Biochemical assessment of berry crops as a source of production of functional food products

I B Kirina, F G Belosokhov, L V Titova, I A Suraykina and V F Pulpitow
Michurinsk State Agrarian University, Internatsionalnaya Str.101, Michurinsk, 393760, Russia

E-mail: ivan0068@bk.ru

Abstract. The article deals with the concept of functional nutrition, the prospects for the use of fruit and berry products in the production of functional products. The issues of biochemical assessment of black currant, red currant, remontant varieties of garden raspberries, edible honeysuckle, high blueberries as a source of production of functional food products are considered. Experimental data on the content of biologically active substances (organic acids, total sugars, ascorbic acid, pectin, P-active substances) in fresh fruits of promising varieties are presented. The best varieties with a high content of antioxidants are selected: ascorbic acid (the black currant Carmelita, Green haze, the red currant Vixne, Marmalade; the remontant raspberry Atlant, Hercules, Orange miracle; the edible honeysuckle Kamchadalka, Cinderella, Gzhel early, Nymph and the high blueberry Herbert, Coville); pectin (the red currant Jonker van Tets, Generous; the remontant raspberry Orange miracle; the honeysuckle Kamchadalka, Cinderella, Nymph, Gzhel early); p-active ingredients (the black currant Green haze, Tamerlane; the honeysuckle Berel, Galochka and the high blueberry Blue crop, Herbert, Coville).

1. Introduction
The problem of preserving human health occupies a significant place in the life of modern society and becomes a priority direction of state policy. Experts of the World Health Organization believe that the health of the population primarily depends on a full diet, and then on genotypic features, environmental conditions, and social conditions [1].

A person treats food not just as a source of food substances, but also as a source of balanced (functional) nutrition. Functional nutrition ensures normal growth and development of children, helps prevent diseases, prolong people's lives, improve their performance, and also creates conditions for human resistance to abiotic environmental stressors. In turn, the malnutrition occurs when the production of food raw materials and food products decreases, and the purchasing power of the population sharply decreases [2, 3].

From an evolutionary point of view, Homo Sapiens was originally an omnivore in terms of food. Anatomical and physiological features of the digestive system structure confirm that at all stages of its development, plant food prevailed over food of animal origin. But in the era of industrial development, urban development, and then megacities, the way of life and nutrition of people changed dramatically. The diet of modern man is dominated by canned food and foods of high energy density, but low nutritional value. Violation of the principles of balanced nutrition caused an increase in the incidence of cardiovascular, oncological, neurological and some other diseases. In this regard, the problem of
searching, preserving and using the resources of wild and cultivated plants as sources of biologically active substances (BAS) for high-quality nutrition is becoming more and more urgent.

In the world practice, the direction of functional nutrition is rapidly developing. In accordance with the GOST standard R 52349-2005, a “Functional food product” is “a special food product intended for systematic use as part of food diets by all age groups of a healthy population, which has scientifically justified and confirmed properties, reduces the risk of developing diseases related to nutrition, prevents a deficiency or makes up for a deficiency of nutrients in the human body, preserves and improves health due to the presence of physiologically functional food ingredients in its composition” [4]. Functional food ingredients include biologically active substances with known physical and chemical characteristics, for which the properties useful for preserving and improving human health have been identified and scientifically justified, and the daily physiological need has been established. Among them, it should be noted: soluble and insoluble dietary fibers (pectins, etc.), vitamins (C, A, E, folic acid, nicotinic acid, etc.), macro- and microelements, fats and substances accompanying fats (polyunsaturated fatty acids, plant sterols, structured lipids, sphingolipids, etc.), polysaccharides, secondary plant compounds (flavonoids, lycopene, etc.), probiotics, prebiotics, and symbiotics.

Functional food products, in contrast to traditional ones, must contain ingredients that effectively increase the functions of some organ and the human body as a whole [5,6]. Functional properties are particularly active in fruits, berries and vegetables, being sources of vitamins, mineral compounds, dietary fibers, and polysaccharides [7,8].

It should be noted that the introduction of biologically active (functional) components into the composition of food products makes it possible to give traditional products new properties. Currently, it is necessary to expand the range and increase the volume of production of functional food products.

Due to the available information about the presence of many of these compounds in the fruits of black currant, red currant, raspberry, edible honeysuckle, blueberry, it is very relevant to assess the biochemical composition of the fruits of these crops in the Central Chernozem region.

2. Materials and methods
The assessment of the biochemical composition of fresh currant, raspberry, honeysuckle and blueberry berries was carried out in the biochemical laboratory of the Center for collective use of high-tech equipment of Michurinsk State Agrarian University. The methodological basis of the biochemical assessment was the Program and method of variety study of fruit, berry and nut crops [9].

The objects of research were promising varieties and elite forms of black currant, red currant, raspberry, edible honeysuckle, high blueberry.

3. Results and discussion
Michurinsk State Agrarian University conducts active research on the study of the biochemical composition of promising varieties of garden crops, as well as on the modeling and development of recipes for functional food products with high antioxidant activity.

The blackcurrant Ribes nigrum L. is one of the most widespread berry crops in Russia and the Central Chernozem region. It is characterized by high plasticity, winterhardiness, productivity, the possibility of full mechanization of cultivation and harvesting.

Ribes nigrum L. fruits have a high level of biologically active substances (BAS) necessary for the prevention of diseases and prolonging human life. They contain soluble dry substances, sugars (monosaccharides are represented by glucose and fructose, and disaccharides – sucrose), organic acids (citric, malic, formic, oxalic, etc.), vitamins p, B1 (thiamine), B2 (riboflavin), folic acid, carotene, pectin, tannins and nitrogenous substances, polyphenols (flavonols, catechins, leucoanthocyanins, anthocyanins).

In the conditions of the Central Chernozem region, the modern assortment of black currant differs in the content of total sugars from 7.2 to 15.7 %, The titrated acidity varies between 2.06 – 3.43 % (table 1).

The value of currant berries as dietary and medicinal raw materials is determined by the amount of vitamin C (ascorbic acid), P-active compounds, macro- and microelements, pectin substances.
Lack of vitamin C causes rapid fatigue, tiredness, irritability, drowsiness, decreased immunity. Ascorbic acid has an antioxidant effect, regulates redox processes in the body. In the human body, ascorbic acid is not synthesized independently and must be regularly supplied from the outside with food.

P-active substances (bioflavonoids) are a complex of plant biologically active compounds (rutin, anthocyanin, catechins, quercetin, citrin, etc.) that can synergize with vitamin C, providing strengthening of blood vessel walls, the immune system, and antiviral effect [10].

Assessment of the biochemical composition of fresh black currant berries revealed a high content of ascorbic acid in the fruits of the varieties Carmelita and Green haze. The range of variation in the vitamin content was from 171 mg% to 220 mg%.

A leader in the accumulation of P-active substances in conditions of the Central Chernozem region is a variety of Tamerlan (324 – 383 mg%).

The red currant Ribes rubrum L. is characterized by high nutritional qualities of fruits, rapid fruit production, abundant annual harvest, and unpretentiousness for cultivation.

The amount of sugars in red currant berries ranges from 6.8 to 9.5%. The content of titrated acids varied from 2.02 to 3.19%. According to the average long-term data of titrated acids at the level of 2.0% accumulates in the berries of the Jonker van Tets variety.

Red currant is characterized by a relatively low content of ascorbic acid—about 3–4 times lower than in black currant berries. Studies of the value of this indicator have allowed us to identify varieties of Vixne (35 – 42 mg%) and Marmalade (52-55 mg %) with an increased content of vitamin.

Table 1. Biochemical assessment of fresh black currant and red currant berries in the conditions of the Central Chernozem region.

| Varieties          | Titrated acids, % | Amount of sugars, % | Ascorbic acid, mg % | P-active substances, mg % |
|--------------------|-------------------|---------------------|---------------------|--------------------------|
| **Ribes nigrum L.**|                   |                     |                     |                          |
| Green haze         | 2.72–3.03         | 9.6–11.4            | 171–220             | 262–354                  |
| Carmelita          | 2.06–2.12         | 11.5–14.1           | 172–198             | 224–257                  |
| Kipianna           | 2.88–3.06         | 9.3–11.2            | 131–142             | 218–289                  |
| The little prince  | 2.67–3.16         | 10.7–13.8           | 125–147             | 254–288                  |
| Constellation      | 2.82–3.10         | 8.5–11.3            | 166–190             | 193–255                  |
| Tamerlan           | 3.02–3.43         | 7.2–8.8             | 115–166             | 324–383                  |
| Tatyana's Day      | 2.84–3.13         | 8.8–11.3            | 141–175             | 245–276                  |
| Chrnavka           | 2.87–3.05         | 10.3–15.7           | 138–171             | 215–227                  |
| **Ribes rubrum L.**|                   |                     |                     |                          |
| Vixne              | 2.95–3.19         | 6.8–7.6             | 35–42               | 2.59–2.86                |
| Jonker Van Tets    | 2.02–2.12         | 7.5–9.5             | 25–28               | 2.35–2.91                |
| Marmalade          | 2.20–2.22         | 7.3–8.6             | 52–55               | 2.60–2.75                |
| Generous           | 2.20–2.28         | 7.8–9.7             | 28–31               | 2.45–2.95                |

Red currant is valued in the processing industry and among amateur gardeners for its gelling properties due to the high content of pectin substances. Pectin is a natural antioxidant that can bind, neutralize and accelerate the elimination of radioactive elements, toxins, heavy metals and slag compounds from the body. Pectin substances contribute to the normalization of cholesterol in the body, increase resistance to allergic reactions, they are used for the treatment of ulcerative, infectious and oncological diseases, diabetes, hypertension, and atherosclerosis. Among the studied varieties, Jonker van Tets (2.91 mg%) and Generous (2.95 mg %) berries have a high pectin content.
**Raspberry*Rubusidaeus*. Fruits are valued for their delicious taste, unique aroma, unique biochemical composition, high therapeutic and dietary properties and are used not only in fresh form, but also as a raw resource for the food, processing and pharmaceutical industries.

Depending on the genotypic characteristics and growing conditions, the sugar content in raspberries reaches 7-11%, and the acidity level is low. In this regard, the berries have good taste. The fruits of cultivated varieties of raspberries contain a complex of hemopoietic elements: iron (2.0-3.6 mg/100 g), copper and folic acid. In addition, raspberries are a source of a number of vitamins: C, B1, B2, E, PP [10, 11].

Technological requirements for raspberry varieties intended for processing products provide for the content of soluble solids of at least 11 %, sugars at least 7 %, organic acids 1.2 – 1.5 %, pectin substances at least 0.8 %, ascorbic acid at least 35 mg % [12]. As a result of the biochemical assessment of berries of 7 remnant varieties of raspberries, the following regularities were identified.

The amount of soluble solids varied by grade from 8.2 (Bryansk divo) to 11.7 % (Atlant) (table 2).

The accumulation level of the amount of sugars was 6.0 – 7.5 %. The maximum values of this indicator (7.2 – 7.5 %) are characteristic of varieties Atlant and Orange miracle. The level of titrated acids varied depending on the grade from 1.15% to 1.62 %. The sugar–acid index was 3.7 and 6.3. The maximum levels of the characteristic varieties: Golden domes, Orange miracle.

Raspberry varieties are characterized by a lower content of ascorbic acid compared to black currant. The fruits of the most vitamin varieties Atlant, Hercules and Penguin contained 40-42 mg% of vitamin.

**Table 2.** Biochemical indicators of raspberry berries of remantant varieties.

| Varieties       | Solubledry substances, % | Amountof sugars, % | Titratedacids, % | Ascorbicacid, mg % | Solublepectin, % | Protopectin, % |
|-----------------|--------------------------|--------------------|------------------|-------------------|------------------|----------------|
| Atlant          | 11.7                     | 7.2                | 1.61             | 40                | 0.62             | 0.55           |
| Diamond         | 10.5                     | 6.9                | 1.51             | 37                | 0.54             | 0.29           |
| Bryansk divo    | 8.2                      | 6.0                | 1.61             | 39                | 0.33             | 0.34           |
| Heracles        | 9.3                      | 6.2                | 1.62             | 40                | 0.44             | 0.65           |
| Golden dome     | 8.3                      | 6.9                | 1.15             | 40                | 0.61             | 0.55           |
| Orange miracle  | 10.6                     | 7.5                | 1.19             | 38                | 0.71             | 0.71           |
| Penguin         | 8.6                      | 6.2                | 1.09             | 42                | 0.59             | 0.47           |

The content of pectin substances in raspberries over the years of research was less than 1.0 %. High accumulation of soluble pectin and protopectin was observed in the Orange miracle variety (0.71 %).

**Blue honeysuckle Lonicera edulis.** The value of berries as dietary and medicinal raw materials is determined by their early maturation period, high content of natural antioxidants: bioflavonoids, vitamins, pectin and trace elements (manganese, copper, silicon, iodine) [13, 14].

The content of soluble solids in the fruit of various varieties ranged from 12.9 to 16.5 %. The average sugar content was 8.8 %, the maximum was 12.8 % (Gzhel early). The average accumulation of organic acids over the years of research in honeysuckle fruits ranged from 1.6 to 3.2 %.

One of the disadvantages of culture is the presence of bitterness in the taste. However, thanks to the purposeful selection work of domestic scientists in this direction, it was possible to create a modern assortment of honeysuckle with improved fruit quality.

Honeysuckle does not have a high level of vitamin C. The culture is characterized by synergy – the therapeutic effect of vitamin C is enhanced by P-active substances.

As a result of research, it was found that honeysuckle varieties of different ecological, geographical and genetic origin accumulate various levels of biologically active substances (BAS).
The content of ascorbic acid in honeysuckle fruits ranged from 14.0 mg/100 g (Gerda) to 42.22 mg/100 g (Nymph). High vitamin content is characteristic of the next varieties: Cinderella (34.75 mg/100 g), Kamchadalka (36.52 mg/100 g), Milori (39.01 mg/100 g), Peacock (39.41 mg/100 g). Low level of ascorbic acid (14.00–18.93 mg/100 g) is marked in the fruit varieties Gerda, Blue spindle, Lazurnaya (table 3).

Table 3. Biochemical assessment of blue honeysuckle fruit.

| Varieties      | Ascorbic acid, mg/100 g | rutin | catechins | anthocyanins | amount |
|----------------|-------------------------|-------|-----------|---------------|--------|
| Antoshka       | 28.92                   | 1355  | 395       | 182           | 1932   |
| Bakcharskaya   | 28.62                   | 1540  | 493       | 145           | 2178   |
| Berell         | 28.62                   | 3150  | 780       | 153           | 4083   |
| Vasyuganskaya  | 25.96                   | 1000  | 540       | 146           | 1686   |
| Galochka       | 29.50                   | 2778  | 751       | 114           | 3643   |
| Gerda          | 14.00                   | 1260  | 355       | 136           | 1751   |
| Gzhel early    | 40.12                   | 1405  | 302       | 142           | 1849   |
| Blue spindle   | 18.05                   | 1050  | 388       | 176           | 1614   |
| Long-fruited   | 22.15                   | 1120  | 548       | 83            | 1751   |
| Cinderella     | 34.75                   | 1700  | 355       | 125           | 2180   |
| Kamchadalka    | 36.52                   | 1050  | 400       | 199           | 1649   |
| Columbino      | 35.49                   | -     | -         | -             | -      |
| Lazurnaya      | 18.93                   | 1460  | 595       | 123           | 2178   |
| Milory         | 39.01                   | -     | -         | -             | -      |
| Nymph          | 42.22                   | 1594  | 366       | 115           | 1875   |
| Peacock        | 39.41                   | -     | -         | -             | -      |
| Bluebird       | 22.00                   | 1500  | 400       | 106           | 2006   |
| Smalta         | 29.87                   | -     | -         | -             | -      |
| Chelyabinka    | 23.75                   | 1655  | 568       | 119           | 2342   |
| Blueberry      | 29.90                   | 1262  | 512       | 133           | 1907   |

Among the fruit and berry crops, honeysuckle occupies a leading position in terms of bioflavonoid content. We assessed the content of rutin, catechins and anthocyanins in fresh honeysuckle berries. The content of rutin varied from 1000 mg/100 g (Vasyuganskaya) to 3150 mg/100 g (Berel). A relatively high level of rutin accumulation (from 2770 to 3150 mg/100 g) was characterized by varieties originating from the Altai honeysuckle: Berel, Galochka.

The catechin content varied in the range from 355 mg/100 g (Gerda) to 780 mg/100 g (Berel). The highest number is noted in the fruit varieties: Galochka, Berel.

Differences in blue honeysuckle varieties in the accumulation of anthocyanins in the fruit are less in absolute value in a number of substances with P-vitamin activity. The range of variation of the indicator was from 83 (long-fruited) to 199 mg/100 g (Kamchadalka). High content of anthocyanins was found in varieties: Antoshka, Blue spindle, Kamchadalka.

In general, the source of P-active substances are varieties of the honeysuckle Berel, Galochka.

Honeysuckle fruits are characterized by a high content of pectin, which causes the gelatinizing ability during processing. The average value of this indicator for varieties was 0.98%. Among the varieties with the highest trait value and high homeostaticity (V < 10%), the following should be noted: Kamchadalka (1.05%), Cinderella (1.44%), Nymph (1.08%), Gzhel early (1.07).

Cranberry crops, including **high blueberry Vaccinium corymbosum**, occupy a special place in the world's cattle breeding. The culture is characterized by resistance to diseases and pests, high yield, large fruit, and taste of berries. When laying industrial plantations and amateur gardeners need to take into account the requirements of *Vaccinium corymbosum* to the acidity of the soil.

Blueberry fruits are a full-fledged source of anthocyanins, flavonoids, ascorbic acid, tocopherol,
vitamin E, as well as minerals: potassium, calcium, magnesium, phosphorus, iron, manganese, selenium, copper.

Berries are recommended for the prevention of allergic reactions, metabolic disorders, neoplasms, as well as a dietary product. The juice has an antiviral and antibacterial effect [10]. Culture is popular for the treatment and prevention of the circulatory system diseases: strengthens the walls of blood vessels, improves blood formation. It has a calming effect. Gastroenterologists recommend blueberries to elderly people to maintain and activate vital forces [15].

Berries are rich in sugars (represented mainly by glucose and fructose) and contain a small amount of organic acids. The range of variability in the amount of sugars was observed in the range from 3.95 (Blue ray) to 8.35 % (Coville). High sugar–acid index was observed in the varieties Blue crop, Herbert, Coville (table 4). This makes it possible to use the studied assortment for the production of food with a low sugar content, which is especially valuable for baby food.

The content of ascorbic acid in the fruit was 9.85 – 18.91 mg/100 g. The maximum value of this indicator is characteristic of varieties: Herbert (18.91 mg/100g) and (16.77 mg / 100 g).

| Types and forms | Titrated acids, % | Amount of sugars, % | Ascorbic acid, mg/100 g | P-active substances, mg/100g | flavonoids | anthocyanins | catechins |
|----------------|------------------|---------------------|------------------------|-----------------------------|-----------|-------------|----------|
| Blue ray       | 0.9              | 3.95                | 9.85                   | 100.75                      | 114.55    | 50.0        |
| Blue crop      | 0.8              | 5.85                | 12.52                  | 300.50                      | 750.05    | 100.0       |
| Rancocas       | 0.5              | 5.50                | 11.34                  | 211.25                      | 438.10    | 100.0       |
| Herbert        | 1.0              | 8.14                | 18.91                  | 1099.00                     | 760.50    | 75.5        |
| Coville        | 0.9              | 8.35                | 16.77                  | 757.25                      | 933.05    | 470.5       |

The biochemical composition of blueberry fruits, as well as edible honeysuckle, is characterized by a high content of bioflavonoids. The value of this indicator on average for the varieties varied in a wide range of values from 265.3 to 2160.8 mg / 100 g. High limits typical varieties: Blue crop, Herbert and Coville.

Analysis of the variation in the biochemical composition of fresh berries by year allowed noting that in hotter, drier growing periods, as a rule, an increased amount of soluble solids and sugars accumulates, and the level of acidity decreases. In cold, wet vegetation periods, the opposite is observed.

4. Conclusion

The results of the research indicate the value of berry crops as a source of raw materials for the production of functional food products. The choice of raw materials for the production of healthy food products primarily depends on the variety characteristics.

The following assortment is selected as sources of biologically active compounds:

- according to the content of ascorbic acid: the black currant Carmelita, Green haze, the red currant Vixne, Marmalade; the remnant raspberries Atlas, Hercules, Orange miracle; the edible honeysuckle Kamchadalka, Cinderella, Gzhel early, Nymph and the high blueberries Herbert, Coville;
- according to the content of pectin: the red currant Jonker van Ttes, Generous; the remnant raspberry Orange miracle; the honeysuckle Kamchadalka, Cinderella, Nymph, Gzhel early;
- according to the content of P-active substances: the black currant Green haze, Tamerlane; the honeysuckle Berel, Galochka; the high blueberries Blue crop, Herbert, Coville.

References

[1] WHO: The World Health Report 2002. Reducing Risks, Promoting Healthy Life 2002 (Geneva: WHO) 253 p
[2] Vinnitskaya V F, Akishin D V,Perfilova O V, Popova E I, Komarov S S and Evdokimov A A 2013 Development and creation of functional products from plant raw materials at Michurinsk State Agrarian University Bulletin of MichSAU 6 83-9

[3] Ogneva O A 2015 Development of technologies for fruit and vegetable products with bifidogenic properties (Krasnodar) 3-15

[4] GOST Standard R 52349-2005. Food Products. Functional Food Products. Terms and Definitions 2005 (Moscow: Standartinform)

[5] Bakulina O N 2005 Use of biologically active substances in food technologies: premixes of vitamins and microelements Food Industry 8 120

[6] Babushkin V A,Perfilova O V, Vinnitskaya V F and Danilin S I 2015 Expansion of food products range for functional and prophylactic nutrition with usage of fruits and vegetables of Tambov region Ecology, Environment and Conservation 21 29-36

[7] Ponomarev A N, Merzlikina A A, Gladneva A A and Lukin 2008 Prospects for the use of antioxidants Dairy industry 6 27-30

[8]Perfilova O V, Babushkin V A, Magomedov G O and Magomedov M G 2018 Quality of jelly marmalade from fruit and vegetable semi–finished productsInternational Journal of Pharmaceutical Research 10(4) 721-4

[9] Program and Method of Selection of Fruit, Berry and Nut Crops 1995 (Orel: All-Russian research Institute of fruit crop selection) 502 p

[10] Kirina I B, Ivanova I A and Samigullina N S 2019 Therapeutic Gardening: a Training Manual (Moscow: Yurait Publishing House) 164 p

[11] Titova L V, Kirina I B, Ob’edkov A A and Titova E G 2019 Research of commodity qualities and complex of biologically active substances of raspberry berries (RUBUS IDAEUS L.) in the conditions of Central Chernozem region Agroecological aspects of sustainable agricultural development: Proceedings of the XVI International scientific conference 429-33

[12] Methods of biochemical research of plants ed. by Ermakov A I 1987 (Leningrag: Agropromizdat) 430 p

[13] Belosokhov F G, Kirina I B and Titova L V 2020 Characteristics of promising varieties of honeysuckle and assessment of their suitability for storage Innovative approaches to the development of technologies for production, storage and processing of crop cluster products: Proceedings of the all-Russian scientific and practical conference 39-43

[14] Eliseeva L G and Blinnikova O M 2011 Complex commodity assessment of edible honeysuckle fruits grown in the Central region of the Russian Federation Commodity Expert of Food Products3 11-7

[15] Kirina I B, Khovanova E V, Bogomolova L S, Yan’kova M M and Dzhikiya D V 2016 Assessment of the suitability of high blueberry and vegetable rhubarb fruits for creating functional products Collection of the Scientific Papers dedicated to the 85th Anniversary of Michurin State Agrarian University pp 218-22