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Development of The Technology of Obtaining A Non-Alcoholic Beverage for Preventing Iodine Deficiency Disorders with The Use of Nonconventional Plant Raw Materials

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Abstract*: The article presents the results of the research on the development of the formulation and the technology for obtaining a non-alcoholic beverage for preventing iodine deficiency disorders based on an extract from the nontraditional plant raw materials of the North-Caucasian region. Using the experiment planning module of the STATISTICA suite, the optimal formulation of the phytocomposition mixture for enriching the developed beverage was obtained, which contained the herb of common thyme (lat. Thimus serpyllum L), the herb of purple coneflower (lat. Echinacea Angustifolia), leaves of black currant (lat. Ríbes nígrum); leaves of walnut (lat. Juglans regia L.), with the predictive total iodine content of 82.001 µg/100 g. Laboratory and modeling experiments were performed for obtaining an extract and developing the technology of making the beverage based on it. The developed non-alcoholic beverage has a distinctive taste and a distinct herbal aroma with light notes of dried fruit; it has a preventive effect for the iodine deficiency conditions, which has been confirmed experimentally – the content of functional ingredient (iodine) in it is 48.0 mg/100 cm3 (32 % of the recommended daily intake of iodine), which corresponds to the requirements of GOST R 56543-2015 applicable to functional drinks. In terms of quality and safety, the beverage meets the requirements of regulatory documents of the Russian Federation and the Eurasian Economic Union and may be included in the diets of various age groups as a taste beverage and a functional beverage for preventing iodine deficiency.

Keywords*: iodine deficiency, nonconventional plant raw materials, plan of the experiment, analysis of variance, phytocomposition mixture, extract, ultrasonic treatment, non-alcoholic beverage.

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I. INTRODUCTION

The problem of removing iodine deficiency remains one of the serious ones in the preservation of the population health worldwide.

According to the World Health Organization (WHO), iodine deficiency is experienced by more than 1.5 billion inhabitants of the planet in 153 countries of the world. In Russia, over 35 % of the population are affected by iodine deficiency, of which 10 – 15 % are urban dwellers [1].

Thyroid hormones have vital functions, and are responsible for the metabolism in the entire organism; they control the consumption of proteins, fats, and carbohydrates, regulate the activity of the brain, the nervous system, the genital and mammary glands, and the growth and development of children. Therefore, lack of iodine leads to the spread of diseases, such as endemic goiter, obesity, neurological cretinism, and retardation of physical and mental development of children and adults, causes reduced immunity, rapid fatigability, impaired development of the fetus during pregnancy, etc. [2 – 3].

According to medical statistics, the actual average iodine intake per person is 40 – 80 µg/day, while the physiological need of adults is 150 µg/day; the upper allowable level is 600 µg/day [4].

One of the main reasons that contribute to the development of iodine deficiency is the nutritional factor – insufficient intake of iodine from food and/or its low digestibility.

To prevent iodine metabolism disruptions, various methods are currently used: iodization of food products with the compounds based on inorganic iodine, using organic forms of iodine, which is predominant in natural food products; taking biologically active supplements based on plant sources of iodine, as well as using iodine-containing hormones.

It should be noted that simply adding inorganic iodine compounds, e.g., potassium iodide, cannot efficiently resolve the problem of iodine deficiency in the population, since the regulation of iodine metabolism in a human organism is a complex biochemical process.

In this regard, a promising area in preventing iodine deficiency is enriching products of mass consumption with compositions of medicinal plant material containing large amounts of easily assimilated iodine associated with organic molecules. Unlike the iodine from inorganic compounds, organic iodine from the iodine-containing plant raw materials does not accumulate in the organism, and the excess is excreted naturally during the first day [5].

One of the best and technologically convenient forms of a food product that may be used for correcting iodine-deficient states of a man is non-alcoholic beverages based on plant raw materials, in which not only iodine but also a complex of biologically active adjuvant substances that promote iodine absorption are present in sufficient quantity.

Regular consumption of such drinks will reduce the iodine deficiency in the organism and promote the prevention of comorbidities [6 – 8].

Purpose of the research is the development of a formulation and a technology of a non-alcoholic beverage for preventing iodine deficiency disorders, based on an extract from a composition of nontraditional plant raw materials from the North-Caucasian region.

Novelty. A formulation and a technology of a non-alcoholic beverage for preventing iodine deficiency disorders based on an extract from a composition of nontraditional plant raw materials from the North-Caucasian region have been developed.

The functional properties of the beverage have been proven experimentally.

II. METHODS

A. Materials

The objects of the study at different stages of the study were the following:

- air-dry plant material from the aerial part of the following plants: grass of common thyme (lat. Thimus serpyllum L), grass of purple coneflower (lat. Echinacea Angustifolia), leaves of black currants (lat. Ríbes nígrum); leaves of walnut (lat. Juglans regia L.). The raw material had been collected in the foothill areas of the Republic of Adygea;

- an aqueous extract from a composition of these plants and a non-alcoholic beverage based on it.

B. General description

In performing the experimental part of the study, a complex of conventional standard methods was used:

The mass fraction (mass concentration) of iodine in the plant raw material, in the extract, and the beverage was determined in accordance with [9, 10].

The content of vitamin E in the extract and the beverage was determined according to [11] with the use of a liquid chromatograph JASCO 875-UV fitted with a photometric detector.

The mass concentration of phenol carbonic acids, rutin, and quercetin in plant raw material, the mass concentration of metal cations in the extract and the beverage were determined according to [12 – 14] with the use of the Kapel 105 M system of capillary electrophoresis.

The mass fraction of iron in the plant raw material, in the extract, and the beverage was determined according to [15, 16].

The antioxidant activity of the extract and the beverage was measured according to [17] using the amperometric method using the Tsvet Jauza-01-AA device.

The organoleptic characteristics of the non-alcoholic beverage were determined according to [18], and the tasting assessment was performed using the 25-score evaluation system.

To determine the optimal ratio of the components that determine the functional purpose of the dry phytocomposition mixture for enriching the beverage, methods of mathematical modeling were used, including statistical packages [19, 20].

The titratable acidity in the non-alcoholic beverage was determined according to [21].

The content of toxic elements (cadmium, mercury, arsenic, lead) in non-alcoholic beverages was determined according to [22, 23].

C. Algorithm

Determination of the mass share of iodine in the plant raw material.

An average sample of the studied plant raw materials was crushed into segments 1 – 2 cm long, dried, and milled; the plant material was calculated, and the ash was dissolved, after which samples of the ash solution and the reference solution were taken with a dosing tool in the amount of 5 cm3 each, the samples were prepared for studying according to [9], and subjected to photometering on the PE-5400UF spectrophotometer.

By the results of the photometering of the compared solutions, a calibration curve was built, which was used to find the values of iodine mass concentration in the analyzed solutions, expressed as the mass share in the plant material in million-1 by the formula [9].

The mass concentration of iodine in the extract and the beverage was determined using the inversion-voltammetric method.

The measurements were performed following cl. 10 of GOST 31660 [10].

The content of vitamin E in the extract was determined by separating tocopherols using the method of liquid chromatography (LC), followed by photometric detection. The working solutions were prepared, and measurements were made following the requirements of GOST R 54634-2011.

To determine the mass concentration of metal cations [14], the leading electrolyte was prepared as follows: 3 cm3 of benzimidazole solution, 1 cm3 of tartaric acid, and 2 cm3 of 18-crown-6 ether were placed in a dried glass vessel, and thoroughly mixed.

Measurement and calculation of the mass concentration of the component by the specified calibration characteristics were performed in accordance with [14].

The mass fraction of iron in the plant material was determined by the photometric method. The samples were prepared for testing according to cl. 2.2.1, tested according to cl. 3.3, and the results of the tests were processed according to cl. 5 of GOST 27998-88 [15].

To determine the mass concentration of iron in the extract and the ready beverage, method [16] was used, which was based on measuring the color intensity of a solution of a complex compound of bivalent iron and red orthophenanthroline. The samples were prepared for testing according to cl. 3.1, tested according to cl. 4, and the results of the tests were processed according to cl. 5 of GOST 26928-86 [16].

To determine the titratable acidity of the beverages, sampling, preparation of the samples for testing, testing and processing the results were performed according to [21].

Measurement of the total content of water-soluble antioxidants on the Tsvet Jauza-01-AA device was performed according to the manual to this type of devices.

The content of toxic elements in non-alcoholic beverages was determined using the inverse voltammetry method, which is based on the dependence of the electric current passing through the analyzer cell with the analyzed solution on the mass fraction of the element contained in the solution, and functionally associated with the shape and the parameters of the polarizing voltage applied to the electrodes. The measurements were performed according to [22, 23].

All experiments were repeated three times.

D. Flow chart

The algorithm of the study is shown in Fig. 1.

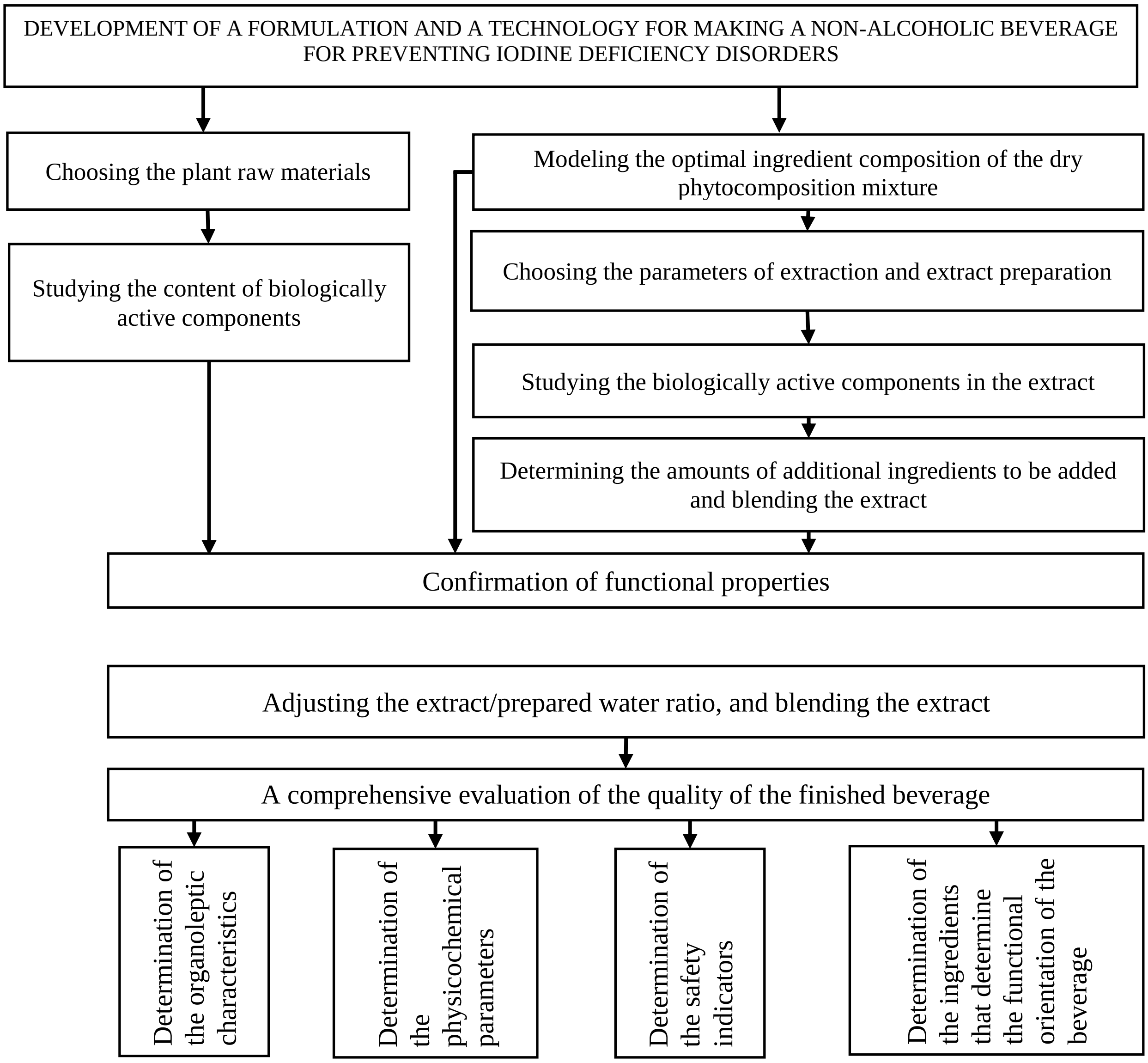

Fig. 1: Algorithm of the study

III. RESULT ANALYSIS

In modeling the composition of functional beverages, one of the main technological challenges is the substantiated choice of functional ingredients that allow developing a product with specified chemical composition and specified functional efficiency.

Therefore, in the first stage of the study, plant material was chosen that could be the source of iodine for enriching the non-alcoholic beverage intended for preventing iodine deficiency disorders.

By the results of studying the chemical composition of some nontraditional plant raw materials, and studying the resource potential of the flora in the North Caucasus region, it was found that walnut leaves nut (lat. Juglans regia L.), grass of purple coneflower (lat.

Echinacea Angustifolia), grass of common thyme (lat. Thimus serpyllum L), and leaves of black currants (lat. Ríbes nígrum) were promising raw materials, containing not only iodine in the amount sufficient for transition to the extract and possibility of identifying it in the finished beverage, but also a wide range of biologically active substances (BAS), including compounds that promote iodine absorption (calcium, iron, vitamin E).

Table 1 shows experimental data about the quantitative content of certain groups of BAS in the selected plant material.

Table 1: The content of BAS in test samples of plant materials

BAS	Experimental samples of plant material			
	Common thyme (lat. Thimus serpyllum L)	Purple coneflower (lat. Echinacea Angustifolia)	Black currant (lat. Ríbes nígrum, leaves)	Walnut (lat. Juglans regia L., leaves)
Phenol carbonic acids, mg/kg	1,792.4	11,776.2	2,252.3	494.8
Rutin, mg/kg	391.0	583.0	39.1	5,280
Quercetin, mg/kg	22.0	83.7	286	250
Potassium, mg/kg	17,690.0	41,710	14,530	4,372
Sodium, mg/kg	2,531.0	1,707	2,493	788
Magnesium, mg/kg	2,034	7,318	3,684	313
Calcium, mg/kg	9,692	6,584	6,014	327
Iron, mg/kg	140	44.0	41.0	4.0
Iodine, mg/kg	0.1	0.1	0.1	1.9
Vitamin C, mg/100 g	6.17	3.96	6.82	20.88
Vitamin E, mg/kg	21.0	114.0	88	92

Table 1 shows the presence of phenolic compounds, macro- and micro-elements, and vitamins C and E in the studied raw material.

As to the iodine content, the main ingredient that contributes to the functional properties, the highest its concentration (1.9 mg/kg) was noted in the leaves of walnut.

Development of a phytocomposition mixture from the above-mentioned plant raw materials was performed using procedure Plans for surfaces and mixes with the limitations of module Planning experiments of the STATISTICA software suite [19, 20].

The criterion of the mix quality was the total iodine content.

To make the phytocomposition mixture meet the functional properties, possible ranges of the composition were specified (Table 2).

Table 2: Composition of the mixture for preventing iodine deficiency disorders

Composition	Formulation, %	Limit conditions %	
		from	to
Walnut (leaves)	30	25	40
Black currant (leaves)	25	20	30
Common thyme (Thyme)	20	15	25
Purple coneflower	25	20	30

Further, with the number of factors (components) equal to 4, and the limitations specified in Table 2, the plan of experiments was built, which consisted of 32 experiments (Table 3) [19, 20]. The last column shows the values of iodine mass concentration obtained experimentally using the traditional research method [9].

Table 3: Plan of experiments for the mixtures

Vertex (V) Centroid (C)	4 act. mixture with lim. No. of limitations specified by the user: 0 No. of initial limitation for the mixture:				
	Walnut	Black currant	Common thyme	Purple coneflower	Iodine
1 V	40.00000	20.00000	15.00000	25.00000	82.00
2 V	25.00000	30.00000	15.00000	30.00000	55.00
3 V	25.00000	20.00000	25.00000	30.00000	55.00
4 V	25.00000	30.00000	25.00000	20.00000	55.00

5 V	40.00000	25.00000	15.00000	20.00000	82.00
6 V	35.00000	30.00000	15.00000	20.00000	73.00
7 V	40.00000	20.00000	20.00000	20.00000	82.00
8 V	35.00000	20.00000	25.00000	20.00000	73.00
9 V	35.00000	20.00000	15.00000	30.00000	73.00
10 C(1)	25.00000	30.00000	20.00000	25.00000	55.00
11 C(1)	25.00000	25.00000	25.00000	25.00000	55.00
12 C(1)	25.00000	25.00000	20.00000	30.00000	55.00
13 C(1)	40.00000	20.00000	17.50000	22.50000	82.00
14 C(1)	40.00000	22.50000	15.00000	22.50000	82.00
15 C(1)	40.00000	22.50000	17.50000	20.00000	82.00
16 C(1)	37.50000	20.00000	15.00000	27.50000	77.50
17 C(1)	30.00000	20.00000	25.00000	25.00000	64.00
18 C(1)	37.50000	20.00000	22.50000	20.00000	77.50
19 C(1)	30.00000	20.00000	20.00000	30.00000	64.00
20 C(1)	30.00000	30.00000	15.00000	25.00000	64.00
21 C(1)	30.00000	30.00000	20.00000	20.00000	64.00
22 C(1)	37.50000	27.50000	15.00000	20.00000	77.50
23 C(1)	30.00000	25.00000	15.00000	30.00000	64.00
24 C(1)	30.00000	25.00000	25.00000	20.00000	64.00
25 C(2)	25.00000	26.66667	21.66667	26.66667	55.01
26 C(2)	40.00000	21.66667	16.66667	21.66667	82.01
27 C(2)	35.00000	20.00000	20.00000	25.00000	73.00
28 C(2)	28.33333	30.00000	18.33333	23.33333	60.99
29 C(2)	35.00000	25.00000	15.00000	25.00000	73.00
30 C(2)	28.33333	23.33333	25.00000	23.33333	60.99
31 C(2)	35.00000	25.00000	20.00000	20.00000	73.00
32 C(2)	28.33333	23.33333	18.33333	30.00000	60.99

Table 4 shows that the linear model is statistically significant, since the level of Fisher's test significance (F) is p = 0.00, and takes the value less than the accepted critical level of significance for statistical hypotheses – 0.05. The quadratic model is not statistically significant since the level of Fisher's test significance (F) p = 0.865 takes the value greater than the critical level of significance.

Table 4: Results of the analysis of variance of the phytocomposition mixture

Model	Analysis of variance; variable.: Iodine (mixture, 32 experiments) 4 act. plan for mix; total val. mix. = 100, 32 experiments Subsequent adjustment of age complexity models						
	SS Effect	Cc Effect	MS Effect	SS Error	F	p	R-Quad.
Linear	3206.070	3	1068.690	0.000481	62225602	0.000000	1.000000
Quadratic	0.000	6	0.000	0.000433	0	0.865419	1.000000

Value R^2 = 1.00 means that the model explains 100 % of the response variability from the average. It may be argued that the relationship between the response of *Iodine* and the components of the mixture is close to the linear model.

Following the literal designations of predictors in Table 5 and denoting the Iodine response with letter Z, the linear regression equation takes the following form (1):

$$Z = 1.900 \cdot A + 0.099 \cdot B + 0.099 \cdot C + 0.099 \cdot D \quad (1)$$

Limitations to the predictors in the model may be represented in the form of a system of linear inequalities (2):

$$\begin{cases} 25 \le A \le 40 \\ 20 \le B \le 30 \\ 15 \le C \le 25 \qquad (2) \\ 20 \le D \le 30 \\ A + B + C + D = 100 \end{cases}$$

Table 5: Coefficients of the regression equation

Factor	Coeff. (initial components); variable.: Iodine; R-sq = 1,;Rate.1, (mixture, 32 experiments) 4 act. plan for mix; total val. mix. = 100, 32 experiments App value Iodine; Residual.SS = 0.0000172					
	Coeff.	Error level	t(28)	p	-95, % Conf. Lim.	+95, % Conf. Lim.
(A) Walnut	1.900083	0.000089	21245.93	0.00	1.899899	1.900266

(B) Black currant	0.099955	0.000150	667.89	0.00	0.099649	0.100262
(C) Common thyme	0.099955	0.000160	624.40	0.00	0.099628	0.100283
(D) Purple coneflower	0.099955	0.000150	667.89	0.00	0.099649	0.100262

Equation (1) and conditions (2) represent the mathematical formulation of the linear programming problem, and, since R^2 = 1.00, are the highly adequate model based on the *Iodine* response level from the shares of components in the mixture. This means that many response values corresponding to 32 experiments may be virtually located on the hyperplane.

Using the Pareto chart in Fig. 2, the shares of the components in the mixture were found: walnut – 49.0; black currant – 17.0; common thyme – 17.0; and purple coneflower – 17.

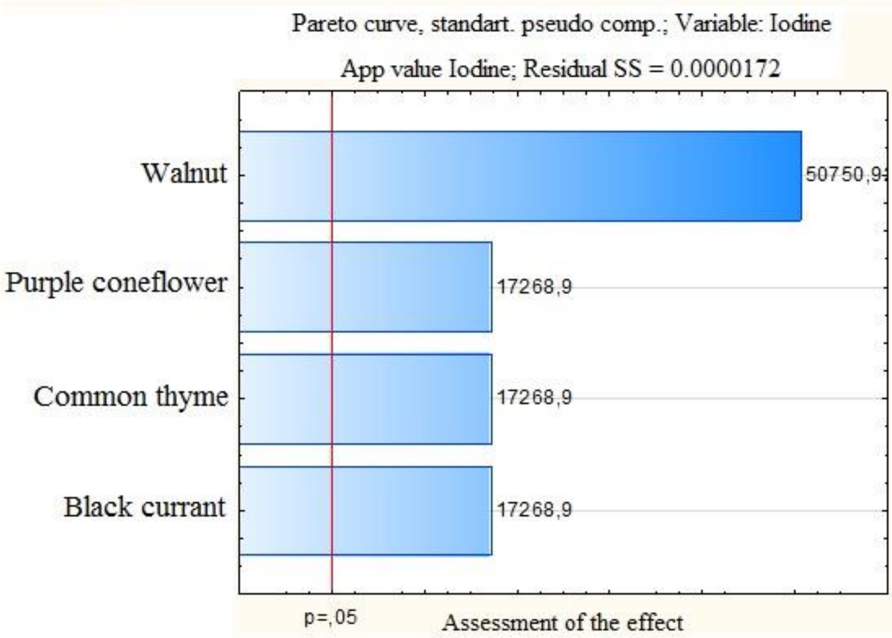

Fig. 2: The Pareto chart of the mixture for preventing iodine deficiency disorders

The calculated values of predictors did not satisfy the conditions (2). Line *predicted* in Table 6 shows the approximately optimum value of iodine predicted by the calculator of the application, which is equal to 99.077 with the 95 % confidence interval (99.071; 99.081). It is easy to see that the found Iodine value = 99.077 exceeds the specified value (80).

Table 6: The predicted value of Iodine according to the Pareto chart

Factor	Predicted Val.; Prm.:Iodine; R-sq = 1,;Rate.1, (mixture, 32 experiments) App value Iodine; Residual.SS = 0.0000172			
	Coeff.	Pseudo comp.	Coeff. * Val.	Initial comp.
(A) Walnut	91.00127	1.224300	111.4129	49,0
(B) Black currant	54.99872	-0.158100	-8.6953	17.0
(C) Common thyme	54.99872	0.091900	5.0544	17.0
(D) Purple coneflower	54.99872	-0.158100	-8.6953	17.0
predicted			99.0766	
-95, %			99.0716	
Conf.				
+95, % Conf.			99.0817	

For improving the results, the *Profiles for predicted values and desirability function* curve in Fig. 3 was used.

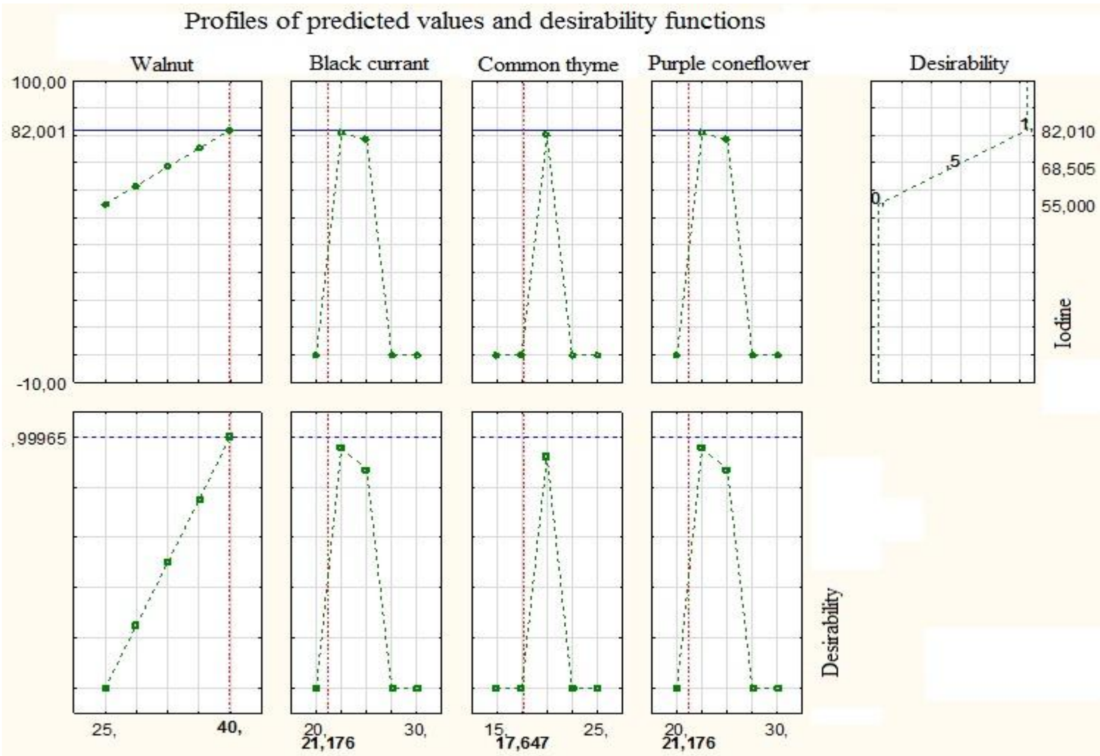

Fig. 3: Profiles for predicted values and desirability function of the mixture for preventing iodine deficiency disorders

The optimal values of the components' content, at which the response reached the maximum value = 82.001, are shown in the bottom of the desirability curves: walnut leaves – 40; black-currant leaves – 21.2; common thyme – 17.6; and purple coneflower – 21.2. The calculations made by the calculator of the module are shown in Table 7.

Table 7: Predicted iodine value by the profiles curve

Factor	Predicted Val.; Prm.:Iodine; R-sq = 1,; Rate.1, (mixture, 32 experiments) App value Iodine; Residual.SS = 0.0000172			
	Coeff.	Pseudo comp.	Coeff. * Val.	Initial comp.
(A) Walnut	91.00127	0.750000	68.25095	40.00000
(B) Black currant	54.99872	0.060000	3.29992	21.20000
(C) Common thyme	54.99872	0.130000	7.14983	17.60000
(D) Purple	54.99872	0.060000	3.29992	21.20000
coneflower				
predicted			82.00063	
-95, % Conf.			81.99809	
+95, % Conf.			82.00317	

It should be noted that the approximate optimal value was reached not at the boundaries of the ranges for the mixture components shares measurement. With that, the value calculated according to the model of values is 82.003, which is less than the value calculated by the Pareto curve – 99.077, but is greater than the set value – 80.

Table 8 shows the difference between the experimental and the predicted response values.

Table 8: Residues between the experimental and the predicted response values

Observ. plan	Observed, predicted values and residuals (mixture, 32 experiments) 4 act. plan for mix; total val. mix. = 100, 32 experiments App value Iodine; R-sq = 1,;Rate.1,		
	Observed	Predicted	Residuals
1	82.00000	82.00063	-0.000631
2	55.00000	54.99872	0.001276
3	55.00000	54.99872	0.001276

4	55.00000	54.99872	0.001276
5	82.00000	82.00063	-0.000631
6	73.00000	73.00000	0.000005
7	82.00000	82.00063	-0.000631
8	73.00000	73.00000	0.000005
9	73.00000	73.00000	0.000005
10	55.00000	54.99872	0.001276
11	55.00000	54.99872	0.001276
12	55.00000	54.99872	0.001276
13	82.00000	82.00063	-0.000631
14	82.00000	82.00063	-0.000631
15	82.00000	82.00063	-0.000631
16	77.50000	77.50031	-0.000313
17	64.00000	63.99936	0.000640
18	77.50000	77.50031	-0.000313
19	64.00000	63.99936	0.000640
20	64.00000	63.99936	0.000640
21	64.00000	63.99936	0.000640
22	77.50000	77.50031	-0.000313
23	64.00000	63.99936	0.000640
24	64.00000	63.99936	0.000640
25	55.01000	54.99872	0.011276
26	82.01000	82.00063	0.009369
27	73.00000	73.00000	0.000005
28	60.99000	60.99915	-0.009148
29	73.00000	73.00000	0.000005
30	60.99000	60.99915	-0.009148
31	73.00000	73.00000	0.000005
32	60.99000	60.99915	-0.009148

Following the built linear model, the optimal formulation of the phytocomposition mixture for preventing iodine deficiency disorders was obtained (%): walnut leaves – 40; black currant leaves – 21.2; common thyme – 17.6; and purple coneflower – 21.2.

The developed non-alcoholic beverage was prepared according to the classical scheme of non-alcoholic beverage production.

One of the most important stages of this technology is the extraction of plant raw materials.

The plant extract was obtained by the method of water maceration (infusion) in combination with ultrasonic treatment.

The optimal parameters of extraction that ensure intensified release of BAS were experimentally determined:

extractant – prepared water t+36 ± 2^0C;

the raw material/extractant ratio – 1:10;

ultrasound intensity – 100 W/cm^2;

duration of ultrasound treatment – 10 seconds;

discretization – every 10 minutes; and

the total duration of extraction – 60 minutes.

The extraction was performed in the following sequence: the plant raw materials were mixed in certain ratios according to the obtained formulation, then the mixture was reduced to fragments at 18^0C to the particle size of 2 mm, filled with one liter of prepared drinking water at t = 36 ± 2^0C, and treated by ultrasound in accordance with the parameters of extraction.

After the extraction, the raw material was squeezed, and the extract was allowed to settle and filtered.

The content of BAS in the obtained extract is shown in Table 9.

Table 9: The content of BAS in the extract of the phytocomposition mixture for preventing iodine deficiency disorders

Indicators	Measurement units	Content
Mass concentration of iodine	µg/100 cm^3	82.0
Mass concentration of vitamin E	mg/100 cm^3	3.8
Mass concentration of calcium	mg/100 cm^3	450.66
Mass concentration of iron	mg/100 cm^3	4.1

The data (Table 9) show that in 100 mm^3 of the aqueous extract, the content of iodine is 82.0 µg, which corresponds to 54.7 % of the recommended daily intake of iodine (150 µg). Besides, bioactive adjuvant substances are found in the extract (calcium, iron, vitamin E), which increase iodine absorption in the human organism.

As the taste and aroma of the finished extract approached the corresponding quality indicators, the possibility of directional formation of its organoleptic characteristics by adding flavoring ingredients (sugar syrup and citric acid) was studied.

Using the *Plans for Surfaces and Mixtures with Limitation* of module *Experiment Planning* with the number of factors (component) equal to three, the plan of the experiments was developed, which consisted of nine experiments.

The optimal ingredient composition of the extract was chosen based on tasting assessment performed by the scientific staff of the Department of Technology, Machines and Equipment of Food Productions at the Maikop State Technological University using a 25-point score system (Table 10).

Table 10: Plan of experiments for the extract

Vertex (V) Centroid (C)	3 act. mixture with lim. (Data. Table 1) No. of limitations specified by the user: 0 No. of initial limitation for the mixture:			
	Extract	Sugar syrup	Citric acid	Tasting results
1 V	75.00000	24.90000	0.100000	19
2 V	89.90000	10.00000	0.100000	23
3 V	75.00000	24.70000	0.300000	21
4 V	89.70000	10.00000	0.300000	22
5 C(1)	75.00000	24.80000	0.200000	20
6 C(1)	89.80000	10.00000	0.200000	25
7 C(1)	82.45000	17.45000	0.100000	19
8 C(1)	82.35000	17.35000	0.300000	22
9 C(2)	82.40000	17.40000	0.200000	23

In order to obtain a blend of model samples of the extract, the ingredients were placed into the blending container in the amounts specified in the plan of the experiment in the following sequence: extract, citric acid, sugar syrup; the mixture was thoroughly mixed and cooled to 20°C.

By the results of tasting assessment (Table 10), the highest tasting score was obtained by sample 6 C(1) with the ratio of the extract, sugar syrup, and citric acid being 89.8:10.0:0.2, respectively, which was opaque liquid of deep amber color, without gloss, without impurities not characteristic of the beverage, with distinct herbal aroma with traces of dried fruit, acerbity, astringent effect, and slightly bitter taste.

For blending the drink, the required amount of prepared water was added to the ready extract according to the formulation in the ratio of 60 % of the extract and 40 % of the water with vigorous stirring for 20 minutes, after which the mixture was cooled to 18°C. The percent ratio of the extract and water was determined experimentally by the results of tasting analysis and physicochemical studies. This ratio not only ensures high organoleptic characteristics of the beverage, but also the specified physicochemical parameters that meet the requirements to functional non-alcoholic beverages.

Dihydroquercetin, which is a flavonoid extracted from the wood of Siberian larch and Dahurian larch, and is a natural antioxidant that prevents self-oxidation of food products and prolongs their storage, was added to the developed beverage as a preserving agent. The recent studies have confirmed its safety and efficiency as a preserving agent for non-alcoholic beverages [24].

The formulation of the developed non-alcoholic beverage is shown in Table 11.

Table 11: The formulation of a non-alcoholic beverage for preventing iodine deficiency disorders, per one dm^3 of the beverage

Raw material type	Consumption of the plant raw materials and blended materials
Extract from plant raw material, dm^3	0.6
Consumption of the plant raw materials for the preparation of the extract composition, g	
Walnut (leaves)	40.0
purple coneflower (grass)	21.2
common thyme (grass)	17.6
black currant (leaves)	21.2
The plant raw material/prepare drinking water (extractant) ratio	1:10
Consumption of blended materials for preparing the extract	
Sugar syrup with the mass fraction of dry substances of 60 – 65 %, dm^3	0.1
Citric acid, g	2.0
Consumption of blended materials for preparing the beverage	
Dihydroquercetin, g	0.025
Prepared drinking water, dm^3	other

In the last stage of the research, a comprehensive assessment of the quality and safety of the obtained beverage was made, the results of which are shown in Tables 12 and 13.

Table 12: Organoleptic characteristics and tasting assessment of the developed non-alcoholic beverage

Indicators	Indicator characteristic	Average score by seven tasters
Appearance	Transparent liquid with glitter without impurities not characteristic of the beverage	6
Color	Dark-amber	5
Taste	Full, harmonious, and pleasant taste	5
Aroma	Pronounced herbal aroma with light notes of dried fruit	4
Aftertaste	Pleasant distinctive aftertaste with slight bitterness, slightly astringent and harsh	3
Total		23

Table 13: Physicochemical, microbiological, and safety indicators of the developed non-alcoholic beverage

Indicator name	Indicator value
Physicochemical parameters	
Acidity, cm^3 1 mol/1,000 cm^3 of the NaOH solution used for titration of 100 cm^3 of the beverage, not more than	5.0
Content of each functional food ingredient, mg/100 g iodine vitamin E	 0.048 1.9
Content of each functional food ingredient in 100 cm^3 of the beverage or a single serving, % of the recommended daily intake: iodine vitamin E	 32.0 12.7
Antioxidant activity, mg/dm^3, expressed as Gallic acid	156.0
Microbiological indicators	
Coliform bacteria (coliforms) in 100 g – not allowed	Not found
Yeast and mold, CFU/100 cm^3, not more than 15	6.0
Safety indicators	
Lead, mg/kg, not more than 0.5	0.1
Arsenic, mg/kg not more than 0.2,	0.05
Cadmium, mg/kg, not more than 0.03	-
Mercury, mg/kg, not more than 0.02	0.008

The obtained data (Table 13, 14) show that the developed non-alcoholic beverage not only has high organoleptic characteristics, meets the requirements of normative documents of the Russian Federation and the Eurasian Economic Union [25 – 27] for the physicochemical characteristics and safety parameters, but also has strong prophylactic properties, since the content of iodine in 100 cm3 of the beverage is 32 % of the recommended daily intake.

IV. CONCLUSION

1. The study has theoretically substantiated and experimentally confirmed the feasibility and efficacy of using the following types of nontraditional plant raw materials of the North Caucasian region in the technology of making non-alcoholic beverages intended for preventing iodine deficiency disorders: grass of common thyme (thyme) (lat. Thimus serpyllum L), grass of purple coneflower (lat. Echinacea Angustifolia), leaves of black currant (lat. Ríbes nígrum), and leaves of walnut (lat. Juglans regia L.).

2. A mathematically valid formulation of the phytocomposition mixture for correcting iodine deficiency has been developed, in which the optimal shares of the components are the following (%): leaves of walnut – 40; leaves of black currant – 21.2; common thyme – 17.6; purple coneflower – 21.2. Such mixture corresponds to the predicted value of the total iodine content, which is equal to 82.001 μg/100 g.

3. The formulation and the technology of a non-alcoholic beverage for preventing iodine deficiency disorders have been developed, based on the extract from a composition of nontraditional plant raw materials from the North-Caucasian region.

It has been experimentally established that the developed beverage contains iodine in the amount of 48.0 μg/100 cm3, which amounts to 32 % of the recommended daily intake of iodine (150 μg). This allows attributing this beverage to functional beverages since following the requirements of GOST R 56543-2015, the content of each functional food ingredient in 100 cm3 of the beverage or a single serving should be 15 – 50 % of the recommended daily intake.

All ingredients in the non-alcoholic beverage are in harmony with each other and give the finished drink a sophisticated taste and a distinct herbal aroma with light tones of dried fruit.

In terms of the quality and safety, the beverage meets the requirements of normative documents of the Russian Federation and CU TR 021/2011.

The developed beverage may be included in the diets of various age groups as both a taste and a functional beverage for preventing iodine deficiency.

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