Foods and Raw Materials, 2019, vol. 7, no. 2
E-ISSN 2310-9599
ISSN 2308-4057

Review Article
Open Access

Check for updates

DOI: http://doi.org/10.21603/2308-4057-2019-2-428-438
Available online at http:jfrm.ru

Functional dairy products enriched with plant ingredients

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Received August 26, 2019; Accepted in revised form September 19, 2019; Published October 21, 2019

Abstract: Milk and dairy products are staple foods in the diet of all social groups. Plant additives are of multifunctional use in the dairy industry. Wild plants are a source of vitamins, minerals, and other biologically active substances. Due to these compounds, they improve digestion, cardiovascular activity, and emotional state. This review describes the latest trends in creating functional milk drinks enriched with plant components. They include drinks based on whole milk and cream, dairy by-products (whey, buttermilk), as well as fermented milk drinks with probiotic cultures (kefir, drinking yogurt). We found that aqueous extracts were most commonly introduced into milk raw materials. Fruits and berries were dried and added to milk raw materials in the powder form. Special attention was paid to 'hairy roots' as a promising technology for producing various functional foods. In addition to being economically viable, this technology can help us expand the range of plant materials with endangered species. Functional milk-based drinks enriched with plant extracts can improve the immune system and be used as part of supportive therapy. They are also suitable for daily use to replenish the balance of essential nutrients. These properties make their production a promising direction in the dairy industry.

Keywords: Milk drinks, plant extracts, functional ingredients, biologically active substances

Please cite this article in press as: Sukhikh SA, Astakhova LA, Golubcova YuV, Lukin AA, Prosekova EA, Milent`eva IS, et al.. Functional dairy products enriched with plant ingredients. Foods and Raw Materials. 2019;7(2):428–438. DOI: http://doi.org/10.21603/2308-4057-2019-2-428-438.

INTRODUCTION

Milk and dairy products are the most common foods in the diet of all categories of the population. The reasons for their popularity lie in the unique properties and components of milk, as well as a possibility of producing a wide variety of foods from this material. Milk is used as a basis for combined foods produced in two ways: 1) by adding plant materials to milk and dairy products and 2) by adding dairy ingredients to plant materials [1].

Combining plant and milk proteins provides a better amino acid composition compared to milk proteins. Milk protein is one of the most valuable proteins of animal origin since, unlike meat proteins, it does not contain purine bases, whose excess has a negative effect on kidney function. Its biological value is close to the value of a standard chicken egg protein. Milk protein has an optimal ratio of amino acids, which is close to the amino acid composition of human proteins. Dissolved milk proteins are readily available for digestive proteinases without prior denaturing. Milk proteins have higher digestibility (95–97%) than the proteins of meat, fish, and cereals. In addition, they are rich in essential amino acids which are often lacking in the human diet, namely lysine, tryptophane, methionine, etc. [1, 2].

The choice of dairy ingredients for functional foods can be justified by their medicinal properties widely utilised in therapeutic, preventative, and dietetic nutrition. It seems difficult to clearly distinguish between ordinary and medicinal dairy products, since even conventional dairy products can be used for dietetic and medicinal purposes due to their chemical composition. In addition, preference is usually given to fermented milk products due to their dietetic and medicinal properties. These properties result from microbiological and biochemical processes that occur during the ripening of milk curd.

The enzymatic systems of lactic acid bacteria break down milk proteins during fermentation into simpler and more easily digestible substances. Organic acids in fermented milk products affect the secretory activity of the stomach and intestines. Helping the glands of the digestive tract to secrete enzymes, they speed up digestion and improve the absorption of food. In addition, beneficial properties of fermented milk products lie in their ability to inhibit the growth of pathogenic intestinal microflora. This is especially important in view of a high incidence of intestinal dysbiosis even among healthy people [3].

Milk ingredients are often used in the production of functional dairy products. They are isolated from conventional dairy products, such as milk, cheese, whey or butter. Thanks to special treatment, they acquire desired properties, for example, texture, taste or water content. They include whey powder, lactose, protein concentrate, milk fat, protein isolate, casein, and albumin. These ingredients are used to create special products, for example, for diabetics, athletes, and children [1, 3].

The world's largest processing companies, such as Fonterra, Lactalis, Friesland Campina, Dairy Farmers of America, and Arla Foods are big investors in the production of milk ingredients. In Russia, it is still a new market. According to Streda Consulting, Russia annually imports about 110 000 tons of such products worth $200 million. These are whey, protein concentrates (used in dairy and confectionery production), and dehydrated milk fat. Belarussian products account for up to 55% of all imported ingredients and up to 25% of their cost.

Russia has a large source of whey which can be used to produce dry whey powder, whey protein concentrate, isolate, and hydrolysate. It is due to the growing production of cheese, where whey is the main by-product. In 2017, Russia produced over 603000 tons of cheese, an 8.5% growth compared to 2016. A significant amount of whey powder produced in Russia is used to meet the needs of the dairy industry. In 2017, its output reached 129 000 tons, a 15% increase since 2010 [1, 2].

Plant additives are quite widely used in the dairy industry for various functional purposes. In recent years, we have seen a clear trend towards combining plant materials with various milk additives [1]. Highly promising is the use of wild plants, edible and medicinal. Wild plants are a raw material for nutraceuticals, one of the main groups of dietary supplements. They are a source of vitamins, minerals, and other biologically active substances. Thanks to these compounds, wild plants improve digestion, cardiovascular activity, and emotional state [1, 4].

Functional properties of dairy products are normally improved by correcting their composition of fatty acids, amino acids, and minerals, as well as fortifying them with micronutrients [2, 3]. Combining milk materials with plant components allows regulating the content of vitamins, carbohydrates, minerals, and dietary fibre in the products. In addition, they give dairy products a pronounced plant taste and smell, as well as an attractive appearance. Using biologically active compounds obtained from plant materials, including medicinal plants, is a promising direction in the production of medicinal, preventative, and functional products [1, 2].

This review is devoted to the latest trends in creating functional milk drinks enriched with plant components. It describes the principles of producing various types of functional drinks, namely drinks based on whole milk and cream, drinks based on dairy by-products (whey, buttermilk), and fermented milk drinks with probiotic cultures (kefir, drinking yogurt).

STUDY OBJECTS AND METHODS

Our objects of study were scientific publications and patents of Russian and foreign authors on the production of milk drinks enriched with plant materials. Our main method was generalisation. In particular, we analysed statistical and economic data on the world-wide production of functional milk drinks, the scientific principles of using plant ingredients in milk drinks, and findings of practically-oriented studies and original research on new types of functional plants.

RESULTS AND DISCUSSION

Modern formulations and technological regulations provide for the use of various forms of medicinal plants. Quite popular are syrups and extracts from wild medicinal herbs with various preventative properties (antimicrobial, immunostimulating, antitoxic, radioprotective, and others). A study of their chemical properties showed that most plants have a unique set of substances, such as vitamins, dietary fibre, antioxidants, minerals, and organic acids [5].

Functional plants used in phytocompositions can be classified according to their pharmacological action. For example, a group of plants used in Russia to strengthen blood vessels include *Tilia Cordata*, *Comarum*, and *Aegopodium podagraria*. Plants that stimulate the cardiovascular system and prevent it from weakening include *Adonis vernalis*, *Betula pendula*, *Crataegus*, *Hypericum*, *Fragaria*, *Calendula officinalis*, *Viburnum opulus*, *Convallaria majalis*, *Melissa officinalis*, *Hippophae*, *Parmelia*, *Leonurus*, *Matricaria Chamomilla*, *Sorbus sibirica*, *Aronia melanocarpa*, and *Gnaphalium* [4,5].

Medicinal plants with psychotropic properties fall into four groups, namely:

– sedatives: *Valeriana officinalis*, *Leonurus*, *Crataegus*, *Mentha*, *Humulus lupulus*, *Chamaenerion angustifolium*, *Polemonium caeruleum*, *Calluna vulgaris*, *Origanum vulgare*, *Cichorium*, *Melilotus officialis*, *Levisticum officinale Koch*., *Gnaphalium uliginosum*, *Thymus*, and *Bidens tripartita*;

– plants with a combined calming and tonic effect (intermediate group): *Paeonia anomala*, *Rhaponticum carthamoides*, *Acorus calamus*, *Rubus idaeus*,

Taraxacum officinale, *Pastinaca*, and *Origanum majorana*;
– stimulants: *Aralia elata*, *Oplopanax elatus*, *Rhodiola rosea*, and *Echinops*; and
– antidepressants: *Hypericum*, *Rhaponticum carthamoides*, *Aralia elata*, and *Oplopanax elatus*.

Plants with phytoncidal properties include *Calendula* offici*nalis*, *Tilia*, *Arctostaphylos uva-ursi*, *Paeonia anomala*, *Matricaria Chamomilla*, *Prunus padus*, and *Rosa*.

Plants with the richest vitamin content include *Hippophae*, *Sorbus sibirica*, *Aronia melanocarpa*, *Salvia officinalis*, and *Rosa* [5].

The consumption of juices and other drinks is on the rise both in Russia and all over the world. There is a growing interest in drinks that not only quench thirst, but also have a positive effect on various systems of the body and human health in general. Depending on the intended action, functional drinks can act as general tonics, boost energy, stimulate mental activity, help to relax, prevent cholesterol metabolism disorders, etc. [1]. The concept of 'drinks for health' has become fundamental for many European manufacturers and is an effective brand that allows them to successfully compete in the market. According to market research, consumers prefer functional drinks made from natural and environmentally friendly materials and ingredients [1, 2].

Milk drinks can also be divided into the following groups: 1) drinks based on whole milk and cream; 2) drinks based on dairy by-products (whey, buttermilk); and 3) fermented milk drinks with probiotic cultures (kefir, drinking yoghurts).

A large number of studies on whole milk drinks have aimed not only to enrich the product with functional substances, but also to extend the shelf-life of the finished product. Some plants contain various compounds that can affect microbial growth, reproduction, or basic cell functions. These include phenols, polyphenols, trace elements, essential oils, and other compounds. They are mainly present in various herbs. Extracts of these plants can be used as natural food preservatives that can inhibit the growth of unwanted microorganisms. Their antimicrobial activity is determined by a high content of phenolic compounds – substances containing aromatic rings with a hydroxyl group and their functional derivatives. These include tannins, flavonoids, glycosides, phenol carboxylic acids, phenol alcohols, anthocyanins, bitter substances, and simple phenols [6, 7].

The disk diffusion method was used to establish the antimicrobial activity of aqueous extracts obtained from the following plants: *Thymus vulgaris*, *Lavandula angustifolia*, *Melissa officinalis*, *Ocimum basilicum*, *Allium schoenoprasum*, and *Petroselinum crispu*. Their antibacterial activity was tested on strains of microorganisms that cause spoilage of milk. The highest antibacterial activity was found in the aqueous extracts of *Ocimum basilicum*, *Allium schoenoprasum*, and *Petroselinum crispu* [6].

Mohamed *et al.* tested the antibacterial properties of aqueous extracts of oregano, marjoram, sage, and liquorice against *B. subtilis* and *E. coli* pathogenic microorganisms [7]. These plants are widely used in the production of functional milk drinks. The study showed that these extracts had a higher antibacterial activity against *B. subtilis* rather than *E. coli.* In addition, oregano extract exhibited the highest antibacterial activity against the studied bacteria compared to marjoram, liquorice, and sage. Also, the mass spectrometric analysis revealed some new volatile compounds in these extracts which could potentially become new antibacterial drugs to be used in the food industry.

Apart from the antibacterial effect, plant additives are able to prevent spoilage of dairy products. They do it by directly absorbing photons of light and act as internal filters that protect sensitive food components by removing radicals and preventing photodegradation and oxidation. Such properties are common for flavonoids, in particular quercetin [8].

Russian manufacturers of dairy products use dihydroquercetin, a natural antioxidant obtained from Siberian and Dahurian larch. Dihydroquercetin is included in the list of food additives as an antioxidant (State Sanitary Standard 2.3.2.1078-01*). Another functional ingredient is larch arabinogalactan – dietary fibre enriched with various contents of dihydroquercetin (5–20%). The use of dihydroquercetin in the dairy industry has scientific and practical significance. In particular, it inhibits the process of lipid oxidation, enriches the products with a natural biologically active water-soluble substance, and increases their shelf-life. Therefore, this group of natural ingredients is used in the production of functional dairy products [9].

The antioxidant properties of plant extracts not only protect the product from spoilage, but also prevent the action of free radicals in the human body, slowing down the aging process. Milk has its own antioxidant system represented by enzymes (catalase, peroxidase, peroxide dismutase, etc.) and non-enzymatic components (vitamins A, E, C, SH-compounds, metal ions Zn2+, Se2+, Cu2+, Mn2+). In addition, milk contains synergists – substances that restore antioxidants, such as citric, tartaric, and lactic acids. However, the amount of these antioxidants is not stable, depending on various factors, and their activity decreases during milk processing. Lazareva *et al.* studied various plant extracts in combination with sterilised and pasteurised milk. They found that the greatest antioxidant effect on lipid peroxidation was exhibited by sterilised milk enriched with extracts of lingonberry leaves and green tea [2].

* SanPiN 2.3.2.1078-01. Gigienicheskie trebovaniya bezopasnosti i pishchevoy tsennosti pishchevykh produktov [State Sanitary Standard 2.3.2.1078-01. Hygienic requirements for food safety and nutritional value]. Moscow: Federal Center for Sanitary Inspection of the Ministry of Health of Russia; 2019. 145 p.

Researchers in [3] recommend honeysuckle powder as an antioxidant component for milk-based drinks, due to a high content of vitamin C [3]. Honeysuckle berries are also rich in vitamin P, iodine, and biologically active substances with health beneficial and diuretic effects. *Aronia melanocarpa* is another promising raw material for various dairy products. Its fresh fruits are used as a source of vitamins for treating hypertension of stages I and II, and as an adjuvant for treating rheumatism, measles, typhus, scarlet fever, allergic reactions, etc. Its juice strengthens the walls of blood vessels [10]. Optimal conditions were developed for enriching milk with *Aronia melanocarpa*: its puree and oligofructose powder were added to milk heated to 75°C, mixed, and kept for 15 min [11].

Thyme extract is used in milk drinks due to a large content of anthocyanins and flavonoids, in addition to the above compounds. Other sources of vitamins, macro- and trace elements, essential amino acids, and dietary fibre include peanuts, walnuts, rose hips, peppermint, and thyme, as well as beetroot, carrots, and oats [12].

A high antioxidant index was also found in pomegranate, oranges, lemons, apples, pomelo, tangerines, and persimmons, which makes them good additives for milk drinks.

Whey is a widely used raw material in the dairy industry. The main types of whey products include whey powder and permeate (59%), demineralised and delactosed whey powder (10%), whey protein concentrates (12%), and lactose (19%) [20]. The composition and properties of whey are determined by the type of the basic product and its technology. Whey contains about 20% of milk proteins. In addition, whey proteins are richer in essential amino acids than milk, and their content is more balanced in terms of nutrition physiology.

The biological value of whey protein is higher than that of chicken egg protein, a gold standard among food products. According to the FAO/WHO scale, the biological value of whey proteins is 112%, whereas that of milk casein is only 78%. Whey proteins are some of the most valuable components of milk. They are rich in sulphur-containing amino acids (cystine, lysine, and tryptophan). Thus, introducing whey proteins in food products, especially of plant origin, contributes to a significant increase in their biological value due to a highly balanced composition of amino acids [4].

Of great interest is a possibility of expanding the range of whey-based drinks and regulating their biological value. Fortifying them with plant extracts rich in biologically active substances with antioxidant properties can help prevent a number of pathological conditions – stress, atherosclerosis, myocardial infarction, malignant neoplasms, and others. In addition, plant extracts increase their shelf-life [4–6].

All components of whey can be fully utilised in the production of drinks [4]. Whey drinks were fortified with black and green tea containing flavonoids – antioxidants that protect the body from premature aging and cardiovascular diseases [5]. Tea normalises blood pressure, dilates blood vessels, and improves the work of the heart. The antihypertensive (lowering pressure) effect of tea is associated with a high content of polyphenols. It was found that tea lowers the level of bad cholesterol in the blood serum, reduces the intensity of sclerotic processes in the arteries, and prevents the accumulation of fats in the blood and the liver.

Tea alkaloids that remain stable during processing include caffeine, theobromine, theophylline, adenine, xanthite, hypoxanthine, guanine, etc. The caffeine content in tea varies from 2 to 4% of dry mass. The studies confirmed the possibility of creating tonic drinks based on aromatic medicinal plants and whey. In addition to black and green tea, mate tea can be used for these purposes. Lorena *et al*. developed formulations for milk drinks with green mate extracts (*Ilex paraguariensis*), cloves (*Syzygium aromaticum*), and lemongrass (*Cymbopogon citratus*) [13].

Keldibekova *et al*. formulated a functional product based on whey and rosehip [14]. Rosehips contain up to 5.5% ascorbic acid (vitamin C), 12–18 mg% carotene (provitamin A), 0.03 mg% vitamin B_2, vitamin K, flavonoids, about 18% sugar, 4% pectin, up to 4.5% tannins, about 2% citric acid, as well as malic and other acids. Rosehip gives the drink a sedative, anti-sclerotic, and tonic effect. The sensory evaluation of the new whey-based drink and its acidity analysis showed that the most optimal amount of rosehip infusion was 15% of whey weight. The physical and chemical parameters of the whey drink meet the requirements of Federal Law No. 88**. In addition, rosehip is an excellent diuretic and choleretic agent. It can also have a sedative, anti-sclerotic, and tonic effect.

Another group of researchers developed drinks based on milk materials combined with apple pectin, rosehip blooms, lemongrass leaves, and barberry fruits [15]. These materials provided the drinks with immunomodulating, antihypertensive, anti-inflammatory, and antiseptic properties.

The current search for new strong natural antioxidants has evoked interest in xanthones, natural polyphenolic compounds. High concentrations of xanthones are present in the pericarp of mangosteen (*Garcinia mangostana* L.), an exotic fruit common in Southeast Asian countries such as Thailand, India, Sri Lanka, Myanmar, Cambodia, Vietnam, China, and others. Xanthones have a wide range of physiological effects: cardiotonic, diuretic, choleretic, psychotropic, antitumor, antifungal, etc. Multicomponent functional drinks based on whey are food systems with low aggregative stability, i.e. they are prone to sedimentation during storage. Therefore, various stabilisers (pectins, gums, seaweed products, etc.) are introduced into their formulations to ensure a uniform structure.

** Federal'nyy zakon №88. Tekhnicheskiy reglament na moloko i molochnuyu produktsiyu [Federal Law No. 88. Technical Regulations for Milk and Dairy Products]. Moscow, 2008.

Cherevach *et al.* developed jellylike whey-based drinks enriched with mangosteen pericarp and extracts of Far Eastern plants, such as *Rosa cinnamomea*, *Aronia melanocarpa*, *Actinidia kolomikta*, *Vitis amurensis*, and *Oxycoccus quadripetalus Gilib* [16]. Their production process was made up of the following basic stages:
– preparation of milk curd whey (clarification at 90°C for 20 min, filtering, and cooling to 25°C);
– preparation of compositions of extracts from Far Eastern plants and mangosteen by dissolving gellan gum in a small amount of whey at 80°C and thorough stirring;
– preparation of plant components in the form of fruit and vegetable purees: primary treatment, cutting, cooking at 85–90°C for 20 min and rubbing through a sieve with 0.5 mm holes (for berry purees – only rubbing), pasteurisation at 70–75°C for 5 min, cooling to 25°C, mixing the ingredients by stirring;
– pasteurisation at 60–65°C for 5 min; hot filling, corking, marking, and cooling to 23–27°C followed by storage at 4 ± 2°C and relative air humidity 70 ± 2%.

The developed drinks had a significantly higher concentration of antioxidant substances compared to analogous products and met the requirements of State Standard R 52349-2005***. The drink with a rosehip extract had the highest concentration of flavonoids. One portion of this drink contains twice as many flavonoids as are recommended for daily intake. The drinks with aronia, cranberries, and grapes were also rich in flavonoids (16.5–89.6% of the daily norm). All the drinks provided 18.6–22.5% of the daily need for xanthones. These drinks should be consumed systematically in order to improve health and reduce the risk of cardiovascular diseases and common cold.

Another study aimed to formulate functional drinks based on dairy by-products and raw materials of plant origin, namely scorzonera and water caltrop [17]. All parts of water caltrop contain flavonoids, tannins, a variety of vitamins, phenolic compounds, as well as mineral salts and beneficial nitrogen compounds. The fruits contain 7.5% fat, 15% protein, and carbohydrates, including 3% sugar and 52% starch. Due to its antiviral, antimicrobial, and immunomodulatory properties, water caltrop can be used in the combined therapy for PTSD. The plant is also known to exhibit astringent, antispasmodic, sedative, choleretic, tonic, and diaphoretic properties. Scorzonera produces beneficial effects due to a variety of biologically active substances. Its roots contain saccharides (20%); pectin substances (2%); vitamins C, B_1, B_2, E, and PP; and salts of copper, potassium, iron, manganese, phosphorus, zinc, and calcium. However, its major medicinal properties are determined by a high content (about 10%) of inulin, as well as asparagine and levulin, making it suitable for diabetics. Asparagine has a positive effect on the work of the heart and activates the kidneys.

*** State Standard R 52349-2005. Foodstuffs. Functional foods. Terms and definitions. Moscow: Standartinform; 2005. 8 p.

Khramtsov *et al.* developed a formulation for milk drinks based on whey from heat-acid cheese production. They also used aqueous extracts of Japanese quince (*Chaenomeles japonica* L.), Chinese magnolia-vine (*Schisandra chinensis* L.), and common barberry (*Berberis vulgaris* L.) (pH 3.5–4) as coagulants [18]. Japanese quince contains 180 mg ascorbic acid per 100 g of product. It is also rich in organic acids, pectin, fibre, fructose, sucrose, essential oils, vitamins B, PP, A, and E, and minerals. Thanks to these components, Japanese quince can increase immunity, strengthen the conducting vessels, remove toxins and salts during intoxication, and normalise blood pressure. It is also used for treating inflammation in the oral cavity and upper respiratory tract, as well as intestinal disorders and other diseases.

The fruits of Chinese magnolia-vine contain sugar, tannins and colouring compounds, fatty acids (glycerides of linoleic, linolenic, oleic, and other acids) and organic acids (malic, citric, and tartaric). In addition, they are rich in essential oils, ascorbic acid, and vitamin E, as well as schizandrol and schizandrin – the compounds that determine basic biological properties of the plant. They improve physical and mental activity, enhance body resistance to negative factors, and stimulate the heart and blood vessels, contributing to the preservation of human health. Common barberry is valued for its content of alkaloids, carotene, tannins, ascorbic acid, tocopherol, and organic acids. Its beneficial properties are used in treating various pathologies, as well as to improve appetite. It also has laxative, antiseptic, tonic, antipyretic, and diaphoretic properties.

Fortified probiotic drinks are a new step in the development of the food industry. Fermented milk products are functional foods that contain biologically active substances with health-beneficial properties. It is generally recognised that probiotics serve as an important tool to prevent and treat dysbiosis resulting from irrational antibiotic therapy, intestinal diseases, improper nutrition, or stress. Among conventional probiotics are lactobacilli and bifidobacteria. Their beneficial effects are manifested in normalising intestinal microflora, activating the entire gastrointestinal tract, and improving calcium absorption. They also perform anti-allergenic and immunostimulating functions [19].

The greatest positive effect on human health can be achieved by using symbiotic products containing both pre- and probiotics. Prebiotics are substances that stimulate the growth and activity of microorganisms (probiotics) and improve their adhesion to the intestinal walls. Such properties are common for nonhydrolyzable oligo- and polysaccharides of plants, such as pectin, inulin, fructo-oligosaccharides, xylo-oligosaccharides, and resistant starch [19, 20].

Probiotics are widely used in the production of dairy products, but the recent focus has been on cultivating lactic acid and bifidobacteria in dairy products with plant additives. The benefits of plant products are determined by high contents of vitamins, antioxidants, minerals, and phytoelements. Thus, current research efforts aim to develop formulations for functional dairy products enriched with plant additives with probiotic properties, improve their technology, and assess their consumer appeal.

Danilova developed a phytocomposition for a functional fermented milk product with gerodietetic properties [19]. The phytocomposition was made up of medicinal plants growing in Western Siberia. It was based on *Comarum* extract that strengthens the joints, which is especially important for older people. The phytocomposition also included extracts of *Crataegus*, which stimulates the cardiovascular system, and *Origanum vulgare*, which has a calming sedative effect on the nervous system.

Crataegus fruits contain flavonoids (up to 3%, mainly hyperin), organic acids (citric and tartaric), sugars (up to 0.29% sucrose; pentose and fructose), carotene (2–30 mg%), vitamin C (25–375 mg%), choline, essential oil, colouring agent (carotene pigment), fats, nitrogen wastes (0.8–1.5%), ash (1%), trace elements (potassium, calcium, manganese, magnesium, iron); tannins, and extractives. Also present are vitexin glycoside, hyperoside, leucocyanidins – bioside, rutin, sesculin, and purine derivatives, triterpene saponins (ursolic and oleanolic acids), soroite, and choline-like substances. *Crataegus* fruits contain a mixture of triterpenic acids (categus, ursolic, chlorogenic, oleanolic, and caffeic acid), flavone glycosides, acetylcholine, and phytosterols. *Crataegus* flowers contain caffeic and chlorogenic acids, hyperoside, choline, acetylcholine, essential oil, trimethylamine, flavone glycosides, hyperoside, and quercetin. The leaves are rich in phytoncide and the roots contain okonakintin (a quinine substitute) [19].

Crataegus primary nutrients are flavone glucosides – crystalline dyes of orange and red colour. This plant is a rich source of vitamin P. The maximum amount of flavonoids in the P-vitamin complex accumulates in the green leaves (4–5% for *Crataegus sanguinea*), remaining in the fallen leaves. An infusion of *Crataegus* fruits and flowers or a liquid fruit extract reduce the excitability of the central nervous system and have a tonic effect on the heart muscle. They increase blood circulation in the coronary vessels of the heart and brain and eliminate tachycardia and arrhythmia by normalıыing the rhythm of cardiac activity. In addition, they slightly reduce blood pressure, improve sleep and a general state of health. *Crataegus* medicines have a beneficial effect on the functioning of the heart, expanding its vessels, which is especially important for the elderly [19].

Origanum vulgare contains up to 1.2% of an essential oil (so-called ‘intoxicating’ oil) that has a pleasant smell and bactericidal properties. It consists of aromatic alcohol, phenols, thymol (up to 3.8–10.2%) and its carvacrol isomer, as well as bi- and geranyl acetate (up to 5%). The plant also contains free alcohols (up to 15%), sesquiterpenes (12.5%), ascorbic acid (up to 565 mg% in leaves), and flavonoids. In addition, it is a source of polyphenolic compounds (up to 12–20%), five flavonic glycosides, tarry substances (10%), coumarins (1.4%), tannins (1.9–4%), and colouring agents. The content of ascorbic acid is 565 mg% in the leaves, 58 mg% in the stems, and 166 mg% in the flowers. Phytocomponents enrich products with micronutrients – biologically active substances that increase their nutritional and biological value. They also provide products with functional properties. Further studies in using non-conventional plants as raw materials for functional products will help us replenish the deficiency of nutrients in the human body. In addition, they will give us an extra opportunity for using natural resources [19].

Potoroko *et al.* patented a formulation composed of skim milk powder, 30% cream, aqueous malt extract, fried green malt, a ginseng dietary supplement, eleutherococcus, milk thistle, echinacea, starter culture of lactic streptococci, Bifilact D and thermophilic bacteria, a stabiliser, fruit or vegetable puree, honey, fat-soluble vitamin D, and water [20]. This formulation ensures a high biological value, long shelf-life, and good sensory characteristics.

In another study, Potoroko *et al.* described the preparation of a functional kefir drink enriched with alfalfa extract [21]. After introducing alfalfa extract into milk, it was fermented at about 20°C for 10–12 h. Then the temperature was lowered to 12–16°C and the product was left at rest for 4–6 h for yeast to develop. After that, the product was cooled to 8–10°C and left for 12–24 h to ripen. Ethanol and carbon dioxide accumulated as a result of yeast development, giving the finished product a specific taste and smell. Alfalfa extract was chosen due to its composition. It contains organic and inorganic compounds, amino acids, monosugars, phenolic compounds, and trace elements characteristic of plant materials, as well as humic and other biologically active substances not commonly found in plant extracts. The extract affected the fermentation rate and intensified lactose conversion and proteolytic reactions, making the kefir drink dietetic. Most importantly, it did not contain any limiting amino acids.

Skorkina *et al.* created a formulation for biokefir based on skim milk and two plant components, hawthorn puree and stevia syrup [22]. Hawthorn puree contains substances that expand the blood vessels of the heart and improve the absorption of oxygen by the heart muscle, relieving arrhythmia. In addition, hawthorn reduces blood pressure and has a calming effect. It contains vitamins C and PP, carotene, some acids, and plenty of sugars (fructose) and pectin, which removes heavy metal salts and other harmful substances from the body. Stevia is rich in glycosides (stevioside, rebaudioside (A, C, D, E); dulcoside, and steviolbioside) which help to improve carbohydrate metabolism and stimulate the secretion of inulin in diabetes mellitus. It also contains vitamin C, β-carotene, and minerals (zinc, selenium) with antioxidant properties. Its mild diuretic effect helps to remove metabolic products, toxins, and salts of heavy metals from the body. The syrup sweetness has a factor of 1:30. According to the study, the acidity of biokefir with natural additives increased throughout its shelf-life, but remained within the normal range.

Lyu patented a formulation for fermented milk yogurt with mild diuretic properties. It contained 200–220 parts of purple sweet potatoes, 10–12 parts of skimmed milk powder, 6–7 parts of dates, 2–4 parts of *Houttuynia cordata*, 5–6 parts of liquorice root, 8–10 parts of peppermint aqueous extract, 2–3 parts of corn fibres, 4–6 parts of algae, 3–5 parts of pomegranate peel, 6–8 parts of *Centaurea*, 0.2–0.4 part of stevioside, 10–15 parts of honey, 10–12 parts of glucose, as well as *Streptococcus thermophilus* and *Lactobacillus bulgaricus* bacteria [23]. The product had a pleasant taste, a long shelf-life, and probiotic properties. It helped to cleanse the urinary system.

Joung *et al.* developed yogurt with extracts from two traditional Korean plants: persimmon (*Diospyros kaki* L.) and lotus (*Nelumbo nucifera* L.) [24]. The extracts were prepared by boiling in a water bath at 100°C for 9 min, with periodic stirring and further filtration of the aqueous part. The resulting product was vacuum-dried at max. 50°C. The plant additives were introduced into whole milk prior to fermentation. Then, *Streptococcus thermophilus* and *Lactobacillus delbrueckii subsp. bulgaricus* bacteria cultures were added in the amounts of 2.95 and 1.14 log CFU/mL, respectively. The plant extracts prolonged the product's shelf-life, reduced the fermentation time, improved the viability of the starter culture, structured the product, and enriched it with phenolic compounds with antibacterial, antioxidant, and immunomodulatory properties.

The authors of another study formulated fermented milk drinks enriched with ayrampo fruit extract [25]. Ayrampo aqueous extract is a rich source of natural beta-cyanine pigments and antioxidants, highly stable during heat treatment and storage.

Oh *et al.* proposed using aqueous extracts of *Cudrania tricuspidata* and *Morus alba* (commonly known as white mulberry). These extracts work as prebiotic additives that increase the rate of bacterial growth and fermentation intensity [26]. *Streptococcus thermophilus* and *Lactobacillus delbrueckii ssp. bulgaricus* were used as probiotic microorganisms. The plant extracts enriched the drinks with monosaccharides, as well as non-chlorogenic, chlorogenic, and caffeic acids, which have a mild stimulating effect on the body.

Chiodelli *et al.* evaluated the effect of *Aloe barbadensis* and *Aloe arborescens* extracts on the properties of a dairy product fermented with *Lactobacillus* bacteria [27]. The extracts helped to structure the product, gave it a pleasant taste and smell, and enriched it with secondary metabolites, improving enzymatic processes and increasing the product's nutritional value. Aloe extracts contain enzymes, vitamins, phytoncides, aloin, nataloin, rabarberon, homonatalain, emodin (1.66%), tarry substances, and traces of essential oils. The latter have a pronounced anti-inflammatory properties, increase the secretion of digestive glands, improve appetite and digestion, and prevent the development of pathogenic flora. In addition, milk drinks enriched with aloe and *Lactobacillus rhamnosus* reduce the size of adipocytes and increase their number. They can also lower body weight and blood glucose levels, which makes them effective in fighting excess weight and treating type II diabetes [28].

The extracts obtained from the roots of *Rhodiola rosea*, *Eleutherococcus senticosus*, and *Panax ginseng* can also be effectively used to enrich fermented milk drinks. These plants are the most widely used adaptogens and natural stimulants. *Panax ginseng* is a rich source of ginsenosides. *Eleutherococcus* contains several eleutherosides which are responsible for adaptogenic activity. *Rhodiola rosea* contains salidroside, tyrosol, and rosavins, which are presumably active compounds. Molgaard *et al.* studied the properties of pasteurised milk drinks enriched with *Rhodiola rosea*, *Eleutherococcus senticosus*, and *Panax ginseng*. The content of active components was determined by HPLC after pasteurisation [29]. The results showed that eleutherosides from *Eleutherococcus* and ginsenosides from *Panax ginseng* could survive pasteurisation, while salidroside and rosavin from *Rhodiola rosea* root were destroyed. Thus, the authors warned against using this additive in heat-treated products.

In the work by Kurnakova, blueberries were used to increase the nutritional value, enhance taste, and prolong the shelf-life of the product. These effects are due to anthocyanosides, which are detrimental to *E. coli* and other pathogenic microorganisms [30]. Anthoconosides protect the cardiovascular system, prevent varicose veins, have antibacterial properties, and are beneficial for vision.

Gabriel *et al.* developed a new probiotic product called 'Rosalact'. It was made from pasteurised milk enriched with extracts of medicinal plants (rosehip, liquorice) and probiotic ABT-5 culture [31]. It was found that liquorice root extract contains carbohydrates and related compounds (glucose, fructose, sucrose, and maltose), polysaccharides (up to 34% starch, up to 30% cellulose, and pectin substances), organic acids (succinic, fumaric, citric, malic, and tartaric), essential oils, triterpenoids (glycyrrhizic acid), resins, steroids (β-sitosterol), phenolcarboxylic acids and their derivatives (ferulic, synomal, and salicylic), coumarins (herniarin, umbelliferone, etc.), tannins (8.3–14.2%), flavonoids (liquiquirithin, isoliquirithin, liququiritozide, quercetin, kempferol, apigenin, etc.), higher aliphatic hydrocarbons and alcohols, higher fatty acids, and alkaloids. Rose hips give the dairy product a wide range of functional properties, making it suitable for daily use, as well as in supportive therapy for colds, kidney disease, cardiovascular disease, and prevention of vitamin deficiency.

In another study, liquorice root extract and sea buckthorn fruits were used to enrich milk-based drinks [32]. Milk was mixed with the plant extracts and fermented at 42°C for 5 h using ABY-3 culture bacteria (*Bifidobacterium*, *Streptococcus thermophilus*, *Lactobacillus acidophilus*, and *Lactobacillus delbrueckii subsp. bulgaricus*). As a result, the final product had an increased content of vitamins B_1, B_2, C, E, K, P, as well as flavonoids, folic acid, carotenoids, betaine, choline, coumarins, glucose, fructose and phospholipids, macroelements and microelements (sodium, magnesium, iron, silicon, aluminium, lead, nickel, manganese, strontium, and molybdenum). In addition, the product had an extended shelf-life.

Mariola *et al.* studied the effect that phenolic compounds of rosemary, hyssop, nettle, caraway, and lemon balm extracts had on the growth of *Lactobacillus acidophilus* and *L. delbrueckii* bacteria [33]. It was shown that rosemary extract suppressed the growth and activity of the bacteria. Lemon balm extract had the maximum amount of antioxidant substances, which extended the product's shelf-life. Thus, the authors did not recommend using rosemary as a functional additive for drinks containing lactobacilli. Alternatively, they could be added at the very end of the process, after fermentation.

In view of the above, there is a clear need to fully utilise plant biodiversity and create effective and safe functional products. Russia is home to many medicinal plants that are absent in the pharmacopoeias of other countries. They include *Eleutherococcus senticosus*, *Schisandra chinensis*, *Paeonia anomala*, *Leonurus cardiaca*, *Rhodiola rosea*, *Rhaponticum carthamoides*, *Thermopsis lanceolata*, *Colchicum*, *Astragalus dasyanthus*, *Phlojodicarpus sibiricus*, *Peganum harmala*, *Hedysarum alpinum*, *Filipendula ulmaria*, *Lespedeza bicolor*, *Lespedezae hedysaroides*, *Securinega suffruticosa*, *Salsola collina*, *Sphaerophysa salsula*, and *Scutellaria baicalensis* [34, 35]. This work should involve research into using cultivated agricultural plants as a source of medicinal raw materials [36].

Many plant species, especially endemic, have disappeared or are threatened with extinction and listed in the Red Book of Russia. Although there is a high demand for them in medicine, pharmacists have to exclude them from the pharmacopoeia. These factors have created a need for further research into their reproduction and return to favourable habitats. Many of these plants are the only sources of unique substances that can be used in treating cancer, Alzheimer's, neurological and other diseases. For example, vogonosin, a flavone of *Scutellaria baicalensis* has apoptotic properties and is able to target cancer cells and destroy them without affecting the healthy ones [36]. This plant grows in the natural environment in very scarce amounts, therefore its medical substances can only be produced by cell bioengineering methods.

Over 40 years ago, scientists tried to propagate cell and tissue cultures *in vitro* and select the most productive cells and differentiated tissues. In most cases, it was impossible to isolate a sufficient amount of required metabolites from plant materials. One of the turning points was the discovery of genetic transformation using *Agrobacterium rhizogenes* soil bacterium [37].

The agrobacterial transformation of plant roots made it possible to obtain secondary metabolites for medical use: alkaloids, coumarins, phenolic compounds, and some others [38]. Plant studies in this direction are especially relevant.

The lack of secondary growth in the roots inhibits the production of a wider range of biologically active substances. It is known that the activity of secondary substances often increases in roots with secondary growth, which can contribute to a greater yield of target metabolic products. Therefore, we need to develop various methods that induce the production of secondary metabolites in hairy root cultures and their secretion into the culture medium.

One of the problems is how to preserve the roots for a long time without causing repeated subinoculation. Although there are numerous methods available today that maintain and preserve the created cultures, further research is needed to develop more advanced methods of cryopreservation and those using bioreactors.

This market segment has a huge growth potential. In Russia, hairy root cultures are still a fairly new concept. Only few scientific groups conduct fundamental and applied research using hairy roots as model objects. Moreover, there are no commercially successful Russian projects in this area. The hairy roots technology could be used in the production of functional foods, lowering costs and extending the list of biologically active plants, including endangered species [39].

CONCLUSION

In general, the state of people's health in Russia calls for more advanced research and full utilisation of local medicinal plants to obtain biologically active substances for using in the food industry. Considerable funds are currently allocated to support innovative research and development of advanced technologies in this area.

There are a number of objective and subjective reasons behind the growing production and consumption

of functional products all over the world. These include:
– changes in the structure and quality of modern nutrition: a significant decrease (2–3 times compared to 100–150 years ago) in vitamins, minerals, dietary fibre, and other vital substances;
– a real risk of chemical and biological contamination of foods with nitrates, nitrites, salts of heavy metals (mercury, tin, lead, copper, cadmium, antimony, vanadium, chromium, molybdenum, manganese, and cobalt), microscopic fungi, pathogenic microorganisms, dyes, preservatives, etc.;
– a need for certain essential nutrients, which are not formed in the body, to come with food: some macro- and microelements (selenium, magnesium, vanadium, zinc, iron, molybdenum, etc.), vitamins (E, D, A, etc.), amino acids (methionine, leucine, lysine, histidine, etc.), and polyunsaturated fatty acids (linoleic, linolenic, arachidonic, etc.); they are important for metabolic processes, the synthesis of enzymes, hormones, and vitamins, for haematopoiesis and tissue repair, etc.;
– a decrease in human motor activity and overconsumption of refined foods with various additives, leading to a 40–60% deficiency of vitamins and essential macro- and microelements in the diet;
– a growing attention to one's own health and efforts to cut down on drugs by having a balanced diet and consuming more functional foods;
– high incidence of chronic diseases (cardiovascular, endocrine, Alzheimer's, motor disease, etc.), which require functional products for medicinal and preventative purposes;
– high cholesterol levels among over 20% of the population, encouraging them to prefer functional foods to reduce the risk of cardiovascular disease;
– a growing number of obese children and adults with a high risk of heart disease, asthma, diabetes, and cancer; and
– active involvement of specialised medical associations and funds in the prevention of cardiovascular, diabetic, orthopaedic, oncological, and other diseases (their logos and recommendations, e.g. glycaemic index, are indicated on food labels); better design and quality of food packaging materials; more packages suitable for microwave ovens [36, 38, 39].

Functional products, including drinks, have a variety of positive effects on metabolic processes. They reduce glucose and cholesterol levels in the blood and help the absorption of trace elements in the large intestine. In addition, they strengthen the immune system, help to prevent cancer, and exhibit a wide range of other properties: anti-allergic, anti-inflammatory, anti-thrombotic, antimicrobial, stimulating, health-beneficial, antispasmodic, and antioxidant. Functional foods increase resistance to infectious diseases and enhance the body's ability to adapt to adverse environmental factors (weather, ionisation, oxygen deficiency, intensive workload, etc.). These adaptogens increase the sensitivity of cells to endogenous insulin, normalising the metabolism of carbohydrates, proteins, and fatty acids [39, 40].

Thus, functional milk-based drinks enriched with plant components are a promising direction in the dairy industry. They improve the immune system and can be used as part of supportive therapy. They are also suitable for daily use to replenish the balance of essential nutrients.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

FUNDING

This work was performed under Agreement No. 075-02-2018-223 of November 26, 2018 and Agreement No. EB 075-15-2019-1362 of June 14, 2019 (unique agreement identifier RFMEFI57718X0285) on the theme entitled 'Obtaining biologically active substances from medicinal plants endemic to Siberia using cell cultures and organs of higher plants.'

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