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Scientific Justification and Development of Critical Solution for the Production of Phytocomposite Mixtures to Enrich Nonalcoholic Beverages

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Abstract

This article presents a scientific substantiation of the choice of nonconventional vegetative raw material of the North Caucasus region for the production of phytocomposite mixtures of different functional orientation (adaptogenic, immunomodulating effect), intended for enrichment of nonalcoholic beverages, as well as identifies the trends for the design of phytocomposite mixtures using mathematical modelling method, taking into account the functional orientation matrix.

Keywords: functional nonalcoholic beverages, nonconventional vegetable raw materials, functional orientation matrix, biologically active components, phytocomposite mixtures, antioxidant and adaptogenic properties.

Introduction

The Russia's population nutritional status is one of the most important determinants of health and the preservation of the nation's gene pool. The significance of this factor is confirmed by the main trends of the State policy in the healthy nutrition of population for 2020 approved by the RF Government Decree No. 1873-r dated 25.10.2010 [1].

The development of the social sphere, including the development of human capital, improvement of the demographic situation and creating the conditions for improving the population's health are the first strategic directions in the priority areas of socio-economic development of the Republic of Adygea designated in the law of the Republic of Adygea No. 300 dated November 23, 2009 "On the strategy of socio-economic development of the Republic of Adygea until 2025". [2]

Therefore, in the context of the establishment of innovative activity, one of the main and promising tasks of food industry development in the Republic of Adygea is the creation of safe specialized food products with full-value composition and consumer properties.

Nonalcoholic beverages are the most convenient form of food product that can be used to correct disorders of human nutritional status through the enrichment with physiologically functional ingredients.

The use of biologically active substances of plant resources is a promising area in the production of functional drinks.

Therefore, the development and production of functional nonalcoholic beverages using nonconventional local vegetable raw materials are among the main ways to solve the problem of nutrition optimization, and among the significant areas of research for the innovative development of the region in the context of import substitution.

Selection Of Vegetative Biologically Active Components To Produce Phytocomposite Mixtures And The Development Of A Functional Orientation Matrix

By analysing scientific studies of domestic and foreign scientists in the field of conceptual approaches to the creation of nonalcoholic beverages, we have scientifically substantiated and selected the principal solution for the production of functional nonalcoholic beverages:

1. Nontraditional vegetable raw materials of the North Caucasus region will be used as sources of biologically active substances;
2. Extracts from phytocomposite mixtures composed of various combinations of vegetable raw materials depending on the functional orientation of the beverages (with adaptogenic, immunomodulating action, and beverages intended for the prevention of iron deficiency anaemia and iodine deficiency states) will be used as an additive to impart functional properties to nonalcoholic beverages.
3. Prepared water will be used as a basis (matrix) for the production of functional nonalcoholic beverages.

In accordance with GOST R 55577-2013 - Functional food products. Information on distinctive features and efficacy - functional food products are recognized as such if the following conditions are met [3]:

- The ratio of nutrients in food products or categories of food products (their presence or absence, or reduced content) should have a beneficial effect on the physiological functions of the body;
- The content of each food or biologically active substance per 100 cm3 or 100 g, or of a single portion of the food product should not be less than 15% of the recommended daily intake [1].

In accordance with regulatory document MP 2.3.1.2432-08 - Standards of physiological needs for energy and nutrients for various groups of the population of the Russian Federation] [4] - the standards are the quantities reflecting the optimal population's needs for food substances and energy.

The standards are based on the main provisions of the Optimal Nutrition Concept:

- the energy value of a person's diet should correspond to the energy expenditure of the body;
- the values of consumption of basic nutrients - proteins, fats and carbohydrates - must be within the physiologically necessary proportions among them.
- the content of macroelements and essential trace elements must correspond to the human physiological needs; and
- the content of minor and biologically active substances in food should correspond to their adequate levels of consumption.

Based on the analysis, it has been found that there is a different systemic approach to the compilation of multicomponent phytocomposite mixtures. The traditional compatibility, pharmacological action, the chemical composition of ingredients, the state of the raw material base and the principles of adequate mobilization of adaptation mechanisms under the influence of damaging factors on the body are taken into account.

In addition, the following principles for the development of multicomponent mixtures should be observed:

1) safety,
2) efficiency, which is provided by a rational combination of ingredients, taking into account the potentiation of their action with each other;

3) provision for the metabolism normalizing effect on the broken links; and
4) standard quality and stability at storage.

For an objective assessment of the prospects for the inclusion of the various types of vegetable material in the composition of the of phytocomposite mixtures with different functional orientation, we:

- conducted a critical analysis of scientific literature and systematized information on the chemical composition of wild plants, including those growing in the North Caucasus. It should be noted, however, that so far the individual chemical composition of a number of widely known plants in Russia, used both in medicine and food industry, has been studied in part or such information is not available at all depending on the regional growth conditions, and the information on their active physiologically active substances is fragmentary;
- took into account the statistical data of the Administration of the Federal Service for Supervision of Consumer Rights Protection and Human Welfare in the Republic of Adygea, which characterized the growth of alimentary-dependent diseases of the population in various nosological groups (diseases of the endocrine system and digestive organs, diseases associated with iodine deficiency).

Based on the analysis of literature sources, such promising plants as black currant (Lat. *Ríbes nígrum*, leaves), meadow clover (Lat. *Trifolium pratense L*., blooms), common origanum (Lat. *Oríganum vulgáre*), common bilberry (Lat. *Vaccinium myrtillus L.*, leaves), common thyme (Lat. *Thimus serpyllum L)*, toad spit (Lat.*Lémna mínor*, leaves), girasol (Lat.*Heliánthus tuberósus,* tubers), black walnut (Lat. *Juglans nigra*), walnut (Lat. *Juglans regia L.*, leaves), briar (Lat. *Rósa majális*, fruits), Saint-Mary-thistle (Lat.*Sílybum mariánum)*, purple echinacea (Lat. *Echinacea angustifolia)*, big-sting nettle *(Lat. Urtica dioica L.*, leaves) were selected from the wide range of wild-growing raw materials to produce phytocomposite mixtures [5; 6; 7; 8; 9; 10; 11; 12; 13; 14; 15].

These wild plants used in the plant collections are allowed for use for children under 14 years old, and their stocks are reproducible.

Biologically active components with the greatest physiological activity and capable of having a positive impact on functional systems of the human body for prevention of alimentary-dependent diseases specific to the Republic of Adygea have been allocated to develop a functional orientation matrix from the chemical composition of vegetable raw materials. The results are shown in Table 1.

Table 1 - Functional orientation matrix of biologically active components of vegetable raw materials to produce phytocomposite mixtures.

The plant type and part thereof used	The content of biologically active components with adaptogenic action	Contribution to the functional orientation								
		The adaptogenic action of the phytocomposite mixture, including the prevention of vitamin deficiency		**Immunomodulatory action**		**Prevention of anaemia**			**Prevention of iodine deficiency**	
		Stimulates the central nervous and cardiovascular systems, and provides strength and the elasticity of blood vessels	Demonstrate antioxidant properties	Reduces the frequency of colds	Accelerates adaptation processes in the body in the context of the aggressive environmental impact	Prevention of vitamin deficiency	General strengthening	Increases the activity of the immune system	Promotes the prevention of iron deficiency anaemia	Promotes the prevention of hypothyroidism
Common dog rose (fruits)	Phenolic compounds (0.443%): anthocyanins (up to 2.3%), tannins (14.1%), flavonols and phenolic acids;	+	+	+	+		+	+		
	Vitamins: vitamin C - from 2 to 18%,	+	+	+	+	+	+	+		
	vitamins B1 (80-120 μg%), B2 (300-430 μg%), K_1, carotene (9.7%),	+								
	E									
	Minerals: The macronutrients: calcium - 28 mg, magnesium - 8 mg, sodium - 5 mg, potassium - 23 mg, phosphorus – 8 mg									
	Microelements: iron - 1.3 mg,									
	zinc —1.1 mg, copper, manganese									
Common origanum (Lat. Origanum vulgare L)	Phenolic compounds: flavonoids (1.13%)									
	Vitamins: ascorbic acid (140.43 mg%), carotenoids (1.23 mg%).									
	Essential oil (up to 1.2%), which includes thymol (up to 10.2%), carvacrol, bicyclic sesquiterpenes (up to 12.5%), free alcohols (up to 15%), geranyl acetate (up to 5%).									
Black currant (Lat.*Ríbes nígrum*, leaves)	Phenolic compounds: flavonoids (2.1%) tannins, coumarins									
	Vitamins:									
	Ascorbic acid (up to 470 mg%),carotenoids,									
	Essential oils, which include α-pinene, 1 and d sabinene, d-karyophyllene, terpene alcohols									

The plant type and part thereof used	**The content of biologically active components with adaptogenic action**	**Contribution to the functional orientation**								
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	Minerals: mineral (potassium, calcium, sodium, magnesium, iron, manganese, copper, lead, argentum, sulfur)									
Meadow clover (Lat. *Trifolium pratense L.*, blooms)	Phenolic compounds: flavonoids (0.785%) isoflavonoids, coumarins (coumestrin, coumarinic acid),									
	Vitamins (ascorbic acid, carotene, vitamin E, B group vitamins).									
	Essential oil, alkaloids, resins, fatty oil, trifolysin (having a fungicidal activity), compounds possessing an estrogenic property, glycosides, trifolin and isotrifolin,									
Milk thistle (Lat. *Sílybumariánum*)	Phenolic compounds: flavonoids (0.248%) (flavolignans-silymarins 2-3% of the dry mass of fruits).									
	Vitamins A, D, E, F.									
	Essential oils									
	PUFA (linoleic - 55.6%, linolenic - 3.0%),									
Big-sting nettle (*Lat.Urtica dioica L.*, leaves).	Phenolic compounds: flavonoids (0.50-1.96%): isocavercitrine, 3-O-glycosides and 3-O--rutinosides of quercetin, kaempferol and isorhamnetin;									
	Vitamins: Vitamin C (up to 600 mg%)									
	B2, K1 (0.2%), pantothenic acid, glycoside urticine, sitosterol;									
	Tannins, gums, phytoncides.									
	Salts of iron, silicon and other substances.									
Common blueberry (Lat. *Vaccinium myrtillus L.*, leaves)	Phenolic compounds - anthocyanins (940-1,900 mg%) and leucoanthocyanins (1,095-1,300 mg%), flavonols, phenolic acids, tannins (7-12%),									
	Vitamin C - 10-40 mg%, carotenoids -0.7-1.6 mg%, sugar – 4.8-9.4%, pectin – 0.4-0.6%, fiber – 1.6-2.4%									
	Ferric salts									
Walnut (Lat.. *Juglans regia L.*, leaves) and Black walnut (Lat. Juglans nigra)	Flavonoids (1.73%)									
	Mass fraction of vitamins, mg/100 g: C (1,300) A (β-carotene- 330)									
	Iodine									
	Ferric salts									
Girasol (Lat. *Heliánthus tuberósus*, tubers)	Flavonoids (0.853%)									
	Vitamins: C - 98.1 - 108.1 mg%									
	B1 (up to 1.2 mg%), B2 (4.0-7.9 mg%), B3 (2, -8.8 mg%) B6 (0.12 - 0.22 mg%) and others									
	Mineral substances: including (mg% per dry matter): iron – 10.1;									
	manganese - 44.0; calcium, 78.8; magnesium - 31.7; potassium – 1,382.5; sodium - 17.2.									

The plant type and part thereof used	**The content of biologically active components with adaptogenic action**	**Contribution to the functional orientation**								
		The adaptogenic action of the phytocomposite mixture, including the prevention of vitamin deficiency		**Immunomodulatory action**		**Prevention of anaemia**			**Prevention of iodine deficiency**	
		Stimulates the central nervous and cardiovascular systems, and provides strength and the elasticity of blood vessels	Demonstrate antioxidant properties	Reduces the frequency of colds	Accelerates adaptation processes in the body in the context of the aggressive environmental impact	Prevention of vitamin deficiency	General strengthening	Increases the activity of the immune system	Promotes the prevention of iron deficiency anaemia	Promotes the prevention of hypothyroidism
Purple echinacea (Lat.*Echinacea angustifolia)*	Flavonoids (2.12 %) derivatives of apigenin, luteolin, quercetin, kaempferol									
	Essential oil (up to 0.1%).									
	Simple sugars (arabinose, galactose, glucose, xylose, mannose, rhamnose, pentosans, fructose), oligosaccharides (sucrose) and polysaccharides (starch, cellulose, hemicellulose, inulin, pectin - 6.7% by weight).									
	The leaves of purple echinacea contain 8.56 * 10-2% provitamin A and 1.72%*10-4% of vitamin C. In the roots, its amount was 8.3 * 10-4%, in fresh blooms -2.14 * 10-4%. Fresh leaves and stems of purple echinacea contain 230 mg									
	Macro- and microelements: calcium (776 mg per 100g of raw materials), potassium (314 mg), aluminum (129 mg), magnesium (117 mg), chlorine (76 mg) and iron (48).									
Toad spit (Lat.*Lémna mínor,* leaves)	Flavonoids (0.589%)									
	Vitamins C, Aa1, B1, B2, B6, E about 0.5 mg/g dry weight), PP (B5) (about 0.8 mg/g dry weight). In spit									
	Minerals phosphorus - up to 3% , calcium - 6%, and magnesium - 2% , cobalt - 0.048 mg; bromine - 0.018 mg; copper - 0.032 mg; nickel - 0.07 mg; titanium - 0.48 mg; calcium, silicon, cobalt, titanium, nickel, copper, zinc, vanadium, zirconium, gold, radium, bromine, etc.									
	Iron									
	Iodine									
Thyme (Lat. *Thimus serpyllum L.)*	Flavonoids (0.98%); Phenolic acids (predominantly salicylic and rosemary); flavonoids and tannins in the amount up to 6.4%; triterpenic acids (ursolic and oleanolic), bitters and									
	macronutrients (mg/g): K - 26.10, Ca - 12.20, Mn - 3.90, Fe – 0.95; micronutrients (nonalcoholic beverage plant): Mg 0.31, Cu 0.48, Co 0.12, Mo 64.00, Cr 0.10, Al 0.66, Ba 0.58, V 0.35, Se- 7.10, Ni – 0.20, Sr – 0.36, Pb – 0.13. B - 108.40 μg/g.									
	essential oils - from 0.1 to 1.2%, in the raw materials of the Altai Territory - from 0.5 to 1.0% (thymol (up to 35%). carvacrol and nerolidol, etc.).									

Flavonoids	Essential oils
Vitamins	Simple sugars, polysaccharides
Minerals	Iodine
Polyunsaturated fatty acids	Tannins

A comparative assessment of the qualitative and quantitative composition of biologically active substances in vegetable raw materials (Table 1) and their contribution to the functional orientation of the composite mixture has shown that flavonoids manifest the most physiological activity of adaptogenic action, followed by vitamins and essential oils.

The variation of the flavonoids' content in the vegetable raw material examined (according to the literature) is in the range from 0.443% to 2.12%. Echinacea (2.12%), black currant leaves (2.1%), blueberry leaves (2.0%), big-sting nettle (1.96%) and black walnut (1.91%) have the greatest content of flavonoids (Fig. 1).

Figures 2 and 3 show the contribution profiles of biologically active substances to the functional orientation of the predicted phytocomposite mixtures.

Thus, the results of the theoretical studies indicate that the influence of such biologically active components of vegetable raw materials as flavonoids, vitamins, minerals and essential oils on the functional orientation should be taken into account when modeling phytocomposite mixtures. These compounds are capable of providing adaptogenic, immunomodulating effects, showing antioxidant properties, stimulating the cardiovascular system, endocrine system activity, endocrine glands, and accelerating the adaptive processes in the body in the context of aggressive environmental impact.

For the prevention of iodine deficiency conditions, when developing polycomponent phytocompositions, special attention should be paid to plant raw materials with high iodine content (black walnut, walnut (leaves) and toad spit).

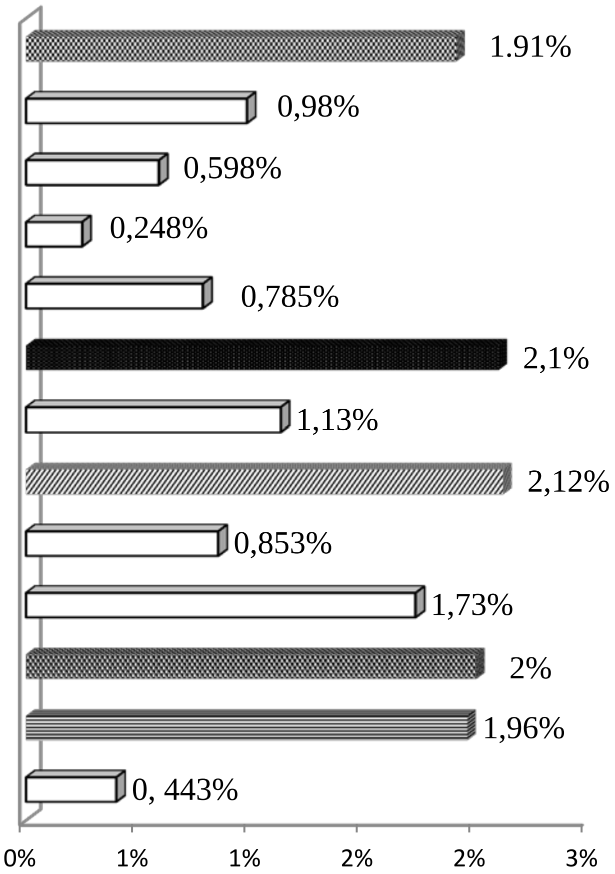

Figure 1 - The content of flavonoids in vegetable raw materials, %.

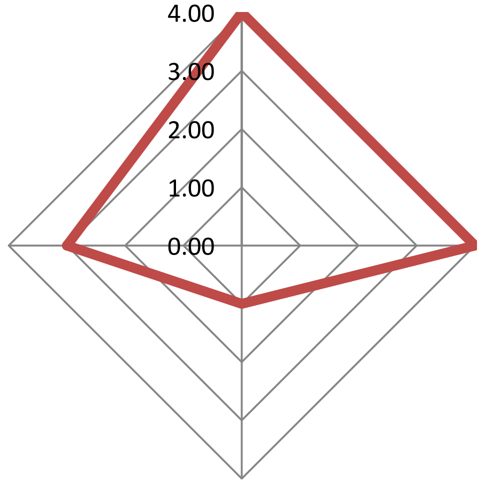

Figure 2 - The contribution profile of biologically active substances to the functional orientation of an adaptogenic phytocomposite mixture.

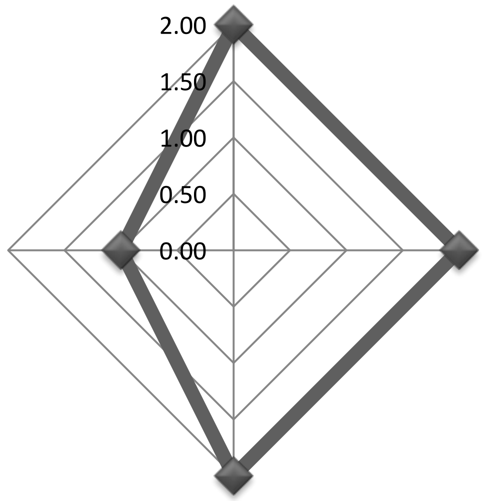

Figure 3 - The contribution profile of biologically active substances to the functional orientation of the immunomodulating phytocomposite mixture.

Development Of A Method For The Production Of Phytocomposite Mixtures Of Different Functional Orientation

When selecting the phytocomposite mixture components, it is necessary to bear in mind the fact that the proportion for each component should be chosen and proposed taking into account the multifactorial mechanisms of development of disorders associated with the negative environmental impact on the human body, the lack or excess of macro- and micronutrients determining the functional orientation.

In this regard, we decided to produce phytocomposite mixtures using two methods:

1) production of a dry phytocomposite mixture followed by its extraction to obtain an extract;
2) production of the phytocomposite mixture in the form of an extract obtained by a combination of extracts from individual species of vegetable raw material.

To use the first method it is necessary:

- to identify the dominant biologically active substances that determine the functional orientation of the mixture (adaptogenic action, for the prevention of iodine deficiency) from a large number of biologically active substances contained in various types of vegetable raw material;
- to develop models that regulate all stages of the creation of phytocomposite mixtures with a targeted functional orientation, which constitute the system of equations, reflecting all the changes of one or more key parameters on the basis of which they are developed. The existence of a system of equations allows to correctly describe the change in the composition of mixtures developed depending on the ratio and quota of the raw components used.

This gives the opportunity to replace a further study of the phytocomposite mixtures formation by analyzing its mathematical model.

Analysis of scientific, scientific and technical and methodological literature has shown that linear programming is the most studied area of mathematical modeling, and to solve its problems a set of effective methods, algorithms and tasks has been developed.

The general form of the equation is as follows:

$$\mathrm{C_i} = \frac{\sum_{j=1}^{n} Aij \cdot x_j}{\sum_{j=1}^{n} x_j}, \quad (1)$$

where *Ci* is the value of the regulated index in the phytocomposite mixture;

Ai is the average value of the relative content of the regulated index in a particular component; and

xj isthe relative content of components in the phytocomposite mixture, wt.%

The systems of equations obtained will be solved by the linear programming method after studying the chemical composition of vegetable raw materials, which will allow us to obtain the relative content of the components of the phytocomposite mixture.

Thus, when designing phytocomposite mixtures for their use in the production of nonalcoholic beverages, the optimal relationships of plant components in phytocomposite mixtures of different functional orientation will be established by mathematical modeling.

Based on the theoretical studies of the chemical composition of vegetable raw materials and the selection of components, we hypothesized that the adaptogenic phytocomposite mixture should contain the following types of vegetable raw material: nettle, blueberry (leaves), currant (leaves), oregano, Echinacea and thyme. A phytocomposite mixture aimed at preventing iodine deficiency should contain the following types of vegetable raw material: walnut (leaves), toad spit, dog rose, clover (blooms) and nettle.

To confirm the hypothesis, studies on the compatibility of biologically active substances in phytocomposite mixtures are necessary.

In the second method, after obtaining single-component extracts from individual vegetable raw materials, the phytocomposite mixtures in the form of extracts will be composed in the same way by mathematical modeling in accordance with the algorithm provided for the first method.

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