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THE IMPACT OF VARIOUS FERTILIZING SCHEMES ON THE BIOCHEMICAL COMPOSITION OF ARONIA FRUITS

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Abstract

The scientific experiment was conducted in a demonstration plantation at the Research Institute of Mountain Stockbreeding and Agriculture of Troyan. A fertilizing scheme was applied to aronia shrubs with various types of fertilizers, as well as combinations among them. The biochemical composition of aronia berries was compared after harvest and after one year of storage at -18°C. High values of dry weight, dry matter by Re, pectin, and total polyphenols were identified in the potassium sulfate fertilizing variant. The combined fertilizing with triple superphosphate, potassium sulfate, and carbamide gave the highest content of total sugars, sucrose and total polyphenols in fruits after the storage period. Statistical differences were proven among fertilizing variants in terms of dry matter by Re, total sugars, sucrose, and ascorbic acid. Organic acids, anthocyanins, and total polyphenols had proven results. The objective of the present study is to analyze the changes in the biochemical composition of aronia berries after the application of various fertilizing variants, after harvest, and one-year storage period.

Key words: *Aronia berries, Aronia melanocarpa L., biochemical composition, fertilizing, storage*

INTRODUCTION

Aronia or black chokeberry (*Aronia melanocarpa* L.) is a perennial shrub with a height of about 2.5-3 m, belonging to the *Rosaceae* family, genus *Aronia*. It originates from North America, from where it was brought to Europe. The fruit type has found wide distribution in Russia, where it is known under the name 'chernoplodnaya ryabina' (T.N. – transliteration from Russian). The first plants were imported into Bulgaria from there in the late 1960s, and early 1970s. The species was originally used in Bulgaria for decorative purposes and the preparation of home products in the past. Its industrial cultivation began in the 80s when numerous plantations were established (Mondeshka, 2005).

Aronia is a precocious species**,** as it starts fruit-bearing in the second year after planting. Its fruits ripen mainly in August, but the optimal harvesting period is the beginning of September when they have matured enough and the anthocyanin content has reached high levels (Andrzejewska et al., 2015). Their taste is pleasant, slightly sour, slightly astringent, and intensely coloured. They are suitable for fresh consumption, drying, and canning. They are used for wonderful juices, syrups, nectars, jam, purees, pestles, fruit teas, dessert wines, with an attractive dark ruby color, and nutritional supplements (Georgiev & Ludneva 2009; Sidor et al., 2019; Yang et al., 2021). Their characteristic rich content of polyphenolic compounds, anthocyanins, and ascorbic acid, makes them desirable ingredients (components) in the composition of bioactive foods, which has a healing effect on physiological processes in the human body (Hakkinen et al., 1999; Oszmiański & Wojdylo, 2005; Ochmian et al., 2009; Denev et al., 2013; Jurikova et al., 2017; Denev et al., 2018). The therapeutic effect of aronia berries is determined by their hypotensive effect, lowering the cholesterol level in the blood, cardioprotective, immunomodulating, antidiabetic, and anticarcinogenic properties (Simeonov et al., 2002; Yaneva et al., 2002; Hellstrom et al., 2009; Kokotkiewicz et al., 2010; Park & Park 2011; Balansky et al., 2012; Ren et al., 2022).

Typical of aronia berries is the low sucrose content, which makes them suitable for the diet of diabetics (Simeonov et al., 2002; Mondeshka, 2005; Valcheva-Kuzmanova, 2007; Banjari et al., 2017; Catană et al., 2021).

The biochemical composition of its fruits is not constant, but changes depending on the soil and climate conditions in the growing region, the applied agrotechnical events, the harvesting period, the cultivated varieties, and the fruit processing techniques (Misiak & Irzyniec 2009; Tolic et al., 2017; Pop et al., 2022).
The objective of the present experiment is to observe the impact of different fertilizing types on the biochemical composition of fresh aronia berries compared to the changes that occurred in them after one year of storage at -18°C.

MATERIALS AND METHODS

The aronia shrubs were planted in 2019 and were grown with drip irrigation. The planting scheme of the plants is 3.00 m x 2.50 m. Inter-row spacings and intra-row areas are naturally grassed, as mowing is performed when necessary. In contrast, the area around the stem is maintained in black fallow by tillage. The collection plantation is located 450 m above sea level, on an eastern exposure slope. The soils are light gray forest soils with pH varying from 4.6 to 5.6.
In 2022, the vegetation amount of average monthly precipitation was 253.3 l/m^2, which was the lowest reported vegetation precipitation amount for the last five years (Atanasova, 2021).
The following experimental fertilizing variants were set up:
Variant I - control;
Variant II - carbamide (0.150 kg) per shrub;
Variant III - triple superphosphate (0.150 kg) per shrub);
Variant IV - potassium sulfate (0.100 kg) per shrub;
Variant V - triple superphosphate (0.150 kg) and potassium sulfate (0.100 kg) per shrub;
Variant VI - triple superphosphate (0.150 kg), potassium sulfate (0.100 kg) and carbamide (0.150 kg) per shrub;
The biochemical composition of fresh and frozen Aronia berries from the 2022 harvest was analyzed (after one year of storage at -18°C), to which the corresponding fertilizing scheme was applied.
The following biochemical parameters of fresh and dried fruits were studied:

- dry matter weight (%);
- refractometric solids (%);
- sugars (total, invert and sucrose %) and acid, according to the method of Schoorl (Donchev et al., 2001), 25 g of sugars were taken from the sample; chemicals: 10% NaCO3, NaHPO4, Fehling's solution I, Fehling's solution II (made in the laboratory), 30% KI, 1: 6 H2SO4 , titrated by 0.1 n Na 2S2 O3 and starch indicator - sugars; 5 ml of acids were taken from the primary filtrate (as malic) by titration with 0.1 n NaOH (%) and phenolphthalein indicator;
- acids (such as malic) (%) by titration with 0.1 NaOH;
- ascorbic acid (mg %) has been made by the following method: 10 g of the ground sample is quantitatively transferred into a 100 cm3 volumetric flask. Top up with 2% HCL, then filter. Take 20 ml and place in a 100 ml Erlenmeyer flask, adding 10 ml H2O and 5 ml KI. Titrate with KIO3 (in the case of starch indicator) until a deep blue-permanent coloration.
- tannins substances (%) according to the method of Levental (Donchev et al., 2000), 25 g of tannins were taken from the sample. Chemicals: 1: 4 H2SO4, titrated by 0.1 KM4O4 and an indicator (indigo carmine);
- anthocyanins (mg %) by the method of Fuleki & Franciss (1968);
- pectin according to the method of Melitz (Donchev et al., 2000), 12.5 g were taken from the sample. Chemicals: 0.1 n NaOH, 1 n CH_3 COOH, $CaCl_2$, $AgNO_3$;
- total polyphenols (mg/100 g) Folin-Ciocalteu, (Singleton & Rossi, 1965).

The data were statistically processed using the program product MS Excel – 2010, Descriptive statistics. The indicators were calculated - Mean, Standard error, Standard deviation, Minimum-Maximum and Coefficient of variation.

RESULTS AND DISCUSSIONS

Table 1 presents the biochemical composition of fresh aronia berries grown under different fertilizing variants. The dry matter weight is from 26.78% (III variant) to 32.61% (IV

variant). The refractometric solids have the highest value after the application of triple superphosphate (19.00%) and those in the variant with potassium sulfate (24.50%), whereas it has the lowest value after using carbamide (15.00%).

There is a wide range in the amounts of total sugars between the variants. The smallest amount (3.85%) was analyzed in the third variant (compared to the control - 5.00%), and the largest was reported in the second variant with 12.10% (CV% - 38.17).

A greater reduction was observed in the inverted sugar compared to the values of the total sugar in the second and fifth variants. The lowest value was registered after fertilizing with carbamide (1.75%). The variation coefficient for sucrose is very high (CV% - 64.96). The lowest value of this indicator was recorded in the variants with triple superphosphate (1.24%) and the control (1.57%), and it was several times more in fertilizing with carbamide (9.83%).

The analyzed organic acids in fresh aronia berries are in the range of 0.13% - 0.20%. Ascorbic acid was in the range of 12.32 mg/% to 14.08 mg/% and no significant difference was observed between the different experimental variants (CV% - 7.04).

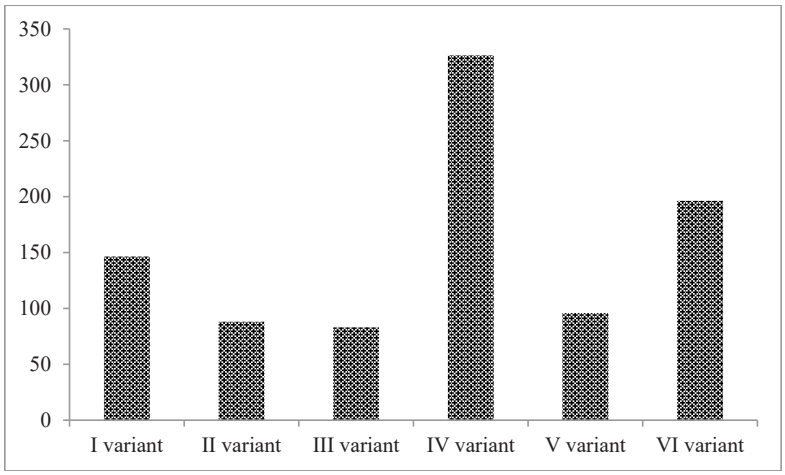
The smallest amount of tannins was recorded in the control variant (0.044%) and more than twice in the shrubs fertilized with triple superphosphate and with the combined application of triple superphosphate, potassium sulfate, and carbamide (0.109%). The calculated coefficient of variation is 37.50%.

The lowest amount of pectin was recorded (0.10%) in the variant with the combined application of triple superphosphate, potassium sulfate, and carbamide. It was slightly higher in fertilizing with triple superphosphate (0.18%), whereas it was the highest in the variant with potassium sulfate (0.95%). The coefficient of variation is very high with 70.59%.

The highest content of total polyphenols was reported in the fourth variant (326.32 mg/ 100 g), lower in the sixth one (196.27 mg/ 100 g) and the first one (146.39 mg/100 g), whereas it was the least in the third variant (83.04 mg/100 g) (Figure 1). The obtained coefficient of variation among the variants is very high – 60.32%.

Table 1. Biochemical composition of fresh aronia fruits, after application of an experimental fertilizing scheme in 2022

Sample No	Dry matter weight %	Refracto-metric solids%	Total sugars %	Inverted sugar %	Sucrose %	Acids (as malic) %	Ascorbic acid mg/%	Tannins %	Pectin %
Variant I	32.00	19.50	5.00	3.35	1.57	0.20	14.08	0.044	0.54
Variant II	27.31	15.00	12.10	1.75	9.83	0.20	12.32	0.066	0.90
Variant III	26.78	19.00	3.85	2.55	1.24	0.13	12.32	0.109	0.18
Variant IV	32.61	24.50	9.20	3.20	5.70	0.13	14.08	0.044	0.95
Variant V	29.93	23.00	8.70	2.55	5.84	0.13	12.32	0.088	0.36
Variant VI	28.94	19.00	9.55	4.20	5.08	0.13	12.32	0.109	0.10
Mean	29.60	20.00	8.07	2.93	4.88	0.15	12.91	0.08	0.51
Minimum-Maximum	26.78-32.61	15-24.5	3.85-12.1	1.75-4.2	1.24-9.83	0.13-0.2	12.32-14.08	0.044-0.109	0.1 0.95
St error	0.98	1.37	1.26	0.34	1.30	0.01	0.37	0.01	0.15
St Dev	2.39	3.36	3.08	0.84	3.17	0.04	0.91	0.03	0.36
CV %	8.08	16.81	38.14	28.70	65.07	23.57	7.04	38.99	71.17



Mean	155.99
Minimum-Maximum	83.04-326.32
St error	38.42
St Dev	94.10
CV %	60.32

Figure 1. Total polyphenols after application of an experimental fertilizing scheme in 2022 (mg/100 g)

Table 2 shows the results for the biochemical composition of aronia berries after a one-year storage period at - 18 ^{0}C. The dry matter weight substance in aronia berries is in a wide range from 17. 67% (II variant) to 28.18 % (V variant), respectively the obtained values are several units lower.

A reduction in the values of refractometric solids was reported after one year of storage. The lowest content was found in the variant with carbamide (12.00%), whereas the highest was reported in the control (16.50%).

The range of variation of total sugars is in close values among the selected variants. The lowest content was found in the control (3.20%), whereas the highest content was found in the fertilizing variant with triple superphosphate, potassium sulfate, and carbamide (4.05%). The variation coefficient is average (10.23%). The decrease compared to the previous year is 57.87%.

Average inverted sugar values were roughly similar for both years: 2.93% (2022) and 2.85% (after storage). The reduction of sucrose in fruits is 89.34%, after one year of storage. In some of the variants, it was not registered at all, whereas the highest was found in the variant with combined fertilizing with triple superphosphate, potassium sulfate, and carbamide (1.57%).

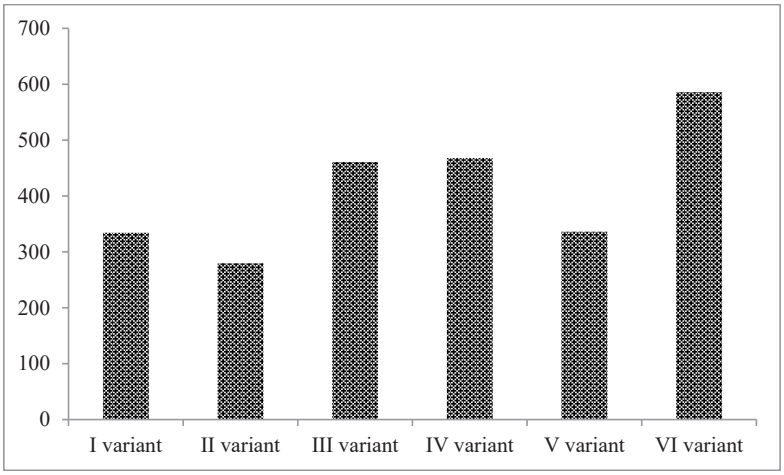
The increase in organic acids is 48.28%, compared to the raw material of the previous year. The average value among variants is 0.29%, and the variation coefficient is 19.48%.

The highest content of ascorbic acid was reported from the variant with carbamide (12.32 mg/%). The average value among the variants is 10.27 mg/%, and the registered reduction is 20.45%, compared to the raw material of the previous year. An analogous trend, as for organic acids, was also found for tannins, as an increase in fruit after storage by 24.53% was reported. The content is in close values among the variants and has a low variation coefficient of 8.77%.

Increased pectin values were found in the control, variant III, variant V, and variant VI. The average value for the variants is 0.78%, and the increase is 34.62%, compared to the starting raw material. An increase in the content of total polyphenols in the fruit was reported in all variants, after storage, which was 62.02%. The highest value was recorded after the application of combined fertilizing with triple superphosphate, potassium sulfate, and carbamide (585.84 mg/100 g), whereas the lowest was in fertilizing with carbamide (279.56 mg/100 g) (Figure 2).

Table 2. Biochemical composition of aronia berries, with a different fertilizing scheme applied, after one year of storage – 2023

Sample No	Dry matter weight %	Refractometric solids%	Total sugars %	Inverted sugar %	Sucrose %	Acids (as malic) %	Ascorbic acid mg %	Tannins %	Pectin %
Variant I	24.19	16.50	3.20	3.20	-	0.34	10.56	0.094	0.96
Variant II	17.67	12.00	3.55	2.70	0.81	0.34	12.32	0.094	0.66
Variant III	26.75	14.50	3.20	3.20	-	0.27	8.80	0.112	0.98
Variant IV	27.63	13.00	3.20	2.40	0.76	0.27	10.56	0.112	0.96
Variant V	28.18	16.00	3.20	3.20	-	0.34	10.56	0.112	0.60
Variant VI	21.75	14.50	4.05	2.40	1.57	0.20	8.80	0.112	0.52
Mean	24.36	14.42	3.40	2.85	0.52	0.29	10.27	0.106	0.78
Minimum-Maximum	17.67-28.18	12-16.5	3.2-4.05	2.4-3.2	0-1.57	0.2 0.34	8.8-12.32	0.094-0.112	0.52-0.98
St error	1.66	0.70	0.14	0.16	0.26	0.02	0.54	0.00	0.09
St Dev	4.06	1.72	0.35	0.40	0.64	0.06	1.32	0.01	0.21
CV %	16.68	11.90	10.23	13.99	122.51	19.48	12.90	8.77	26.84



Mean	410.75
Minimum-Maximum	279.56-585.84
St error	46.58
St Dev	114.10
CV %	27.78

Figure 2. Total polyphenols with a different fertilizing scheme applied, after one year of storage (mg/100 g)

Table 3. Percentage decrease and increase in the indicators of the biochemical composition of aronia berries after one year of storage

Indicators	Dry matter weight %	Refractometric solids%	Total sugars %	Inverted sugar %	Sucrose %	Acids (as malic) %	Ascorbic acid mg /%	Tannins %	Pectin %	Total polyphenols mg/100 g
Percentage (%) decrease / increase, compared to 2022	Decrease 17.70%	Decrease 27.9	Decrease 57.87	Decrease 2.73	Decrease 89.34	Increase 48.28	Decrease 20.45	Increase 24.53	Increase 34.62	Increase 62.02

CONCLUSIONS

Aronia, as a representative of the small-fruited fruit species, is a more unpretentious crop to growing conditions.

The biochemical composition of fruits was evaluated depending on the applied fertilization. The values of the ascorbic acid index in the fresh fruits are higher in the control than in the variant with added potassium sulfate. The highest content of total sugars and sucrose was recorded in a urea fertilization scheme. The highest values of dry weight, dry refractometric substance and pectin were found in the variant with added potassium sulfate.

Freezing as a storage method for aronia berries ensures the preservation of their biological activities and provides an opportunity for their longer use and inclusion in organic products and nutritional supplements.

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