Physical-chemical characteristics and ecological cleanliness of wild forest berries in the Vologda Region

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Abstract. In recent years, the demand for forest food and medicine products has increased, as it is a source of vitamins, minerals and biologically active substances. In addition, they are more environmentally favorable food products and are not processed with chemicals during the growth period. High nutritional value or useful medicinal properties are reduced to zero when the level of toxic substances in them exceeds the maximum permissible norms. Research on the ecological purity of wild plants is an urgent issue. The object of the study is wild-growing berries growing in the Vologda Region. The study used generally accepted methods in assessing the food safety of food products. As a result, it was established that the Vologda Region has a significant resource potential of wild berries. Procurement can be carried out on an area of 110510 thousand km$^2$, and the estimated annual amount of resource withdrawal may be 40591.1 tons. The quality of berry raw material exceeds established standards. When assessing environmental cleanliness, it was found that wild forest berries of the Vologda Region contain less cesium-137 and nitrates than the maximum permissible levels of hazardous concentrations. This fact indicates the possibility of using berries in food production, including baby food.

1. Introduction
Russia, being the largest forest power, throughout all its state history has been receiving a significant share of national income through the exploitation of forest resources. The significance of the forest is great and multifaceted. In the current conditions of the development of the forest sector, the task of multi-purpose economically viable, environmentally responsible and socially beneficial forest management comes to the fore. Russian forests are rich in renewable non-timber natural resources. In recent years, their importance has increased due to increasing demand (primarily for food and medicine products) both domestically and abroad [1].

The rational use of non-timber forest resources contributes to the growth of the economic potential of the forest industry, the preservation of biological diversity and the well-being of the population [1]. The use of food and medicinal products of the forest began at the dawn of human history and continues until the present. F. K. Arnold (1893) already considered the harvesting of wild-growing food products as one of the links in a single chain of productive activities of the Russian peasant, which is inextricably linked not only with his arable land, but also with the forest [2].

Interest in wild edible plants is justified. According to various authors, 700-1000 plant species can be used for food, however, no more than 40-50 of them are used. Wild food plants are sources of vitamins, minerals and biologically active substances. At the same time, they are environmentally
more favorable food products, which is now the focus of particular attention. [3]. The value of wild plants lies in the fact that they have a relatively high adaptability to environmental conditions and are immune to many diseases. In this regard, wild plants are characterized by the most stable crops, and in terms of the content of many biologically active substances and nutritional value they are superior to cultivars. In addition, wild berries, unlike cultivated ones, are not treated with chemicals during the growth period. [4].

The relevance of scientific research and the constant scientific support of this type of activity increases especially when establishing the ecological cleanliness of wild plants and revealing the degree of pollution with various pollutants (contaminants): radionuclides, pesticides, nitrates, heavy metals. High nutritional value or useful medicinal properties are reduced to zero when the level of toxic substances in them exceeds the maximum permissible norms.

2. Research objective
To determine the reserves of wild berries in the Vologda Region, to study their physical and chemical parameters, to assess the safety of their use in food production.

3. Research objects and methods
The object of the study was wild-growing fruits of cranberries, blueberries, lingonberries, cloudberries, raspberries and wild strawberries growing in the Vologda Region. Determination of physical-chemical parameters of wild berries and indicators of their food safety is carried out in accordance with generally accepted methods used in the food industry [5-9].

4. Results and discussion
Research was conducted in the Vologda Region. Its geographical location has determined landscape features: flatness, forest cover, excessive moisture, and significant marshiness. The territory of the region is a plain with elevated plots in combination with lowlands. Its contemporary surface was formed mainly under the influence of glaciation and flowing water. The formation of the soil cover of the region takes place under the conditions of a wide variety of parent rocks, vegetation, relief, the nature of moisture and types of water supply. The main type of soil creating the background of the soil cover is podzolic (subtypes of podzolic and sod-podzolic soils). Podzolic soils are characterized by very low natural fertility.

The geographical location of the territory of the region determines the peculiarities of its climate. The proximity to the Atlantic gives some features of the transitional climate, from maritime to continental one. The average annual temperature drops from west to east from + 2.50°C to + 1.50°C. The duration of the frost-free period is 98-116 days on the average.

The analysis of forestry regulations of state forestries in the Vologda Region demonstrated that the potential of the Vologda Region in the use of wild food berries is great (Table 1). The possible total area of harvesting food berry resources in the region is 110510 thousand km², and the estimated annual amount of resource withdrawal is 40591.1 tons [10].

For industrial harvesting, lingonberries (Vaccinium vitis-idaea), huckleberries (Vaccinium myrtillus), cranberries (Vaccinium oxyccocos) and blueberries (Vaccinium uliginosum) can be used. In addition, other types of wild berries grow in the region, such as cloudberries (Rubus chamaemorus), strawberries (Fragaria verca), raspberries (Rubus idaeus) and others. However, the thickets of these species are of limited distribution and are not considered by forest management as species recommended for industrial harvesting.

The data presented give an idea of the potential harvesting amount of wild berries in the context of administrative regions, but they do not reflect the amount of resources per area unit. In order to objectively assess the amount of berry food resources, we developed an indicator characterizing the average productivity of berries (kg) per unit (ha) of the area of their potential harvesting - the productivity of berry fields (Figure 1).
### Table 1. Potential amounts of berry food resources in the Vologda Region

| The name of the district | Harvesting area, ha | Annual permissible amount of berries withdrawal, tons | lingonberry | huckleberry | cranberry | blueberry | Total amount |
|-------------------------|---------------------|-----------------------------------------------------|--------------|-------------|-----------|-----------|-------------|
| Babaevskii              | 831846.0            | 203.9                                               | 502.1        | 5012.4      | -         | 5718.4    |
| Babushkinskii           | 656599.0            | 501.7                                               | 876.0        | 1623.8      | 0.7       | 3002.2    |
| Belozerskii             | 426454.0            | 47.9                                                | 188.3        | 1757.9      | 0.5       | 1994.6    |
| Vashkinskii             | 244177.0            | 24.4                                                | 43.4         | 169.6       | -         | 237.4     |
| Verkhovazihskii         | 356615.0            | 175.9                                               | 379.8        | 349.1       | 2.4       | 907.2     |
| Vozhegodskii            | 500691.0            | 3.3                                                 | 54.5         | 54.7        | -         | 112.5     |
| Vologodskii             | 224708.0            | 0.8                                                 | 98.8         | 72.8        | -         | 172.4     |
| Veliko-USTugskii        | 607080.0            | 64.9                                                | 218.3        | 150.3       | -         | 433.5     |
| Vytegorskii             | 1087747.0           | 140.0                                               | 1239.0       | 4810.0      | -         | 6189.0    |
| Gria佐ovetskii          | 354307.0            | 0.7                                                 | 77.9         | 23.2        | -         | 101.8     |
| Kaduiskii               | 249667.0            | 32.0                                                | 60.0         | 1517.0      | -         | 1609.0    |
| Kirillovskii            | 350733.0            | 1.2                                                 | 361.3        | 429.0       | -         | 791.5     |
| Kich-Gorodetskii        | 600926.0            | 67.0                                                | 472.0        | 464.0       | -         | 1003.0    |
| Mezhdurechenskii        | 303406.0            | 21.7                                                | 126.0        | 728.8       | -         | 876.5     |
| Nikolskii               | 611601.0            | 199.5                                               | 293.3        | 68.5        | -         | 561.3     |
| Niukenskii              | 453271.0            | 41.7                                                | 728.1        | 1809.4      | 1.0       | 2580.2    |
| Sokolskii               | 294902.0            | 1.3                                                 | 53.3         | 339.8       | -         | 394.4     |
| Siamzhenskii            | 311270.0            | 153.0                                               | 293.0        | 586.0       | -         | 1032.0    |
| Tarnogskii              | 415167.0            | 90.0                                                | 255.0        | 849.0       | -         | 1194.0    |
| Totemskski              | 703804.0            | 37.6                                                | 417.8        | 1719.1      | 0.1       | 2171.5    |
| Ust-Kubitski            | 168402.0            | 10.0                                                | 18.0         | 74.0        | -         | 102.0     |
| Ustiuzhenskii           | 264181.0            | 391.0                                               | 290.0        | 4421.0      | 2.0       | 5104.0    |
| Kharovskii              | 280551.0            | 3.7                                                 | 219.0        | 166.1       | -         | 388.8     |
| Chagodoshchenskii       | 190668.0            | 3.8                                                 | 2.5          | 6.9         | -         | 13.2      |
| Cherepovetskii          | 422454.2            | 111.0                                               | 494.0        | 3250.0      | 5.0       | 3860.0    |
| Sheksninskii            | 139804.0            | 0.2                                                 | 12.7         | 24.7        | -         | 37.6      |
| **Total**               | **11051031.2**      | **2328.2**                                          | **7774.1**   | **30477.1** | **11.7**  | **40591.1**|

* - share of total stock, %

As the results of the performed calculations show, the highest productivity of berry fields is noted in the western regions of the region. The leader in terms of this indicator is the Ustiuzhenskii district, with berry productivity of (19.32 kg / ha), Cherepovetskii (9.14 kg / ha), Babaevskii (6.88 kg / ha) and Kaduiskii (6.44 kg / ha) districts. On the average for the Vologda Oblast, the indicator of berry fields productivity is 3.41 kg / ha.

It is known that each plant synthesizes a certain spectrum of chemical compounds depending on many factors: environmental temperature, luminous flux, soil composition, relative air humidity, oxidative stress, etc. In other words, the plant adapts to survival, developing its "immunity" [11]. The study of the chemical composition of wild berries is an important and urgent task. Its results can become the scientific basis for the selection and assessment of the prospects of using wild-growing raw materials for the production of healthy foods.

One of the most important indicators by which the quality of the processed plant material is judged is the content of dry matter in it. The biochemical processes that occur in the raw materials during storage, as well as the consumption of raw materials per unit of output, equipment productivity, the duration of the production cycle and the quality of the finished product depend on their content.
The content of dry matter depends not only on the type and variety of raw materials, but also on climatic conditions (weather). Watering, especially before picking fruits and vegetables, although it increases the yield, reduces the concentration of dry matter in raw materials, worsening its portability and keeping quality.

It is known that the amount of dry matter in fruits and berries for the most part ranges from 10% to 20%. In some cases (some grape varieties) it can reach 25% and more. According to our data, dry matter content in wild berries is 8-14% (table. 2). The highest content of dry matter was observed in strawberries (13.9%), the lowest - in cloudberries (8.4%).

Organic acids are formed in plant materials at various stages of metabolism. They are dissolved in cell juice and are found both in free form and in the form of salts, ethers with spirits.

Playing an important part in metabolic processes, organic acids are the starting materials for the synthesis of carbohydrates, amino acids, lipids and other compounds. In many cases, acidity is one of the most important indicators of the quality of raw materials, intermediates and finished products. The harmonious taste of the final product depends on the mass fraction.

The total acid content does not exactly characterize the degree of acid taste of the product. It depends substantially on the degree of dissociation of individual acids, i.e. concentration of hydrogen ions in their solutions (pH).

The degree of dissociation of acids, i.e. the pH of cell sap varies greatly depending on the type and variety of fruits, as well as the conditions for their cultivation. So, for example, in apples it is 2.50 - 4.64; in blackcurrant - 3.22; in raspberries - 3.14; in carrots - 5.8-6.3; in cucumbers - 5.8-6.9; in tomatoes 4.1-4.8; in cabbage - 6.0-6.3; in onions - 5.4-5.9; in potatoes - 5.8-6.2; in beets - 5.9-6.6; in watermelons - 4.6-5.4; in melons - 6.0-6.9.

According to our data, cranberries (2.26) have the lowest pH value and, as a result, the highest acidity (3.24%). The highest pH was observed for strawberries (3.50), the lowest acidity for huckleberries (1.02%).

An indispensable condition for assessing the quality of food is the establishment of food safety of the product. This indicator is assessed when establishing the ecological cleanliness of food products. The content of dry matter depends not only on the type and variety of raw materials, but also on climatic conditions (weather). Watering, especially before picking fruits and vegetables, although it increases the yield, reduces the concentration of dry matter in raw materials, worsening its portability and keeping quality.

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and identifying the degree of contamination with various pollutants: radionuclides, pesticides, nitrates, heavy metals.

Table 2. Physical-chemical characteristics of wild berries

| Characteristics                        | Berry species |
|----------------------------------------|---------------|
|                                        | cranberry     | huckleberry | cloudberry | raspberry | strawberry | lingonberry | blueberry |
| Content of soluble dry matter, %       | 9.6           | 10.9        | 8.4        | 13.5      | 13.9       | 11.3        | 11.0      |
| Acidity, pH                            | 2.26          | 2.96        | 3.14       | 3.21      | 3.50       | 2.45        | 2.65      |
| Titratable acidity, % (in malic acid equivalent) | 3.24          | 1.02        | 1.20       | 1.59      | 1.50       | 2.05        | 1.38      |
| Cesium-137, Bq / kg                    | 5.9±6.2       | 24.1±13.6   | 19.1±6.6   | -         | -          | 8.1±2.6     | 10.3±5.3  |
| Nitrates, mg / kg                      | 11.5          | 4.9         | 18.9       | 9.26      | 7.8        | 9.80        | 10.9      |

Berries tend to accumulate radiation, which is retained in the upper soil layer and in the forest litter. In addition, a problem for lovers of picking berries is that forests are a natural barrier to the spread of radioactive emissions and, accordingly, accumulate a significant amount of them. A common factor determining the ability to absorb radiation is the place of growth, in a swampy area and ravines, berries accumulate a greater amount of radionuclides, compared with berries growing in dry places. According to data presented in literature, strawberries, raspberries, mountain ash are the least contaminated with cesium berries; huckleberries, cranberries, and lingonberries are the most contaminated with it.

The maximum permissible level of cesium-137 for wild berries should not exceed 160 Bq / kg [12], and for baby food 60 Bq / kg.

Through the chemical analysis of berries harvested in the Vologda Oblast, we found that the level of cesium-137 in berries was the highest in huckleberries - 24.1 Bq / kg, the lowest - in cranberries - 5.9 Bq / kg. Comparison of the maximum values obtained by us (huckleberries 24.1 Bq / kg) with the maximum permissible concentration of cesium-137 shows that berry raw materials harvested in the Vologda Region contain 6.6 times less cesium-137 than the maximum permissible value.

In the production of baby food, stricter requirements are imposed on raw materials, in terms of radiation content it should contain no more than 60 Bq / kg of cesium-137. The results of the tests indicate the possibility of using berries from the Vologda Region for the production of baby food. Nitrates are present in any plant, since they play a key role in their growth (they synthesize amino acids and form proteins). Throughout its existence, man used plants as food, so her body is used to a certain amount of nitrates and is able to remove them without harm.

The situation changed when people began to increase productivity by using mineral fertilizers. Plants are not able to convert all nitrates received from the soil into proteins, especially if there are many of them and they are not delivered on time (late fertilization). In this case, an accumulation of excess nitrates occurs, primarily in the roots, stems, leaves and stalks. In the fruits themselves, nitrates are distributed mainly on the surface (peel), in the core and seed part (depending on the type of plant). For humans, as consumers of vegetables, fruits, berries and other plants, it is not the fact of the content of nitrates in food products that matters, but their quantity. When they talk about the content of nitrates, their excess is implied.

According to Decree No. 36 of November 14, 2001 of the Chief State Sanitary Doctor of the Russian Federation, the maximum permissible concentration of nitrates in various products is different...
and amounts to 60 mg / kg for apricots, watermelons, grapes, pears, nectarines, peaches, apples, and 100 mg / kg for strawberries, and - 50 mg / kg for baby food.

Our data indicate that all berries harvested in the Vologda Region contain less nitrates than the maximum permissible concentration established by law. The greatest amount of nitrates was recorded in cloudberries (18.9 mg / kg), however, their amount is less than the permissible concentration for baby food. The smallest amount of nitrates was recorded in huckleberries (4.9 mg / kg).

5. Conclusion
As a result of the study, it was found that the Vologda Region has a significant resource potential of wild berries. Procurement can be carried out on an area of 110510 thousand km², and the estimated annual amount of resource withdrawal may be 40591.1 tons.

The quality of raw berry meets established standards. When establishing food safety and assessing ecological purity, it was determined that wild forest berries of the Vologda Region contain less cesium-137 and nitrates than the maximum permissible levels of hazardous concentrations. This fact indicates the possibility of using berries in food production, including baby food.

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