoghurts into production at large food enterprises, in cafés and restaurants, and in individual nutrition.

Keywords: bio-yoghurts, fruit and vegetable nanoadditives, healthy food, natural biologically active substances, extracts, cryoadditives, nanobeverages.

additives (thickening and flavouring agents, colourants, etc.), that affect adversely the human body, are used in manufacturing these products, too [7,8]. That is why, there is a never-stopping search for high quality natural additives that are high in BAS and can strengthen the body's defences. Scientists and businesspeople in the leading countries of the world (Japan, the USA, Germany, the Netherlands, and others) are working to create high quality plant additives and bio-yoghurts containing them as fillings [5,9,10].

Analysis of recent research and publications

In the leading countries of the world, combined milk-herbal food and beverages are used as health-promoting products [2,3,6].

Combined sour-milk products (bio-yoghurts, bio-kefirs, curd snacks, etc.) are among the most important immune-enhancing and health-promoting products [1,5,6]. It is well-known that human immunity by 80% depends on the state of the intestines. Dairy products contain beneficial lactic acid bacteria that support the health of the human intestines. Among these products, the most popular ones in many countries are milk-based beverages – bio-yoghurts. The main disadvantages of these products are the low BAS content and the presence of various food additives in their composition [11-13]. An analysis of the literature data has shown that the objective difficulties in the production of sour-milk beverages, bio-yoghurts, are related to:

- the lack of high quality natural plant fillings (from fruits and vegetables) and extracts from medicinal and spice-aromatic plants to enrich yoghurts with natural BAS [14,15];

- the use of various artificial food additives (stabilisers, structure-forming and flavouring agents, colourants, gelling agents, thickeners, etc.) that are harmful to people [14-16];

- the use of low-quality fruit and vegetable fillings, and the low BAS content (fruit spread, precooked fruit mass, frozen fruit and vegetables, etc.) [14-16].

The use of these additives and fillings of poor quality in bio-yoghurts results in obtaining low-quality products. Consuming them does not strengthen the body's natural defences, and can cause allergies and diseases.

Research works on the development of new yoghurts are mainly focused on how different additives effect on their physico-chemical and organoleptic characteristics [17-19], in particular, on those of synbiotic sour-milk bio-yoghurt obtained from soybean with the use of hydro-soluble salt extract (10%), fructooligosaccharides (3%), sucrose (12%), and the prebiotics *Paracasei* and *Lactobacillus rhamnosus* (5×10^6 CFU/ml) [17]. In [18], it was studied how additives effected on the sensory and physico-chemical parameters of frozen yoghurt fortified with sea buckthorn berries and prebiotics. A number of works are devoted to how bio-yoghurts, including frozen yoghurts (an alternative to ice-cream) can be enriched by adding various berries, in particular black currants and gaultheria (salal) [18-20], orange waste [12], Moringa berries [20]. These works, too, mainly considered the physico-chemical and organoleptic parameters of the products. A lot of studies are devoted to using various thickeners in bio-yoghurt production, such as carrageenan, xanthan [11,12], maize starch [11], prebiotics, in particular, rice bran [21].

Thus, to solve these problems and shortcomings in production of high-quality immune-enhancing combined bio-yoghurts, we need fundamentally new approaches, ideas, innovations.

As a possible solution to these problems, it was suggested to use the specially developed natural frozen horticultural nanoadditives [5,9,10] and nanoextracts from natural spices and non-traditional medicinal plants (NMP) [5,21]. It was proposed to use fruit and vegetable nanoadditives in bio-yoghurts as natural fortifiers enriching them with BAS, as their structure-forming agents, colourants, and texture stabilisers [21]. Nanoextracts were used in the production of bio-yoghurts to enrich them with BAS and prolong their shelf life [5,21,23]. The fruit and vegetable nanoadditives suggested have no comparable equivalents, are by 70% nanosized, and have unique properties [5,21]. The BAS and prebiotic content of fruit and vegetable nanoadditives is 2.5–5 times as high as the quality of fresh raw materials. The use of these nanoadditives makes it unnecessary to use traditional food additives and synthetic ingredients when manufacturing bio-yoghurts. When nanosized fine-dispersed fruit and vegetable cryoadditives and extracts from spices and NMP are used to make bio-yoghurts, the texture-formation and biochemical, enzymatic, and physico-chemical processes will be somewhat different from those observed when using traditional food additives. This requires more research.

A promising direction in the production of new types of bio-yoghurts is using whey as their basis. It is a by-product of making sour milk cheese, hard rennet cheeses, and milk protein concentrates, and is a secondary raw material resource of dairy enterprises. Whey is a source of essential amino acids and B vitamins. It is a unique product with a natural combination of vital mineral compounds that can maintain the body's water-salt balance, increase its resistance to disease, improve physiological processes, refresh, and quench thirst. Substances dissolved in whey, compared to those in milk, are more easily absorbed by the body, since electrolytes from aqueous solutions diffuse faster than from fat emulsions [5].

Despite the beneficial properties of whey, its rational use still remains a problem worldwide, because whey quickly spoils and requires immediate processing or disposal. A lot of enterprises cannot fully process the whey remaining after the production cycle. So, it is fed to livestock or drained as sewage, which has a disastrous impact on nature.

The main component of whey solids is lactose, its mass fraction being over 70%. A feature of lactose is its slow hydrolysis in the intestine, which restrains the fermentation processes, normalises the life of beneficial intestinal microflora, slows down decay and gas formation. Besides, milk sugar is least used in the body to produce fat. Whey is a low-calorie product with a solids content of about 5%. That is why, whey and whey-based products are traditional and

indispensable in the diet of elderly and overweight people, and of those with low physical activity [5].

The use of whey as a basis for combined sour-milk beverages seems to be the most affordable and appropriate. Today, there are almost no whey-based drinks on the Ukrainian market. Their technologies and formulations are under development or still to be implemented. Usually, to improve the taste and enhance the nutritional and biological value of whey in beverages, manufacturers add sugar, fruit and berry juices and syrups, aromatic spices, vitamins, protein supplements of plant and animal origin, other fillings [5].

The purpose of the work is to develop an innovative technology of health-promoting sour-milk beverages – bio-yoghurts high in BAS, with the use of natural cryogenically frozen horticultural nanoadditives and nanoextracts from natural spices and medicinal plant raw materials (MPRM).

To achieve this goal, it was necessary to achieve the following **tasks**:

- to study the quality, the amino acid composition, and the amino acid score of whey as the main raw material for the production of bio-yoghurts;
- to study the BAS complex of natural fruit and vegetable cryoadditives made from carrots, unpeeled lemons, apples, Jerusalem artichoke as sources of BAS, structure-formers, texture-stabilisers, and colourants for yoghurts;
- to study the content of biologically active substances in extracts from natural spices and NMP (echinacea, coriander, melilot, oregano) obtained after cryomilling the raw materials before the extraction;
- to develop a technology of manufacturing health-promoting bio-yoghurts on the basis of whey, nanosized fruit and vegetable cryoadditives, and nanoextracts from natural spices and medicinal plants;
- to study the patterns and mechanisms of formation of a stable dispersed texture and of BAS retention in the manufacture of combined milk-herbal beverages.

Research materials and methods

The research was conducted at Kharkiv State University of Food Technology and Trade (KSUFTT, Ukraine) in the Research Laboratory of Innovative Cryo- and Nanotechnologies of Plant-Based Additives and Health-Promoting Products (the Department of Processing Technologies of Fruits, Vegetables, and Milk), in collaboration with the Odessa National Academy of Food Technologies (the Department of Hotel and Restaurant Business).

When developing combined bio-yoghurts, the authors used whey manufactured by the private limited company Kupyansk Milk Canning Plant (Kupyansk, Kharkiv region, Ukraine). Besides it, fresh fruit and vegetables (carrots, unpeeled lemons, apples,

Jerusalem artichoke tubers) and the resulting fine-dispersed additives in the form of frozen pastes were used as raw materials. The extracts from natural spices and non-traditional medicinal plants (coriander, melilot, oregano, echinacea) were also used. The components of the bio-yoghurts' are characterised in detail in the experimental part of the work.

The mass fraction of protein, bound and free α -amino acids (essential and non-essential), fat, organic acids were the parameters to evaluate the quality of the bio-yoghurts and whey.

The parameters controlled in the fresh fruit and vegetables, cryogenic nanoadditives, and combined milk-herbal beverages were the content of L-ascorbic acid, β -carotene, phenolic compounds (determined by chlorogenic acid and rutin), polyphenols (determined by tannins), and prebiotic substances (total content of pectin, soluble pectin, cellulose, inulin). The mass fractions of sugar, organic acids, and solids were determined, too. More details of the materials and methods of the research, as well as the methodology of determining the parameters of the samples are given in [22, p. 226, 273-275]. For IR spectroscopy, a spectrophotometer Specord 75 IR (Karl Zeiss) was used. The samples were prepared in the form of KBr tablets (1% of the test sample, and 99% of KBr).

Results of the research and their discussion

The study of the quality of the whey the new bio-yoghurts were based on has shown that the mass fraction of dry solids ranged within 5–5.4%. The dry solids were lactose (3.5%) and protein (1.1–1.2%). Besides, the whey contained a small amount of fat (0.2–0.3%) and minerals (0.6–0.7%).

The amino acid composition of the whey has been studied (Table 1). It has been established that 89% of whey proteins are protein-bound amino acids, and 11% are free amino acids that form supramolecular structures of protein molecules. It has been found that the total amino acid content in 100 g of whey is 1103.1 mg, 121.3 mg of which are free amino acids, and 981.8 mg are bound amino acids.

The study of the whey amino acid score has shown that the protein was biologically complete (Table 2). There are no limiting amino acids in its composition. According to the FAO/WHO scale, the amino acid score of the whey, compared to the ideal protein, ranges from 117.3% (for threonine, leucine) to 157.1% (for methionine and cystine taken together).

The next objective of the research was to study the biological complex of phytochemicals of the nanosized fruit and vegetable cryoadditives (made from carrots, unpeeled lemons, apples, Jerusalem artichoke tubers) developed by the authors to enrich a wide range of healthy products (Table 3).

Table 1 – Amino acid composition of whey used as a basis for combined sour-milk beverages – bio-yoghurts (n=3, P≥0.95)

| No. | Name of amino acid | Mass fraction of amino acids, mg/100 g | | Total amino acid content, mg/100 g | Ratio of free amino acids and total of amino acid content, % |
|--------|--------------------|--|-------|------------------------------------|--|
| | | bound | free | | |
| 1 | Valine | 66.1 | 11.0 | 77.1 | 14.3 |
| 2 | Tryptophan | 12.4 | 0 | 13.1 | 0 |
| 3 | Lysine | 68.3 | 10.9 | 79.2 | 13.8 |
| 4 | Threonine | 43.9 | 7.7 | 51.6 | 14.9 |
| 5 | Methionine | 18.5 | 3.8 | 22.3 | 17.8 |
| 6 | Cystine | 37.7 | 0.5 | 38.2 | 1.3 |
| 7 | Isoleucine | 64.6 | 0.8 | 65.4 | 1.2 |
| 8 | Leucine | 82.8 | 7.5 | 90.3 | 8.3 |
| 9 | Phenylalanine | 41.5 | 3.7 | 45.2 | 8.1 |
| 10 | Tyrosine | 46.6 | 1.2 | 47.8 | 2.5 |
| 11 | Aspartic acid | 77.8 | 10.7 | 88.5 | 12.1 |
| 12 | Serine | 49.7 | 13.1 | 62.8 | 20.8 |
| 13 | Glutamic acid | 170.4 | 5.5 | 175.9 | 3.1 |
| 14 | Proline | 59.9 | 26.7 | 86.6 | 30.8 |
| 15 | Glycine | 40.6 | 6.2 | 46.8 | 13.2 |
| 16 | Alanine | 51.9 | 6.0 | 57.9 | 10.4 |
| 17 | Histidine | 22.1 | 5.9 | 28.0 | 21.2 |
| 18 | Arginine | 26.3 | 0.1 | 26.4 | 0.2 |
| Total: | | 981.8 | 121.3 | 1103.1 | 11.0 |

Table 2 – Amino acid score of whey used as a basis for combined sour-milk beverages – bio-yoghurts (n=3, P≥0.95)

| Name of amino acid | Mass fraction of amino acids, mg/1 g of protein | | Amino acid score, % |
|-------------------------|---|--------------|---------------------|
| | Ideal protein (FAO/WHO scale) | Whey protein | |
| Valine | 50.0 | 70.1 | 140.2 |
| Tryptophan | 10.0 | 11.9 | 119.0 |
| Lysine | 55.0 | 72.0 | 130.9 |
| Threonine | 40.0 | 46.9 | 117.3 |
| Methionine+Cystine | 35.0 | 55.0 | 157.1 |
| Isoleucine | 40.0 | 59.5 | 148.8 |
| Leucine | 70.0 | 82.1 | 117.3 |
| Phenylalanine+ Tyrosine | 60.0 | 84.5 | 140.8 |

Table 3 – Biocomplex of phytocomponents of nanosized fruit and vegetable cryoadditives – the enriching agents of the new bio-yoghurts (n=3, P≥0.95)

| Product | Mass fraction, mg/100 g | | | | | Mass fraction, % | | |
|--|-------------------------|------------|-------------------------------|--|----------------------------|------------------|----------------|-----------|
| | L-ascorbic acid | β-carotene | phenolic compounds (by rutin) | phenolic compounds (by chlorogenic acid) | tanning agents (by tannin) | total pectin | soluble pectin | cellulose |
| Fresh carrots | 19.2 | 11.5 | 72.4 | 165.0 | 245.2 | 2.0 | 1.2 | 2.0 |
| Carrot-based cryoadditive | 40.5 | 40.2 | 130.2 | 285.6 | 420.4 | 8.2 | 4.4 | 1.5 |
| Unpeeled fresh lemons | 85.4 | 0.2 | 78.6 | 145.2 | 342.4 | 2.9 | 2.1 | 3.0 |
| Cryoadditive from unpeeled lemons | 215.6 | 0.4 | 142.4 | 250.4 | 570.2 | 8.6 | 7.5 | 2.1 |
| Fresh apples | 72.0 | 0.1 | 170.2 | 560.2 | 420.6 | 2.8 | 1.5 | 1.7 |
| Apple-based cryoadditive | 165.2 | 0.2 | 325.6 | 970.4 | 750.4 | 7.7 | 6.8 | 1.5 |
| Fresh Jerusalem artichoke tubers | 22.4 | 0.1 | 235.0 | 370.6 | 280.4 | 1.8 | 1.3 | 1.4 |
| Cryoadditive from Jerusalem artichoke tubers | 41.2 | 0.2 | 400.1 | 685.5 | 520.1 | 5.8 | 5.2 | 1.1 |

It has been shown that the fruit and vegetable cryoadditives are 2.5–4.5 times as high in BAS as the original fresh raw materials (Table 3). The new cryoadditives, unlike the traditional ones, have a record content of natural phytocomponents, among them low-molecular-weight and high-molecular-

weight phenolic compounds. Thus, the mass fraction of low-molecular-weight phenolic compounds is 0.4 to 1.2%, that of polyphenols (tannins) is 0.42 to 0.75% (Table 3). These substances are known to be powerful natural antioxidants, and to have immunomodulatory, detoxifying, and anti-

oncological properties. They strengthen the vessels of the heart and brain and have a preserving, bactericidal effect. The carrot-based cryoadditive contains a record amount of natural β -carotene: 40.2 mg of carotene per 100 g of the cryoadditive, which is about eight times as much as the body needs every day (its daily requirement being 5.0–6.0 mg). 100 g of the cryoadditive made from unpeeled lemons contains about three daily requirements of L-ascorbic acid (215.6 mg). 100 grams of the apple-based cryoadditive contains an adult's 2.5 daily requirements of ascorbic acid (165 mg).

Besides, it has been shown that the fruit and vegetable cryoadditives contain prebiotics (pectins, cellulose) that have structure-forming properties. Thus, the total pectin content is 1.8–8.6%, the mass fraction of soluble pectin is 1.4–7.5%, that of cellulose 1.1–3.0%.

The presence of a BAS-complex in the fruit and vegetable cryoadditives indicates their potential therapeutic and prophylactic properties: they can strengthen the body's defences (the immunity), have a detoxifying, antioxidant, antibacterial, and anti-inflammatory effect. BAS, prebiotics, and structure-formers present in the fruit and vegetable cryoadditives make it unnecessary to use traditional food additives (structure-forming agents, gel-forming agents, thickeners, colourants, enriching agents) in the production of bio-yoghurts. The new types of fruit and vegetable cryoadditives differ from the existing fillings and additives for bio-yoghurts by their record BAS content. They are nanosized, easily digestible, and have no analogues [5,24]. The mechanisms of the processes occurring in the course of production of nanosized fruit and vegetable cryoadditives are described in the monographs [4,5,24].

The next stage was devoted to studying the BAS content in the extracts from natural spices and NMP (echinacea, coriander, melilot, oregano) obtained with the use of cryomilling of raw materials before the extraction. These extracts were used in the production of bio-yoghurts to enrich them with BAS

and as a source of substances that have a preservative effect.

It is known that sour-milk beverages, bio-yoghurts, made by the classical technology are perishable products. Their shelf life is 36 hours at $+(4-6)^{\circ}\text{C}$, and 7–10 days at $(0-2)^{\circ}\text{C}$. To increase the shelf life of bio-yoghurts and enrich them with more BAS, it has been suggested to use additives from natural spices (coriander, melilot, oregano) and non-traditional plant raw materials (echinacea) in the form of nanosized water-alcohol extracts. These herbal raw materials contain substances with a preservative, antioxidant, and detoxifying effect. This is due to the high content of phenolic compounds, tannins, aromatic substances of terpenoid nature, and other phytochemicals [4,6].

The extracts were prepared by the method developed by the specialists of the department, which involves cryogenic fine-dispersed milling of the plant raw materials after preparing them for extraction. The use of cryogenic milling, in comparison with the traditional method of preparing raw materials, makes it possible to increase significantly (by 10–15 times) the rate of extraction and to double the mass fraction of extracted BAS [5].

In the extracts from coriander, echinacea, oregano, and melilot, the content of phytochemicals has been studied. The extracts samples are high in soluble biologically active phytochemicals (Table 4) in nanosized form. It has been found that the mass fraction of aromatic substances contained in 100 ml of nanoextracts is: sodium thiosulfate 138.0–202.3 mg, low-molecular-weight phenolic compounds (determined by chlorogenic acid) 250.8–1260.4 mg, flavonol glycosides (determined by rutin) 85.6–385.6 mg, tannins 308.2–458.6 mg. The highest content of phenolic compounds is in the extracts of echinacea and melilot, of aromatic substances in the oregano extract (Table 4). The mass fraction of dry substances in the nanoextracts ranged 2 to 5.4%. It is twice as much as when using traditional milling [5] to prepare plant raw materials for extraction.

Table 4 – The content of biologically active phytochemicals in the extracts from natural spices and non-traditional medicinal plant raw materials (n=3, P \geq 0.95)

| Phyto-extract | Mass fraction, mg/100 ml | | | | | Solids, % |
|----------------|---|--|--------------------------------|--------------------------------|--------------------------------|-----------|
| | aromatic substances (by the odour number), ml of sodium thiosulfate | phenolic compounds (by chlorogenic acid) | flavonol glycosides (by rutin) | free catechins (by d-catechin) | tanning substances (by tannin) | |
| from echinacea | 168.2 | 1260.4 | 385.6 | 67.8 | 458.6 | 5.4 |
| from coriander | 138.0 | 250.8 | 85.6 | 42.0 | 308.2 | 2.0 |
| from melilot | 174.6 | 1092.4 | 108.6 | 55.6 | 417.3 | 5.2 |
| from oregano | 202.3 | 1044.6 | 97.2 | 48.9 | 380.7 | 5.1 |

FAO/WHO recommendations were followed to create healthy whey-based bio-yoghurts, cryoadditives from fruit and vegetables, and nanoextracts from natural spices and medicinal plants. Besides, recommendations of well-known experts in

vitaminisation of food and functional products were used [25–27]. These recommendations and the analysis of the BAS content of the products allow evaluating their therapeutic and prophylactic properties. A product can be regarded as a health-promoting one if 100 g of it

contains a person's daily requirement of BAS, but not less than 1/2 of it, that is: 50.0–70.0 mg of ascorbic acid, 5.0–6.0 mg of β -carotene, 25.0–50.0 mg of P-active phenolic compounds, and others.

On the basis of whey with natural plant additives (fruit and vegetable cryoadditives and extracts from natural spices and non-traditional herbal raw materials), the recipes and technology of new sour-milk drinks have been developed: the healthy diet yoghurts Carotinka, Carotella, Oranzhon. Their formulations differ in the amounts of cryoadditives made from carotene-containing (carrots), citric (lemons), and inulin-containing (Jerusalem artichoke) raw materials. The total amount of fruit and vegetable cryoadditives in the bio-yoghurt formulations was 20 to 22%, of which the carotenoid additive obtained from carrots ranged 8 to 10%. In accordance with the recommendations of the Ministry of Health of Ukraine, the extracts from natural spices and medicinal plants (coriander, burkun, oregano, echinacea in the ratio 1:1:1:1) were taken in the amount 25–30 litres per 1 tonne. In comparison with their analogues, the new yoghurts, which differ in the quantity and ratio of fruit and vegetable cryoadditives and extracts from natural spices and non-traditional medicinal plants, have a record content of β -carotene, phenolic antioxidant compounds, tannins (Table 5 and Fig. 1). The new bio-yoghurts are orange-and-yellow-coloured, have a pleasant taste and a natural aroma, and are made without using food additives and synthetic ingredients.

The rational technological parameters have been experimentally determined and confirmed. The technology and the production scheme of bio-yoghurts containing natural herbal nanoadditives have been developed on the department's test-bench semi-industrial equipment (Fig. 1). The bio-yoghurts were made by the tank method. 5% of sugar was added into the formulation. The pasteurised whey with sugar was cooled to 45–47°C, and then, a direct-to-the-vat starter was added to it in the amount 5 kg per 1 tonne. The bacterial starter consisted of pure cultures of *Streptococcus Thermophilus* and *Lactobacillus Bulgaricus*. The fermentation was carried out in 2 stages. At the first stage, the whey with sugar was fermented for 6 hours. At the second stage, the pre-prepared fruit and vegetable nanoadditives (defrosted and subjected to short-time pasteurisation) were added into the fermentation tank in the amount 20–22%. At the same time, a composition of nanoextracts from natural spices and echinacea was introduced into the fermentation tank. The second stage of the fermentation lasted 1.5–2 hours. The yoghurt obtained was cooled, while stirred, to 20–25°C, bottled, and packaged (Fig. 1). The whole fermentation process lasted about 8 hours. The mass fraction of dry substances in the new yoghurts was 12.7–14.1%, of organic acids 1.8–2%, of total sugar 6.7–6.9%, of fat 2.5%.

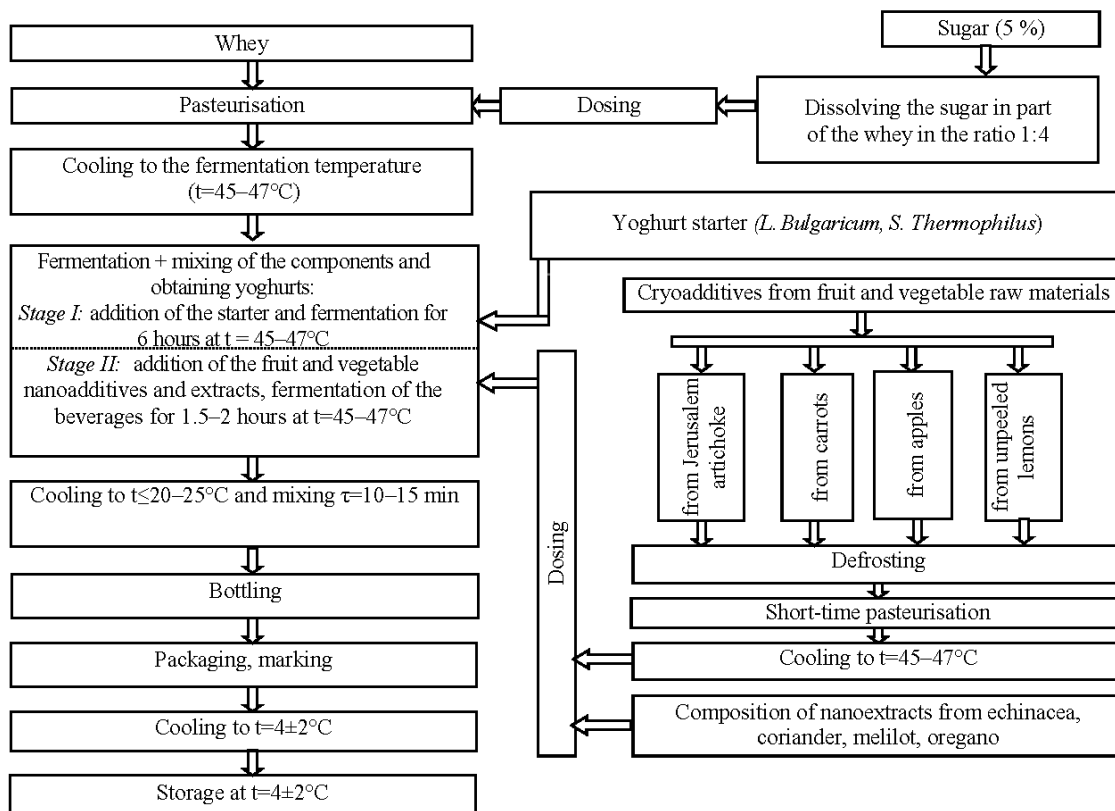


Fig. 1. Production scheme of combined sour-milk beverages – whey-based bio-yoghurts with fine-dispersed fruit and vegetable cryoadditives and nanoextracts from natural spices and medicinal plants

Table 5 shows the results of studying the quality of the combined sour-milk beverages obtained (bio-yoghurts) by the BAS content, in comparison with their analogue – the drinking pasteurised yoghurt with the apple and cinnamon taste (2.5% fat) from the domestic manufacturer PLC *Halychyna*. The new fruit and vegetable bio-yoghurts have the original taste and aroma of a natural product and a natural vivid colour. Besides, the new bio-yoghurts differ from the existing sour-milk

beverages by a record content of natural phyto-components – BAS (β -carotene, phenolic compounds, tannins, L-ascorbic acid). Bio-yoghurts also contain prebiotic substances: pectic substances in soluble form, inulin, cellulose (Table 5). According to the standards recommended by the Ministry of Health of Ukraine, the new yoghurt types can be classified as health-promoting products due to their BAS content.

Table 5 – Characteristics of the biologically active complex of the new bio-yoghurts made with the use of plant nanoadditives (n=3, P \geq 0.95)

| Parameter | Bio-yoghurts | | | Analogue |
|---|--------------|-----------|----------|----------|
| | Carotinka | Carotella | Oranzhon | |
| β -carotene, mg/100 ml | 3.5 | 3.0 | 2.5 | 0 |
| Phenolic compounds (by chlorogenic acid), mg/100 ml | 37.2 | 45.3 | 48.0 | 0 |
| Tanning substances (by tannin), mg/100 ml | 94.2 | 102.3 | 110.2 | 0 |
| L-ascorbic acid, mg/100 ml | 31.0 | 32.9 | 35.1 | 3.0 |
| Pectic substances, % | 1.3 | 1.2 | 1.1 | 0.9 |
| Inulin, % | 1.2 | 1.1 | 1.0 | 0 |
| Cellulose, % | 0.7 | 0.6 | 0.4 | 0.2 |
| Protein, % | 1.5 | 1.4 | 1.3 | 1.1 |
| Fat, % | 2.5 | 2.5 | 2.5 | 2.5 |
| Total sugar, % | 6.9 | 6.8 | 6.7 | 6.8 |
| Dry matter, % | 13.0 | 12.8 | 12.6 | 12.0 |

* yoghurt with the apple and cinnamon filling (PLC *Halychyna*)

The new bio-yoghurts can be stored twice longer than those made by the traditional technology. The shelf life of the bio-yoghurts developed is 72 hours at 4–6°C and 15–18 days at 2°C with no loss in BAS [5]. This results from the complete inactivation of oxidising enzymes in the product during its manufacture, and from the presence of natural phyto-substances with a preservative effect.

The new bio-yoghurts are intended for healthy nutrition. They contain α -amino acids in easily digestible form. The size of their molecules ranges from 0.5 nm to 1.5 nm (about 1.5%). Bio-yoghurts contain quite a lot of BAS in nanosized form and contribute to strengthening the immunity. 100 ml of the new bio-yoghurts contain 80% of the daily requirement for β -carotene (2.5–3.5 mg) and 50% of daily requirement for L-ascorbic acid (31.0–35.1 mg in 100 ml). A glass of yoghurt (200 ml) contains 1.5 daily requirements for β -carotene (5.0–7.0 mg) and a daily requirement for L-ascorbic acid (62.0–70.2 mg). Besides, bio-yoghurts contain a lot of phyto-components, like phenolic compounds, which are natural detoxifiers, antioxidants, and immunomodulators, in far larger quantities than the body needs daily. It has been found that bio-yoghurts also contain natural structure-forming agents (pectin, inulin, cellulose), which, at the same time, are prebiotics, well-known for their curative properties (Table 5).

The proteins, pectins, and cellulose act as complex-makers and stabilisers during the texture formation in the new sour-milk beverages, which has been confirmed by

the infrared spectroscopy method (Fig.2). This group of biopolymers stays in the active nanosized form.

It has been determined that the intensity of the IR spectra of the experimental yoghurt samples increases in the frequency range 3000–3600 cm^{-1} . These frequencies are characteristic of the stretching vibrations of the functional groups –OH that are involved in the formation of hydrogen bonds. The increase in the intensity indicates an increased ability to bind water by means of formation of hydrogen bonds of proteins, polysaccharides, some pectic substances, inulin, cellulose, and their nanocomplexes of fruit and vegetable nanoadditives, which are among the main bio-yoghurt components. The data obtained correlate with the texture of the new bio-yoghurts (which is denser than that of their analogues) and with their structural and mechanical properties.

An increase in the intensity of the IR spectra in the frequency range 1800–3000 cm^{-1} has also been established. This is due to the enrichment of yoghurts with various components of nanosized plant biopolymers: monomers of protein, pectin, cellulose, and others (in particular, α -amino acids, galactic acid, glucose, fructose, etc.). This indicates the intermolecular rearrangement and complex formation of associates of molecules and nanocomplexes of the compounds of these biopolymers and nanosized low-molecular-weight BAS capable of structure formation and gelation. This intensity increase indicates the stabilising effect the components of herbal nanoadditives have on the product's texture during the manufacture of bio-yoghurts.

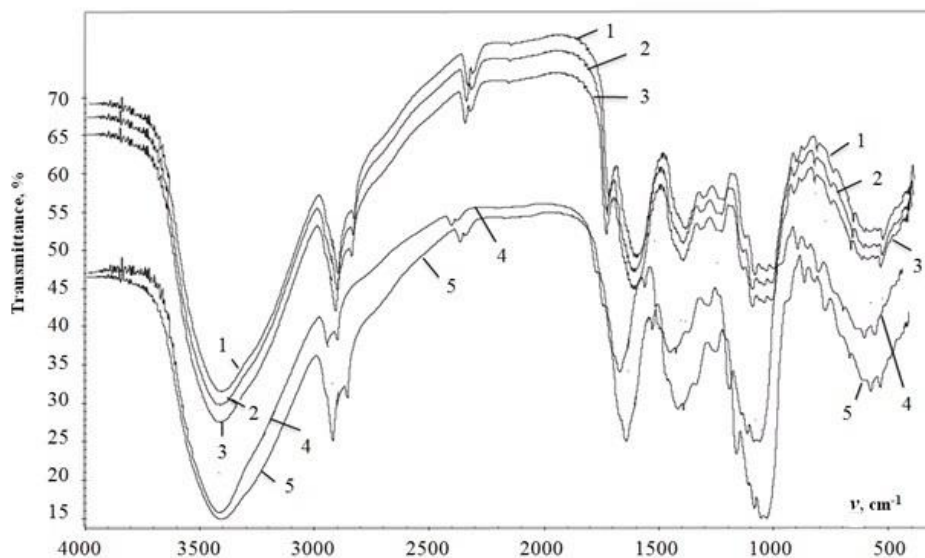


Fig. 2. IR spectra of the whey-based bio-yoghurts containing natural herbal nanoadditives, in comparison with the yoghurt analogue and the whey the beverages developed are based on: 1 – Carotinka, 2 – Carotella, 3 – Oranzhon, 4 – apple and cinnamon yoghurt from PLC *Halychyna* (analogue), 5 – whey

Conclusions

1. It has been determined that whey can be used as the main component to manufacture sour-milk beverages – bio-yoghurts enriched with fine-dispersed fruit and vegetable cryoadditives high in BAS and nanoextracts from natural spices and medicinal plants. It has been established that the dry matter in the whey is 5.4%, of which 3.5% is milk sugar, 1.1–1.2% is protein, 0.2–0.3% is fat, 0.6–0.7% is minerals. It has been shown that whey protein is complete, limiting amino acids are absent. Compared with the ideal protein, the amino acid score of the tested dairy raw material, according to the FAO/WHO scale, for all essential amino acids, is 117.3–157.1%.

2. It has been shown that the fruit and vegetable cryoadditives contain by 2.5–4.5 times more BAS than the original fresh raw materials. The new cryoadditives differ from the traditional ones by the content of natural phytochemicals, including low-molecular-weight and high-molecular-weight phenolic compounds. Thus, the mass fraction of low-molecular weight phenolic compounds ranges 0.4 to 1.2%, that of polyphenols (tannins) 0.42 to 0.75%. These substances are powerful natural antioxidants and have immunomodulatory, detoxifying, and anti-oncological properties. They strengthen the vessels of the heart and brain and have a preservative, bactericidal action. It has been found that the carrot-based additive contains a record amount of natural β -carotene: 40.2 mg of carotene per 100 grams of the cryoadditive, which is about eight times as much as the body needs every day (its daily requirement being 5.0–6.0 mg). It has been shown that 100 grams of the cryoadditive from unpeeled lemons contains about three daily norms of L-ascorbic acid the human body needs (215.6 mg). It

has been found that 100 grams of the cryoadditive from apples contains 2.5 as much ascorbic acid as an adult requires daily (165 mg). It has also been shown that the fruit and vegetable cryoadditives contain prebiotic substances (pectins, cellulose) with structure-forming properties. Thus, the mass fraction of total pectin is 1.8–8.6%, soluble pectin 1.4–7.5%, cellulose 1.1–3%. BAS, prebiotics, and structure-forming substances present in the fruit and vegetable cryoadditives make it unnecessary to use traditional food additives (structure-forming agents, gel-forming agents, thickeners, colourants, enriching agents) in the production of bio-yoghurts.

3. It has been shown that the extracts from coriander, echinacea, oregano, and melilot have a high content of nanosized soluble biologically active phytochemicals. It has been shown that the mass fraction of aromatic substances in 100 ml of nanoextracts is 138.0–202.3 mg (determined by sodium thiosulfate), that of low-molecular-weight phenolic compounds (determined by chlorogenic acid) 250.8–1260.4 mg, of flavonol glycosides (determined by rutin) 85.6–385.6 mg, of tannins 308.2–458.6 mg. The highest content of phenolic compounds is in the extracts of echinacea and melilot, aromatic substances are the highest in the oregano extract. The mass fraction of dry matter in nanoextracts ranged 2 to 5.4%, which is 2 times more than when using traditional milling to prepare the vegetable raw materials for extraction. The extracts were used to enrich the bio-yoghurts with BAS during their production, and as a source of preservative substances to extend the shelf life of yoghurts.

4. The technology of new yoghurts for healthy diet, with a record content of BAS, prebiotics, and structure-forming substances has been developed on

the basis of whey with the use of natural herbal nanoadditives (fruit and vegetable cryoadditives and extracts from natural spices and non-traditional plant raw materials). The rational parameters of the technology have been experimentally determined, worked out, and scientifically confirmed on semi-industrial test-bench equipment. The technological scheme for the production of natural bio-yoghurts for healthy diet with the use of herbal nanoadditives has been developed. It has made it unnecessary to use artificial food additives.

5. It has been shown that the new fruit and vegetable bio-yoghurts have the original taste and aroma of a natural product, a stable texture, and a bright orange and yellow colour. It has been determined that the new bio-yoghurts differ from the existing analogues by the record content of biologically active substances of plant origin (β -carotene, phenolic compounds, tannins, L-ascorbic acid) and natural

structure-forming and prebiotic agents (pectin, cellulose, inulin) in nanostructured form. 100 g of the bio-yoghurts contain 0.5–1 daily requirement for the above mentioned BAS. They are recommended as health-promoting and disease-prevention food. It has been studied what patterns and mechanisms are responsible for the formation of a stable dispersed texture and the retention of BAS in the production of bio-yoghurts containing fruit and vegetable nanoadditives and nanoextracts from natural spices and medicinal plants, with no dietary supplements and synthetic components used. New yoghurts are recommended for introduction at large food establishments and for individual consumption.

Approbation of the results. These technologies of manufacturing combined fruit and vegetable bio-yoghurts have been tested at the enterprises of Kharkiv and the Kharkiv region (Ukraine): LLC Bogodukhovskiy Dairy Plant, RDE KRIAS Plus.

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РОЗРОБКА КИСЛОМОЛОЧНИХ ОЗДОРОВЧИХ НАПОЇВ З ВИКОРИСТАННЯМ НАТУРАЛЬНИХ РОСЛИННИХ НАНОДОБАВОК

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Анотація. Розроблено технології оздоровчих продуктів – біоюгуртів з унікальними характеристиками. Нові продукти відрізняються високим вмістом натуральних біологічно активних речовин – фітокомпонентів плодів та овочів (моркви, лимонів з цедрою, яблука, топінамбура), зокрема, β-каротину, фенольних сполук, дубильних речовин, аскорбінової кислоти, тобто речовин, що мають антиоксидантні та імуномодулюючі властивості. Крім того, відрізняються високим вмістом пребіотичних речовин – розчинних пектинових речовин, целюлози, інуліну та білків. Останні в біоюгуртах виконують роль натуральних загусників та структуроутворювачів. Це дає можливість виключити необхідність застосування при виробництві біоюгуртів харчових домішок та синтетичних добавок. Технології виготовлення біоюгуртів засновані на застосуванні як інновації кріодобавок із плодовоовочевої сировини в нанорозмірній формі з рекордним вмістом біологічно активних речовин (БАР), масова частка яких в кріодобавках в 2,5–4,5 разів більша, ніж у вихідній свіжій сировині. Отримання останніх засновано на комплексній дії на сировину кріогенного «шокового» заморожування з використанням рідкого та газоподібного азоту та кріодеструкції при дрібнодисперсному подрібненні. При виготовленні біоюгуртів кріодобавки виступають як збагачувачі натуральними БАР, структуроутворювачі, стабілізатори текстури та барвники. Крім того, для збагачення БАР та подовження термінів зберігання нових біоюгуртів в рецептурі введено фітоекстракти із натуральних прянощів та лікарської рослинної сировини (ехінацеї, коріандру, буркуну, орегано). Як основу при виробництві біоюгуртів використовували молочну сироватку. Нові види біоюгуртів за вмістом БАР перевищують відомі аналоги і мають в 2 рази подовжений термін зберігання (ніж контрольні зразки). Відпрацьовані технологічні режими виробництва біоюгуртів на стендовому напівпромисловому устаткуванні. Нові йогурти рекомендуються для впровадження у виробництво на великих харчових підприємствах, в закладах ресторанного бізнесу та для індивідуального харчування.

Ключові слова: біоюгурти, плодовоовочеві нанодобавки, здорове харчування, натуральні БАР, екстракти, кріодобавки, нанонапої без харчових домішок.

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