Integrated Biochemical Estimation of Seabuckthorn Berries in Conditions of the Forest-Steppe Area of the Altai Krai

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Abstract. Seabuckthorn (Hippophae rhamnoides L.) is considered a multipurpose crop. Different parts of the plant are marked with a unique composition of nutrients and biologically active substances (soluble sugars, fatty acids, vitamins, organic acids, etc.). The study of biochemical composition is necessary for successful breeding and widening seabuckthorn utilization in medicine, food, and cosmetics industries. The paper presents the integrated biochemical features of seabuckthorn berries bred by the Lisavenko Institute in Barnaul, Russia (3 varieties and 58 hybrids). Biochemical analysis was carried out according to common research methods. We established the variability for such substances as soluble solids, sugars, vitamin C, titratable acids, oils, and sugar acids. Significant variability for sugars content (22%), vitamin C content (32%), and sugar-acid index (36%) was revealed. According to the assessment results, we selected 12 promising genotypes. We also identified genotypes combining maximum levels of 1–3 biochemical features.

Keywords: Seabuckthorn · Berries · Biochemical composition · Integrated estimation · Food nutrition improvement

1. Introduction

Seabuckthorn varieties bred in the Altai Krai are distinguished by a significant level of nutritional value and fatty biochemical composition [13]. Three daily doses of vitamin C and more than ten carotene doses are contained in just 100 g of seabuckthorn berries. It is also rich in vitamins B, E, PP, and K [1, 2, 3, 4, 5, 8]. Moreover, seabuckthorn contains substances with antioxidant, anti-inflammatory, antitumor, phytoncide, and preserving properties. It also has organic acids (malic, sorbic, ascorbic), polyphenols (catechins, leukoanthocyanins, anthocyanins), amino acids, etc. [8, 11].

As a result, seabuckthorn is often considered as a source for different sectors of the food industry. It leads to the task of multipurpose seabuckthorn selection directed to numerous types of utilization based on high organoleptic properties. Therefore, its breeding should be increased significantly. The targeted piece is closely connected to biochemical investigations of the genetic material.

Based on the above, the present research conducts an integrative biochemical estimation of seabuckthorn berries in the condition of the forest-steppe area of the Altai Krai.
2. Materials and Methods

The biochemical investigation of seabuckthorn fruits was carried out in the Laboratory of Industrial Technologies of the M. A. Lisavenko Scientific Research Institute of Horticulture of Siberia (SRIHS) in 2018. The objects of the study are the berries of 3 varieties and 58 hybrids of seabuckthorn.

The content of soluble solids was determined by the refractometric method [12]; sugars content – by direct titration [6]; titratable acidity – by extraction [12]; vitamin C content (mg / 100 g) – by potentiometric titration [7]; oil – using the Soxhlet apparatus [12]. The integrated biochemical assessment was carried out according to the Tyurina method [10].

3. Results

Based on the biochemical investigation of seabuckthorn berries, we conducted an integrated analysis of the hybrid fund of the Lisavenko Institute. The content of soluble solids inside the analyzed group varied from 7.14 (hybrid 6-95-4) to 14.08% (hybrid 249-00-2) with a moderate variation (14%). Soluble solids had a normal distribution: in stages 1–2 and 5–6, there were 4–12 genotypes (20% and 29%); in stages 3–4, there were 15–16 genotypes (51%). According to this parameter, the standard variety Chuiskaya entered the first grade (table 1).

Table 1. Integrated biochemical estimation of seabuckthorn berries, 2018.

| Parameter          | Grade of parameters |
|--------------------|---------------------|
|                    | 1                  | 2                  | 3                  | 4                  | 5                  | 6                  |
| Soluble solids, %  |                    |                    |                    |                    |                    |                    |
| 1                  | 7.14–8.28          | 8.29–9.43          | 9.44–10.58         | 10.59–11.73        | 11.74–12.88        | 12.89–14.04        |
| 2                  | Chuiskaya; 6-95-4; 149-00-1; 521-13-1 | 149-00-2; 149-00-4; 14-01-4; 93-08-6; 681-09-1; 374-13-1; 759-13-1; 783-13-1 | Aurelia; 140-00-2; 149-00-3; 149-00-5; 14-01-5; 79-01-1; 205-01-2; 143-02-1; 217-03-1; 506-08-2; 561-08-1; 600-08-1; 114-13-1; 746-13-1; 785-13-1 | Afina; 721-93-4; 203-00-4; 226-00-1; 14-01-6; 57-01-1; 62-01-2; 125-02-1; 131-02-1; 175-02-1; 590-08-1; 380-09-1; 156-13-1; 252-13-1; 766-13-1; 786-13-1 | 1237-86-4; 146-00-3; 250-00-2; 14-01-1; 145-02-1; 165-02-2; 18-03-1; 621-08-1; 538-09-1; 711-09-1; 708-13-1; 7154-13-1 | 218-00-1; 243-00-2; 131-02-2; 146-02-1; 625-08-1; 695-09-1 |
| Sugars, %          |                    |                    |                    |                    |                    |                    |
| 1                  | 2.45–3.35          | 3.36–4.26          | 4.27–5.17          | 5.18–6.08          | 6.09–6.99          | 7.00–7.91          |
| 2                  | 6-95-4; 203-00-4; 374-13-1; 521-13-1; 759-13-1 | 140-00-2; 149-00-1; 149-00-2; 149-00-4; 14-01-6; 125-02-1; 143-02-1; 746-13-1; 783-13-1 | Afina; Aurelia; 149-00-3; 149-00-5; 226-00-1; 14-01-4; 14-01-5; 62-01-2; 79-01-1; 205-01-2; 145-02-1; 18-03-1; 217-03-1; 93-08-6; 561-08-1; 600-08-1; 380-09-1; 538-09-1; 681-09-1; 711-09-1; 114-13-1; 156-13-1; 708-13-1 | Chuiskaya; 1237-86-4; 146-00-3; 218-00-1; 250-00-2; 14-01-1; 57-01-1; 131-02-1; 131-02-1; 146-02-1; 175-02-1; 590-08-1; 695-09-1; 252-13-1; 766-13-1; 785-13-1; 786-13-1 | 165-02-2; 506-08-2; 621-08-1 | 721-93-4; 243-00-2; 625-08-1 |
| Titratable acidity, % |                    |                    |                    |                    |                    |                    |
| 1                  | 1.020–1.254        | 1.255–1.489        | 1.490–1.724        | 1.725–1.959        | 1.960–2.194        | 2.195–2.430        |
| 2                  | 721-93-4; 57-01-1; 79-01-1; 217-03-1 | 149-00-2; 149-00-5; 226-00-1; 250-00-2; 14-01-5; 62-01-2; 131-1 | Aurelia; Chuiskaya; 1237-86-4; 95-4; 146-00-3; 149-00-3; 203-00-4; 218-00-1 | Afina; 140-00-2; 149-00-4; 14-01-1; 14-01-4; 125-02-1; 146-02-1; 93-08-6; 538- | 205-01-2; 114-13-1; 759-13-1; 783-13-1 | 149-00-1; 14-01-6; 145-02-1; 561-08-1 |
| Sugar acid index | Vitamin C, mg/100 g | Oil, % |
|-----------------|---------------------|-------|
| Afina; 6-95-4; 140-00-2; 149-00-1; 149-00-4; 203-00-4; 14-01-6; 125-02-1; 143-02-1; 145-02-1; 561-08-1; 538-09-1; 114-13-1; 374-13-1; 521-13-1; 746-13-1; 759-13-1; 783-13-1 | 220.47–253.76 | 226-00-1; 14-01-6; 205-01-2; 131-02-1; 506-08-2 | 625-08-1 | 721-93-4 |
| Aurelia; Chuiyskaya; 146-00-3; 149-00-2; 149-00-3; 14-01-4; 14-01-5; 62-01-2; 79-01-1; 205-01-2; 131-02-2; 146-02-1; 18-03-1; 93-08-6; 590-08-1; 600-08-1; 380-09-1; 681-09-1; 711-09-1; 156-13-1; 708-13-1; 754-13-1; 785-13-1; 786-13-1 | 187.20–220.47 | 203-00-2; 149-00-1; 218-00-1; 226-00-1; 14-01-6; 205-01-2; 131-02-1 | Afina; 146-00-3; 218-00-1; 226-00-1; 14-01-6; 205-01-2; 131-02-1; 506-08-2 | 374-13-1 |
| Aurelia; 1237-86-4; 149-00-0; 149-00-4; 149-00-5; 243-00-2; 250-00-2; 14-01-4; 62-01-2; 125-02-1; 217-03-1; 621-08-1; 625-08-1; 746-13-1; 766-13-1 | 153.92–187.19 | 140-00-2; 149-00-1; 218-00-1; 226-00-1 | 146-00-3; 218-00-1; 226-00-1; 14-01-6; 205-01-2; 131-02-1; 506-08-2 | |
| 6-95-4; 14-01-5; 79-01-1; 14-01-6; 600-08-1; 380-09-1; 252-13-1; 786-13-1 | 87.36–120.63 | 120.64–153.91 | 187.20–220.47 | 226-00-1; 14-01-6; 205-01-2; 131-02-1; 506-08-2 | |
| Afina; 146-00-3; 218-00-1; 226-00-1; 14-01-6; 205-01-2; 131-02-1 | 54.08–87.35 | 220.47–253.76 | 226-00-1; 14-01-6; 205-01-2; 131-02-1; 506-08-2 | |
The same distribution of genotypes was observed for sugar content. It ranged from 2.45 (hybrid 374-13-1) to 7.91% (hybrid 721-93-4) with a high variation (22%). Six genotypes were the base of 5–6 grades (10%): 3 genotypes in 5 grade – 165-02-2, 506-08-2, and 632-08-1; 3 genotypes in grade 6 – 721-93-4, 243-00-2, and 625-08-1. Sugars content of standard variety corresponded to grade 4.

Titratable acidity varied from 1.02 (hybrid 721-93-4) to 2.43 (hybrid 149-00-1) with a moderate coefficient of variation (19%). The population’s core is concentrated in 2–4 classes, including 13-21 genotypes (80%). The berries of four genotypes were marked with minimal acidity (721-93-4, 57-01-1, 79-01-1, and 217-03-1). Four of them (149-00-1, 14-01-6, 145-02-1, and 561-08-1) had maximum volumes. The standard variety was included in grade 3.

The sugar-acid index ranged from 1.46 (hybrid 149-00-1) to 7.75 (hybrid 721-93-4) with high variation (36%). By this parameter, the population’s core concentrated on grades 1–2, where 18–25 genotypes (70.5%) were registered, including standard varieties. Grade 3 included 11 genotypes; grade 4 – 5 genotypes; grades 5 and 6 – one genotype each (625-08-1 and 721-93-4, respectively).

The variability of Vitamin C ranged from 54.08 (hybrid 681-09-1) to 253.76 mg/100 g (hybrid 374-13-1) with high variation (32%). The majority of hybrids (70.5%) were distributed in grades 2–4. Grade 1 included nine genotypes (15%) with a minimum content of ascorbic acid (54.08-87.35 mg / 100 g). Inside the fifth grade, eight genotypes were noted (13%) with vitamin C content from 187.20 to 220.47 mg / 100 g. Inside the sixth grade, we recorded only one genotype, 374-13-1, with the maximum value.

The oil content varied from 2.21 (hybrid 506-08-2) to 5.21% (hybrid 746-13-1) with moderate variability (19%). Most hybrids were included in 2 and 4 grades – 19 (31%) and 16 genotypes (26%). Grade 3 consists of 14 genotypes (23%), including the standard variety. The berries of 5 genotypes (8%) have minimum oil content; 3 genotypes have maximum oil values – 145-02-1, 600-08-1, and 746-13-1). Grade 5 included 4 genotypes (6.5%).

A scoring estimation of breeding material is permitted to classify all varieties and reveal the best ones with maximum values of several biochemical parameters. The mean point number within the population was 18.34 ± 0.45 (figure 1). In 37 genotypes (61%), the number of points was the same or above the mean value. The standard variety obtained 16 points. At X + σ level (22 points or more), 12 genotypes (20%) were identified, including Afina variety; at the level of X + 2σ (25 or more points) it had 4 genotypes (6.5%).

|         | 02-1; 143-02-1; 93-08-6; 590-08-1; 380-09-1; 114-13-1; 521-13-1; 708-13-1; 754-13-1; 766-13-1 | 13-1; 785-13-1; 786-13-1 | 1; 217-03-1; 621-08-1; 681-09-1; 711-09-1; 759-13-1 |
|---------|--------------------------------------------------------------------------------------------------|--------------------------|----------------------------------------------|

Note: 1 – grade interval; 2 – seabuckthorn varieties.

Source: Compiled by authors.
During our research, we identified some promising genotypes of seabuckthorn for further breeding activity in specific directions.

4. Discussion
The obtained data revealed a high variability of three of the six biochemical parameters (sugar content, vitamin C, and sugar-acid index). Similar variability was earlier established by S. M. Sabir, S. D. Ahmed, and N. Lodhi [9] for seabuckthorn in mountain regions of Pakistan, which is highly positive for selecting new varieties with economically valuable features.

The average content of sugar, titratable acidity, and the sugar-acid index was at the same level as 2014–2015 [14]. The soluble solids and vitamin C are higher on 1.3% and 10.8 mg/100 g, respectively. The oil content is lower by 1.1%.

5. Conclusion
Thus, significant changes (V>20%) of such biochemical parameters as sugar content (2.45%–7.91%), sugar-acid index (1.46–7.75), and vitamin C content (54.08–253.76 mg/100 g) were found in the berries of seabuckthorn varieties in conditions of the Altai Krai. Medium variation of soluble solids equals to 7.14%–14.04%; titratable acidity – 1.02%–2.43%; and oil content varies from 2.21% to 5.21%.

Genotypes with maximum values of several biochemical parameters were identified: hybrids 243-00-2 and 621-08-1 – by sugars and soluble solids content; 721-93-4 – by sugars content, sugar-acid index, low titratable acidity; 374-13-1 – by vitamin C and oil content; 145-02-1, 600-08-1 and 746-13-1 – by oil content; 625-08-1 – by sugar-acid index, soluble solids, and sugars content.
One variety and 10 hybrids were selected with the total number of points at the level of X + σ (22 points or more): Afina variety, hybrids 1237-86-4, 721-93-4, 205-01-2 (22 points each); hybrids 146-00-3, 131-02-2, 621-08-1, 695-09-1 (23 points each); hybrids 218-00-1, 218-00-1, 625-08-1 (25 points each). The hybrid 243-00-2 was selected with a maximum number of points (26), exceeding the X + 2σ level (25 points).

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