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Obtaining Functional Products from Sea Buckthorn Berries

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***Abstract*-Authors do researches on the development of new functional ingredients at complex processing of plant raw materials of the Siberian region. As a result of the conducted researches, the choice of plant raw materials components is substantiated (fruits of sea-buckthorn) as sources of functional ingredients. The resource-saving technological scheme of complex processing of fruits of sea-buckthorn where along with sea-buckthorn oil the production of fruit powder from pulp of sea-buckthorn and clarified juice has been offered to develop. Rational use of seeds is provided. Complex dietary supplements based on the products of sea-buckthorn processing have been developed. Efficiency of the developed antioxidant and emulsifying additives using natural biologically active agents in the production technology of food emulsions has been theoretically proved and experimentally confirmed. Relevance and prospects of further developments and researches in the field of new domestic micro-ingredients development have been proved.**

Keywords-functional and technological additives, formation of properties, microemulsions, antioxidant complexes, irreplaceable feedstuffs, sea buckthorn

I. INTRODUCTION

Obtaining and use of natural biologically active substances with a complex of beneficial properties of directed action is of great scientific and practical interest. The body's need for biologically active substances is obvious, since they are directly involved in the regulation of many physiological reactions and processes occurring in the human body. The use of biologically active substances as functional and technological additives performing the role of antioxidants, structure stabilizers, natural colour and flavouring agents in food production and helps to create a diverse range of foods of high nutritional value, including products of functional and therapeutic and preventive purposes [1].

Wild-growing raw materials are a source of water-soluble and fat-soluble vitamins, macronutrients and micronutrients and biologically active substances, which have a healthy and protective effect even in minimal amounts. The use of plant raw materials in the production of functional technological additives will increase the nutritional value and therapeutic properties of food. Moreover, regular use of such products reduces the negative effects of adverse factors, both external and internal environment of the human body. However, the wider use of wild-growing raw materials can be limited due to insufficient knowledge of its chemical composition and, as a result, the lack of effective technologies for its processing.

In view of the above, the production of multifunctional nutritional and biologically active additives from natural raw materials is a highly relevant issue.

II. THE PURPOSE AND OBJECTIVES OF THE STUDY

The purpose of the work is the development of functional products of key nutrients (essential fatty acids, phospholipids, antioxidant vitamins, etc.) for various sectors of the food industry, intended for use as functional and technological additives acting as antioxidants, consistency improvers, natural colour and flavouring agents as well as for direct consumption by all groups of the population as functional food additives

To achieve this purpose the following objectives were determined:

- to analyze the state of production and use of functional and technological additives in various sectors of the Russian food industry in order to justify the possibility of import substitution of these products;

- to find theoretical and experimental substantiation for the directions of forming the functional properties of microemulsions intended for use as functional and technological additives, as well as for human consumption in order to prevent alimentary-dependent diseases among various groups of the population;

- to choose the raw materials for the production of the developed products taking into account the possibilities of Siberian region in terms of available plant raw materials containing natural key nutrients in their composition;

- to investigate the composition and properties of the products obtained by complex processing of plant raw materials;

- to obtain functional additives containing key nutrients (membrane lipids, antioxidant vitamin complexes, and others).

III. MATERIALS AND RESEARCH METHODS

Experimental research methods were used to select and justify the raw materials for the manufacturing the developed products. To implement the objectives set, we applied generally accepted and special methods of researching raw materials and finished products.

IV. RESULTS AND DISCUSSION

Practical implementation of this objective involves the complex processing of unique plant materials from the Siberian region, containing in its composition natural key nutrients that are ideal ingredients for obtaining functional food additives, including for various sectors of the food industry, as well as for direct consumption by all groups of population.

Currently, in order to ensure the required level of life safety and health of citizens, as well as to increase the competitiveness of Russian functional products, research is being conducted on the selection of effective food additives, including antioxidants, used to prevent the oxidation of oil and fat-containing products. Along with the study of the antioxidant properties of lecithin (E322), citric acid (E330), and dehydroquercetin, theoretical and practical studies are being carried out on the use of tocopherols (E306, E307, E308, E309) and carotenoids as antioxidants. Moreover, the preference in this area is still given to the use of individual products or multicomponent systems derived from natural raw materials.

One of the areas of comprehensive scientific work to obtain functional and technological additives is the development of new approaches to the processing of plant materials from the Siberian region. Research on the complex processing of viburnum, wild rose and sea buckthorn is currently underway.

Sea buckthorn is one of the most valuable natural sources of water- and fat-soluble vitamins and vitamin-like compounds, organic acids, minerals and other substances, as well as oils rich in carotenoids, tocopherols, essential fatty acids. Given the variety of useful properties of the sea buckthorn berries, it seems appropriate to obtain biologically active ingredients from it.

We have developed a technology for complex processing of sea-buckthorn berries, which, along with pharmacopoeial sea buckthorn oil provides for obtaining fruit powder and clarified juice from sea-buckthorn pulp. In addition to this, rational use of seeds is proposed [6].

The advantage of the developed technology is a mild temperature regime and the absence of other effects that affect destructively on biologically active substances of sea buckthorn during its processing, which allows obtaining a number of valuable products from sea buckthorn berries.

The proposed flow scheme for complex processing of sea-buckthorn berries was tested in an experimental workshop for processing fruit and berry raw materials. The products obtained underwent biochemical and microbiological examinations with positive results. This flow scheme can be successfully used in the processing of other berry raw materials from the Siberian region; only minor changes in the process parameters are required, depending on the morphological characteristics of the processed raw materials.

According to the flow scheme proposed in Fig. 1 sea buckthorn berries are accepted for processing following the inspection, during which substandard berries are removed and impurities are separated. Some fresh berries are immediately processed, and some proportion is frozen. Moreover, it was found that technologically fresh berries are inferior to fresh-frozen, because in fresh ones, juice recovery is difficult and, when they are separated on the disintegrator, part of the pulp remains on the seeds. Therefore, it seems appropriate to first freeze the berries of sea buckthorn and then process them after storage in freezers.

Next, the berries are fed to a disintegrator, where they are divided into pulp (juice, crushed pulp and shell) and whole seeds. The disintegrator achieves a high degree grinding of the cell structures of the pulp and the shell, the seeds remain intact. Whole seeds are dried at a temperature of 35±2oC to a moisture content (12±0.5)%. After determining the germination rate, it is recommended to use them as seeds for land reclamation. The pulp is sent to centrifugation, as a result of which the pulp is divided into three layers: sea buckthorn pulp (the upper layer), clarified juice (the middle layer) and sea buckthorn pulp (the lower layer).

Clarified sea buckthorn juice is a valuable vitamin product and after pasteurization it is recommended to blend it with carrot juice, pumpkin juice with added sugar or milk whey, which will balance the chemical composition and improve the taste of the product.

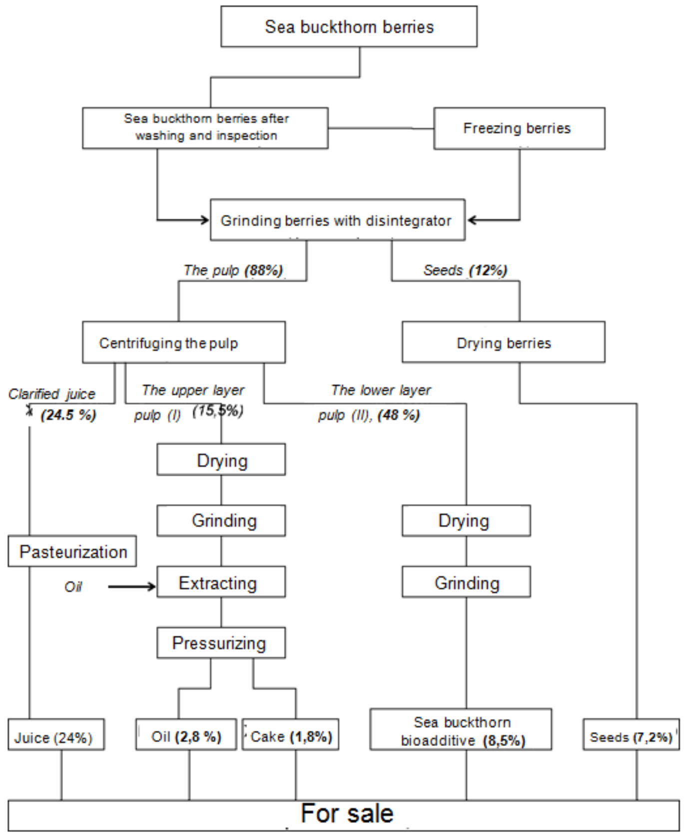

Figure 1 – Flow scheme of complex processing of sea buckthorn berries

Since the pulp of the upper and lower layers has a fairly high humidity – 75-79% and is microbiologically unstable, under the proposed technology sea-buckthorn pulp is proposed to be dried at mild temperatures: temperature (55-60)°C to the humidity of (140.5)%. As a result of experimental studies it was found that when drying to a moisture content of 6%, there is a loss of carotenoids up to 30%, tocopherols up to 12%, ascorbic acid up to 20%, bioflavonoids up to 32%. In addition, deep drying requires high energy costs.

Upon determining the microbiological indicators, the guaranteed stability of dried sea buckthorn pulp for 12 months was established.

After drying, the chemical composition and physicochemical properties of the sea-buckthorn pulp of the upper and lower layers were determined. According to the results of the research, it was proposed to obtain pharmacopoeial sea buckthorn oil from the sea-buckthorn pulp of the upper layer as the upper layer of this pulp is rich in lipids (45 - 50) %.

It is recommended that after drying, sea buckthorn pulp should be crushed for deeper destruction of cellular structures, which in turn will lead to an increase in the oil-pulp contact surface and, consequently, more rapid and complete extraction of the oil by a solvent with high molecular weight, which is vegetable oil.

To obtain sea buckthorn oil from dry crushed pulp, a diffusion method has been proposed consisting in heating in vegetable deodorized oil.

Using the correlation analysis method, we investigated the influence of such factors as the pulp : oil ratio, the amount of extraction, the time and temperature of extraction on the resulting criteria: product yield, amount of carotenoids and oil acid value. Our study found that the optimal extraction temperature is between 55 to 60 ℃; the amount of extraction – 4; the oil: pulp ratio – 1.4: 1; and the extraction time is 4 to 5 hours.

In this case, the diffusion method using vegetable oil is the most acceptable from a practical and theoretical point of view, compared with the extraction method. Extraction with organic solvents (n-hexane, petroleum ether, or methylene chloride) requires large economic costs for the purchase of solvents and expensive equipment (extractor, filters, vacuum distiller, and evaporator). In addition, the solvent removed from miscella and cake requires regeneration, i.e. separating the solvent from a mixture of its highly concentrated vapors with water vapor, resulting, therefore, in additional costs. At the same time, a small part of the solvent remains in the water, which in turn leads to environmental pollution. In addition, removing the solvent from the miscella requires a high temperature and takes a long time, which leads to the destruction of the temperature-sensitive biologically active substances.

Thus, summarizing the above, we can note the expediency of the selected diffusion method.

The sea buckthorn oil obtained meets the requirements for pharmacopoeial oil: the amount of carotenoids is more than or equal 180 mg% and the acid value is 14 mg KOH at most. It can be used not only as a medical drug, but also as a target product in the form of a biological additive in the preparation of microemulsions.

TABLE 1. ORGANOLEPTIC AND PHYSICO-CHEMICAL CHARACTERISTICS OF THE OBTAINED OIL SAMPLES

Characteristics	**Sea buckthorn oil made from upper layer pulp**	**Sea buckthorn oil made from upper layer pulp**	**Sea buckthorn Seed oil**
Transparency	Clear fluid		
Odour and taste	Aromatic, characteristic of sea buckthorn oil		
Appearance, consistency at 20 ℃	Oily liquid		
Colour	Light-brown		
Moisture content, %	10.0	12.1	14.3
Total carotenoids, mg/100 g	160.5	329.4	20.62
Total tocopherol s, mg/100 g	160.0	160.0	90.0
Oil acid value, mgKOH/g, max 6.0 mg KOH/g	4.6	4.4	6.0
Peroxide value, 10 meq/kg, max.	2.3	2.1	3.5
Density at 20 ℃, g/cm^3	0.915	0.915	0.914
Refractive index, 20^{0}C	1.474	1.472	1.473

Having analyzed the data presented, we can conclude that the oil made from the lower layer of sea buckthorn pulp is more stable to oxidation than that made from the upper layer, besides, the oil made from the lower layer pulp contains the greater amount of carotenoids.

Sea buckthorn cake, the residue formed after the oil extraction with diffusion method, is a product of high biological value, containing lipids, which include essential fatty acids, proteins, vitamins, and minerals in its composition. In our case, sea buckthorn cake is supposed to be used in the production of a functional technological additive that serves as a stabilizer and a source of dietary fiber in emulsion food products. In addition, in sea buckthorn oil cake, the lipid complex is mainly represented by unsaturated acids (palmitoleic, oleic, linoleic), which have been found to transform gluten making it more elastic as a result. Thus, powdered additive made from sea buckthorn cake can be used in the manufacture of sponge-cake semi-finished goods.

The conducted research allowed us to conclude that there are more proteins, vitamins, mineral elements in the lower level of sea buckthorn pulp than in the upper layer. Therefore, the dried and ground sea buckthorn pulp of the lower layer having a well balanced composition of protein-lipid, vitamin and minerals, is recommended as fruit filler in the production of ice cream.

Thus, the proposed scheme for the integrated processing of sea buckthorn berries allows obtaining several types of products simultaneously – oil, juice, fruit powder additive, and seeds. In addition, it enables increasing the preservation degree of biologically active substances using optimal technological parameters of the processes.

Products of sea buckthorn processing, in particular, the oil obtained from the pulp of the upper and lower layers, rich in carotenoids and tocopherols, are proposed to be used in the complex food additive in the form of a functional additive acting as an antioxidant and emulsifier. The choice of these compounds is explained by their important physiological functions and high antioxidant efficiency [7].

Phospholipids with surface-active properties are proposed as an emulsifying agent in the composition of this complex. Phospholipids, being natural emulsifiers, can be used both in direct emulsions (oil/water) and in reverse ones (water/oil), which ensures its activity in the composition of a wide range of products. Owing to their bipolar characteristics phospholipids are able to stabilize water-in-oil emulsions, decreasing the surface tension between water and fat, which makes it possible to achieve a thin homogeneous distribution of water droplets in the final emulsion product. Additionally, phospholipids have antioxidant activity. This is essential for increasing the shelf life of the finished product, as well as when products are exposed to thermal loads.

We have obtained functional additives with an oil phase content of 95%. The quality indicators of functional additive with antioxidant and emulsifying effects developed on the basis of sea buckthorn oil and phospholipids are summarized in Table 2.

This functional additive is distinguished by an increased content of carotenoids (67-69 mg/100 g) and tocopherols (43-46 mg/100 g), while fractions characterized by antioxidant activity (β and γ - tocopherols) amount to 23-25 mg/100 g (Table 3).

TABLE 2. ORGANOLEPTIC AND PHYSICO-CHEMICAL INDICATORS OF FUNCTIONAL ADDITIVES

Characteristics	**Using sea buckthorn oil made from upper layer pulp**	**Using sea buckthorn oil made from lower layer pulp**
Odour and taste	Weak, characteristic of the type of vegetable oil and phospholipids used.	
Consistency	Soupy	
Colour	Orange-yellow	
Moisture and volatile substances content, % max.	5.0	5.0
Weight ratio of phosphatides,%, min.	10.0	10.0
Weight ratio of soybean oil,%, min.	75.0	70.0
Weight ratio of sea buckthorn oil,%, min.	10	5
Weight ratio substances insoluble in ethyl ether,%, min.	1.5	1.5
Oil acid value, mg KOH/g, max.	3.5	2.5
Peroxide value, mmol of active oxygen/kg, max.	10.0	10.0
Density (15 °C) g/cm^3	0.924	0.922
Refractive index (20 °C)	1.474	1.476
Viscosity (20 °C), cP	55.1	58.4
Iodine value, % J_2	123	126

TABLE 3 THE PORTION CONTENT OF TOCOPHEROLS AND CAROTENOIDS IN FUNCTIONAL ADDITIVES

Substance	**Using sea buckthorn oil made from upper layer pulp**	**Using sea buckthorn oil made from lower layer pulp**
Vitamin E, mg/100 g	43	46
α-tocopherol	20	21
γ- tocopherol	5	6
δ-tocopherol	18	19
Carotenoids, mg/100 g	67	69
including		
β-carotene	21	23

V. SUMMARY

The use of a complex additive in the form of functional additive containing phospholipids, tocopherols and carotenoids make it possible to create whole new foods that are balanced in their nutritional and biological value, including increased antioxidant stability.

It should be noted that the results presented here are part of a comprehensive study on the development of the range and technologies for new types of functional technological additives using plant materials from Siberia.

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