Biochemical and technological evaluation of peppers
(Capsicum annuum L.) for functional food products

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Abstract. Pepper is one of the main nightshade vegetables in open and protected ground. There are a large number of varieties and hybrids that differ in agrotechnological characteristics and biochemical composition of fruits (content of dry substances, sugars, vitamins and other biologically active substances). However, not all varieties are suitable for being processed into functional food products. The article considers the assortment of sweet and hot peppers for open ground in terms of yield, commercial qualities and biochemical composition of fruits: the content of dry substances, sugars, vitamin C. Comprehensive assessment of 8 varieties of sweet peppers and 5 varieties of hot peppers identified the varieties Spartak, Kvazar and Pleiades (sweet pepper) and varieties G-1713 and Debut (hot pepper), which have high yields, marketability, vitamin value and suitability for processing into functional products. In breeding work, varieties of sweet pepper are of interest for use as sources of the main economically valuable traits: by yield – Spartak, Pleiades; by weight of fruits – Kvazar; pericarp wall thickness – Spartak, Kvazar; by the content of sugars and dry substances – Spartak, Biktash; by the content of vitamin C – Spartak, Biktash, Kvazar, Pleiades; hot pepper varieties: by yield – G-1713; by weight of fruits – Debut, Kozerog, G-1713; by the content of dry matter and vitamin C – Kozerog, G-1713; by vitamin C content – Debut.

1. Introduction
Vegetables contain a significant amount of vitamins, mineral nutrients, carbohydrates, phytoncides and other biologically active substances, which makes vegetables very useful for the human body [1, 2]. The range of types and varieties of vegetable crops containing a complex of diverse biologically active substances contributes to developing functional food products that are useful for humans [3, 4].

Pepper is a perennial subshrub. As a cultivar it is an annual vegetable plant of the nightshade family (Solanaceae), Capsicum variety with a lignified upright branching stem in the lower part. Out of the entire Capsicum variety, four species have been introduced into the culture. The annual pepper (Capsicum annuum L., Capsicum longum L.), both sweet and hot is the most famous and widespread in our country. In tall varieties and hybrids, the height of the bush reaches 1.5 m, in medium-sized varieties – approximately 1 m, and scrubby varieties do not exceed 40-60 cm in height [1].
The fruit of the pepper is a 2-3-locular false berry, which consists of a pericarp (pulp) and an overgrown placenta with seeds. The shape, weight and thickness of the fruit walls are different for different varieties. The color of ripe fruits can be yellow, red and orange. In the phase of technical ripeness, the fruits are green, milky-white or purple. The color depends on the variety [4, 7].

The fruits of the pepper contain the alkaloid capsaicin (up to 0.7%), which causes an irritating effect and a peppery taste. Depending on the level of content of this compound, varieties of sweet and hot peppers are distinguished. In addition, the fruits of vegetable peppers contain sugar (up to 8.4%), proteins (up to 1.5%), vitamins C (up to 500 mg%), carotene (up to 14 mg%), P, B1, B2, essential (1.5%) and fatty (in seeds up to 10%) oil, steroid saponins [5, 8, 9].

The purpose of the work was to give a comparative assessment of the studied varieties of pepper in terms of yield, size and main biochemical indicators of fruits and to select varieties with a complex of economically valuable traits and a high content of biologically active substances in order to obtain functional products.

2. Materials and methods
Vegetable crops varieties were studied in 2006-2018 at the experimental plots of the FSBSI “Federal Scientific Center for Vegetable Growing” in the Ramensky district of the Moscow region. The agrotechnological assessment of the assortment of vegetable crops was carried out in the experimental production farm “Bykovo” of the Moscow Region and on the basis of farms in the Tambov Region.

The objects of research were 8 varieties of sweet pepper (Biktash, Zdorovye, Zukhra, Kvazar, Pleiades, Ruza F1, Spartak, Chrysolite F1) and 5 varieties of hot pepper (G-540, G-1713, Debut, Zhguchiy bouquet and Kozerog). Varieties Zdorovye (sweet pepper) and Zhguchiy bouquet (hot pepper) were taken as control.

The indicators of the yield of varieties, fruits size, content of dry substances, sugars, and vitamin C (ascorbic acid) in the fruits were studied. The yield, marketability and average weight of fruits of vegetable plants were determined according to the VIR method (1986); the dry matter content was determined by the drying method according to GOST 28561-90; sugar content – by Bertrand and GOST 8756.13-87; ascorbic acid content – by the fluorometric method.

To determine the relationships between the indicators of the biochemical composition of the fruits, the vitamin-sugar index was calculated.

Vitamin-sugar index $K_{SV}$ expressed as the ratio of the vitamin C content in fruits to the sugars content, according to the formula:

$$K_{SV} = \frac{B}{C},$$

where $C$ is sugar content in fruits; $B$ is vitamin C content.

The biological meaning of the vitamin-sugar index is that the higher the index is, the greater the vitamin value and dietary usefulness of the product is.

The integral point assessment of the complex of qualitative indicators of $K_{INT}$ varieties was determined as the sum of indicators reduced to a common denominator, according to the formula:

$$K_{INT} = \frac{b_1 + b_2 + b_3 + b_n}{n},$$

where $b$ is scoring of specific indicators, $n$ is number of indicators

The point assessment of specific indicators was reduced to a common denominator taking the maximum value of each specific indicator as the highest point (5 points). Thus, the significance of individual indicators was leveled (not taken into account). Therefore, this assessment is valid only within the framework of a specific experience.

Symbols:
1 - varieties yield;
2 - fruit size;
3 - dry matter content;
4 - sugar content;
5 - vitamin C content;
6 - vitamin-sugar index;
7 - pericarp wall thickness;
8 - tasting score.

Variance analysis of the experimental material was carried out according to B.A. Dospekhov (1985).

3. Results and discussion

Table 1 shows data on yield, average weight of fruits, acidity and biochemical composition of fruits of 8 varieties of sweet pepper. Variety Zdorovye served as the control variety.

**Table 1.** Yield, morphobiological and biochemical evaluation of fruits in sweet pepper varieties (*Capsicum annuum* L), for 3 years on average

| Variety     | Productivity, kg/m² | Average fruit weight, g | Pericarp wall thickness, mm | Tasting score, point | Dry matter content, % | Sugar content, % | Vitamin C content, mg% | Vitamin-sugar index |
|-------------|---------------------|-------------------------|------------------------------|----------------------|------------------------|------------------|------------------------|---------------------|
| Zdorovye (K)| 4.5                 | 45                      | 3.0-4.0                      | 4.4                  | 6.3                    | 3.8              | 145.8                  | 38.4                |
| Biktash     | 6.1                 | 110                     | 4.5-5.0                      | 4.3                  | 7.4                    | 4.3              | 172.5                  | 40.1                |
| Zuhra       | 6.2                 | 85                      | 5.5-6.0                      | 4.6                  | 6.9                    | 4.0              | 152.1                  | 38.0                |
| Kvazar      | 5.4                 | 150                     | 5.5-6.5                      | 4.5                  | 6.4                    | 4.1              | 169.4                  | 41.3                |
| Pleiades    | 6.8                 | 90                      | 5.0-5.5                      | 4.6                  | 6.2                    | 4.1              | 174.3                  | 42.5                |
| Ruza F₁     | 5.9                 | 110                     | 4.5-5.0                      | 4.3                  | 6.3                    | 4.1              | 127.2                  | 31.0                |
| Spartak     | 6.9                 | 100                     | 6.0-6.5                      | 4.7                  | 6.5                    | 4.6              | 178.2                  | 38.7                |
| Chrysolite  | 5.7                 | 120                     | 5.0-5.5                      | 4.4                  | 6.4                    | 3.9              | 134.5                  | 34.5                |
| LSD₀₅       | 1.2                 | 13                      | -                            | 0.3                  | 0.6                    | 0.9              | 19.5                   | 2.8                 |

The yield of sweet pepper varieties varied greatly within 4.5-6.9 kg/m². On the control variety Zdorovye, 4.5 kg/m² of fruits were harvested. The yield of all the studied sweet pepper varieties exceeded the yield of the control variety. However, the highest yield was formed on the varieties Spartak (6.9 kg/m²) and Pleiades (6.8 kg/m²). The excess of yield over the control level on these varieties was significant and amounted to 53.3 and 51.1%, respectively.

Such indicators as pericarp wall thickness, fruit average weight and its tasting assessment are of significant importance in the selection of sweet pepper. The average weight of fruits in sweet pepper cultivars weakly correlated with yield and depended, primarily, on the genotypic characteristics of cultivars. The largest fruits were formed in the varieties Kvazar (150 g) and Chrysolite F₁ (120 g). The smallest fruits were in the Zdorovye variety (45 g). Other studied varieties produced medium-sized fruits. The greatest thickness of the pericarp walls was formed in the varieties Spartak (6.0-6.5 mm), Kvazar (5.5-6.5 mm) and Zuhra (5.5-6.0 mm). The highest tasting score for sweet pepper fruits was in Spartak (4.7 points), Pleiades and Zuhra (4.6 points). The best in terms of the set of these indicators were the Spartak and Kvazar varieties.

In accordance with the requirements to varieties of sweet peppers for industrial processing, the dry matter content in fruits must be at 5.0% level and higher. The dry matter content in fruits in all studied varieties exceeded this indicator by 1.3% in the control variety (6.3%), by 1.9% in the Zuhra variety (6.9%) and by 2.4% in the Biktash variety (7.4%).

A significant characteristic of varieties both in breeding and in technological variety study is the biochemical composition of the fruits.

The sugar content was the highest in the varieties Spartak (4.6%), Biktash (4.3%), Kvazar, Pleiades (4.1%). These indicators significantly (by 13.2-21.1%) exceeded the control variety Zdorovye (3.8%). For other varieties, this indicator was at the control level (6.2-6.5%).
The content of ascorbic acid in sweet pepper fruits was quite high and varied in the range of 127.2-178.2 mg% (10 times more than in apples). The highest vitamin C content significantly exceeding this indicator of the control variety Zdorovye (145.8 mg%) was in 4 out of 8 studied varieties: Spartak (178.2 mg%), Pleiades (174.3 mg%), Kvazar (169.4 mg%) and Biktash (172.5 mg%), in other studied varieties it was at the control level.

The vitamin-sugar index of all sweet pepper varieties ranged in the scope of 31.0-42.5, which characterized the production of these varieties as highly dietary. The highest indicator was found in the Pleiades (42.5) and Kvazar (41.3) varieties.

Table 2 shows data on the integral scoring of the complex of indicators of sweet pepper varieties.

| Varieties, hybrids | Indicators | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | K_{INT} |
|--------------------|------------|---|---|---|---|---|---|---|---|--------|
| Spartak            | 5.0        | 3.4| 4.4| 5.0| 5.0| 4.6| 5.0| 5.0| 4.7 |
| Kvazar             | 3.9        | 5.0| 4.3| 4.5| 4.8| 4.9| 4.8| 4.8| 4.6 |
| Biktash            | 4.4        | 3.7| 5.0| 4.7| 4.8| 4.7| 3.8| 4.6| 4.5 |
| Pleiades           | 4.9        | 3.0| 4.2| 4.5| 4.9| 5.0| 4.2| 4.9| 4.5 |
| Zuhra              | 4.5        | 2.8| 4.7| 4.3| 4.3| 4.5| 4.6| 4.9| 4.3 |
| Chrysolite F1      | 4.1        | 4.0| 4.3| 4.2| 3.8| 4.1| 4.2| 4.7| 4.2 |
| Ruza F1            | 4.3        | 3.7| 4.3| 4.5| 3.6| 3.6| 3.8| 4.6| 4.1 |
| Zdorovye (K)       | 3.3        | 1.5| 4.3| 4.1| 4.1| 4.5| 2.8| 4.7| 3.7 |

The data presented in Table 3, shows that the highest integral score for the complex of indicators of sweet pepper was obtained for the varieties Spartak, Kvazar and Pleiades.

Table 3 shows data on yield, average weight of fruits, acidity and biochemical composition of fruits of 5 varieties of hot pepper, the control variety was the variety Zhguchiy Bouquet.

| Variety           | Productivity, kg/m² | Average fruit weight, g | Dry matter content, % | Sugar content, % | Vitamin C content, mg% | Vitamin-sugar index |
|-------------------|---------------------|-------------------------|-----------------------|----------------|------------------------|---------------------|
| Zhguchiy bouquet (K) | 2.1                 | 4.9                     | 9.6                   | 3.5            | 160.6                  | 45.9                |
| G-540             | 2.8                 | 8.7                     | 9.8                   | 3.7            | 169.2                  | 45.7                |
| G-1713            | 5.3                 | 11.0                    | 10.6                  | 4.1            | **177.4**              | 43.3                |
| Debut             | 3.6                 | 12.4                    | 10.2                  | **4.7**        | **196.5**              | 41.8                |
| Kozerog           | 3.5                 | 10.9                    | 10.6                  | 4.1            | 165.1                  | 40.3                |
| LSD_{05}          | 1.1                 | 2.6                     | 2.3                   | 1.1            | 16.9                   | 5.8                 |

The yield of hot pepper varieties was significantly lower than that of sweet pepper, and varied within the scope of 2.1-5.3 kg/m². On the control cultivar Zhguchiy Bouquet, the minimum amount (2.1 kg/m²) of fruits was harvested. The yield of all the studied hot pepper varieties exceeded the yield of the control variety. The highest yield was formed on the G-1713 variety (6.9 kg/m²), as well as on the Kozerog and Debut varieties (3.5-3.6 kg/m²). The excess of yield over the control level on these varieties was significant and amounted to 66.7 and 71.4%, respectively.

The average weight of fruits in hot pepper varieties significantly correlated with yield. The largest fruits were in the high-yielding varieties Debut (12.4 g), G-1713 (11.0 g) and Kozerog (10.9 g). The smallest fruits were in the control variety Zhguchiy Bouquet (4.9 g). In general, the average weight of fruits in hot peppers was almost 10 times less than that of sweet peppers.
The content of dry matter in fruits in all studied varieties of hot pepper was almost the same and was at the control level.

The vitamin-sugar index of all hot pepper varieties ranged in the scope of 40.3-45.9, which characterizes the production of these varieties as highly vitamin. This indicator was the highest in the control cultivar Zhguchiy Bouquet (45.9).

Table 4 shows data on the integral scoring of the complex of indicators of hot pepper varieties.

| Varieties, hybrids  | Indicators | K_\text{INT} |
|---------------------|------------|-------------|
| G-1713              | 5.0        | 4.4 5.0 4.4 4.5 4.7 |
| Debut               | 3.4 5.0 4.8 5.0 5.0 4.6 |
| Kozerog             | 3.3 4.4 5.0 4.4 4.2 4.4 4.3 |
| G-540               | 2.6 3.5 4.6 3.9 4.3 5.0 4.0 |
| Zhguchiy bouquet (K)| 2.0 2.0 4.5 3.7 4.1 5.0 3.6 |

The data presented in Table 4, shows that the highest integral score for the complex of indicators of hot pepper was obtained for varieties G-1713 and Debut.

4. Conclusion

A comprehensive study of the varieties pepper samples in terms of morphological, agrobiological and biochemical indicators enabled to identify the following varieties as the most promising for industrial processing:
- varieties of sweet peppers: Spartak, Pleiades, Kvazar having a high yield, pericarp wall thickness and vitamin C.
- varieties of hot peppers: G-1713 and Debut having a high yield, large fruit size and a high content of vitamin C.

The following varieties of sweet pepper are of interest as sources for breeding:
- by yield – Spartak, Pleiades,
- by weight of fruits – Kvazar,
- by pericarp wall thickness – Spartak, Kvazar,
- by the content of sugars and dry substances - Spartak, Biktash,
- by the content of vitamin C - Spartak, Biktash, Kvazar, Pleiades,
- by a set of signs - Spartak, Kvazar, Pleiades.

The following varieties of hot pepper are of interest as sources for breeding:
- by yield – G-1713,
- by weight of fruits – Debut, Kozerog, G-1713,
- by the content of dry matter and vitamin C – Kozerog, G-1713,
- by the content of vitamin C – Debut,
- by a set of characteristics – Debut and G-1713.

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