agriculture

MDPI

Article

The Yield, Fruit Quality and Some of Nutraceutical Characteristics of Saskatoon Berries (*Amelanchier alnifolia* Nutt.) in the Conditions of Eastern Poland

Ewa Szpadzik * and Tomasz Krupa

Department of Pomology and Horticulture Economics, Institute of Horticultural Sciences, Warsaw University of Life Sciences (SGGW-WULS), 159C Nowoursynowska Street, 02-787 Warsaw, Poland; tomasz_krupa@sggw.edu.pl
* Correspondence: ewa_szpadzik@sggw.edu.pl; Tel.: +48-22-593-21-02

Abstract: The Saskatoon berry (*Amelanchier alnifolia* Nutt.) is a prospective and increasingly popular species in Poland. Its main attributes are extremely valuable fruits, rich in anthocyanins with high antioxidant activity, which are very valuable in processing. Studies aimed at comparing the suitability for cultivation under the climatic and soil conditions of east Poland of the three Canadian cultivars of Saskatoon berry ('Honeywood', 'Martin' and 'Pembina'), were conducted at the Warsaw University of Life Sciences in 2017–2018. The study evaluated parameters such as yield and fruit quality, as well as the health-promoting value of the fruit. These studies revealed significant differences between the studied cultivars, both in yield and in fruit physicochemical properties, i.e., fruit mass and diameter, firmness, and soluble solids content, as well as in terms of the content of anthocyanins, flavonoids, and polyphenols. These differences were also found between years, which may indicate that the content of the abovementioned compounds is also influenced by annual climatic conditions.

Keywords: *Amelanchier alnifolia*; fruit quality; firmness; soluble solids; phenolic compounds

Citation: Szpadzik, E.; Krupa, T. The Yield, Fruit Quality and Some of Nutraceutical Characteristics of Saskatoon Berries (*Amelanchier alnifolia* Nutt.) in the Conditions of Eastern Poland. *Agriculture* **2021**, *11*, 824. https://doi.org/10.3390/agriculture11090824

Academic Editors: Franc Štampar, Robert Veberič and Isabel Lara

Received: 28 July 2021
Accepted: 26 August 2021
Published: 29 August 2021

1. Introduction

The Saskatoon berry (*Amelanchier alnifolia* Nutt.) has been cultivated in Poland for approximately 20 years, although it is quite common in Canada and the northern regions of the USA [1]. This plant belongs to the *Rosaceae* family and can be found in the form of both a tree and a bush, depending on the species. The genus *Amelanchier* is represented by about 25 species The most popular are the Pacific serviceberry (*A. alnifolia*), Canadian serviceberry (*A. canadensis*), juneberry (*A. lamarckii*), snowy mespilus (*A. ovalis*). Although, in Poland, the most cultivated is the *Amelanchier alnifolia* [2]. Bushes of the 'Honeywood', 'Martin', 'Pembina', 'Northline', 'Smoky' and 'Thiessen' cultivars were brought to Poland in 2007. Scientists have reported that the Saskatoon berry is not difficult to cultivate and can be successfully cultivated in Poland. It tolerates the local climate well, is winter hardy, and it can grow in almost all types of soil, except marshy sites and sands that are too dry and barren [3].

In the last few years, the interest in the cultivation of this species in Poland has significantly increased, mainly due to the incredibly health valuable of the fruits. This plant is also grown amateurishly, not only because of its valuable fruit, but also because of its ornamental qualities. Its extremely high content of bioactive components deserves special attention. Taking into account the content of health-related beneficial phytochemical compounds of this plant, i.e., anthocyanins and phenolic acids, it is considered to be one of the most valuable berry species in terms of health-promoting nutrients [4,5]. Researchers also claim that Saskatoon berries are a functional food rich in antioxidants. Functional foods, as well as natural health products, are believed to improve our health. Such foods, which contain biologically active compounds, improve the body's defense mechanisms, prevent and reduce the risk of some diseases and reduce the ageing process [6]. It is a widely held view that phenolic compounds have antioxidant, anti-inflammatory, antibacterial, anti-allergic and anti-atherosclerotic properties, and also show anticoagulant effects and dilate blood vessels [7–10]. Thus, it may be a very useful dietary supplement for people leading a healthy lifestyle. Many scientific reports have also indicated the antidiabetic and anticancer potential of the fruit and leaf extracts. It is also claimed that Saskatoon berries, as a natural food, may be one of the best alternatives for the prevention and treatment of diabetes in the future [4,5].

Saskatoon berry fruits are also a good source of minerals, vitamins C, A, E, and B6, riboflavin, folic acid, thiamine, and pectin. The Saskatoon berry fruits are also rich in potassium, magnesium, and iron. It is believed that this phytochemical abundance even exceeds blueberries—e.g., contains approximately twice as much vitamin C and seven times as much calcium compared to blueberries (*Vaccinium corymbosum*). Saskatoon fruit is often compared to blueberries (member of the *Ericaceae* family) as well as to chokeberry (*Aronia melanocarpa*) due to many similar features, i.e., the colour and shape of the fruit, its texture, as well as its high nutritional value. However, in Saskatoon berry the anthocyanin composition is different from those of the species mentioned. The main components of *A. alnifolia* are: cyanidin-3-galactoside, cyanidin-3-glucoside, cyanidin-3-arabinoside and cyanidin-3-xyloside [11,12].

These features all make the Saskatoon berry very perspective and provide it with an extremely high potential.

The fruits of *A. alnifolia* can be eaten fresh as a typical dessert fruit (e.g., 'Martin', 'Honeywood' and 'Pembina'), as well as can be processed (e.g., 'Prince William') for drinks, syrups, fruit pies, wine, and jams [13]. It is believed that even processed plant foods have the potential to be a good source for high added-value bioactive compounds, e.g., polysaccharides, proteins, dietary fibers, flavor compounds, and phytochemicals [14–18].

Cultivation of cultivars with tasty and large fruit (such as 'Pembina', 'Martin' and 'Honeywood'), as well as intensive fruit promotion with an emphasis on their health-promoting properties, would certainly make this fruit known on the Polish market as a typical dessert fruit, although its great potential lies in processing. Under Canadian climate and soil conditions the 'Honeywood' cultivar is considered having great yields of juicy, blueberry-like fruit produced on very hardy bushes. This shrub, also known in Canada as Service Berries, is very widely adapted but does best in well-drained soil. 'Honeywood' is more compact than the other cultivars, usually staying under 2.5 m height, making it more suitable for backyard gardens. The fruits have an excellent flavor, and can be eaten right off of the bush. 'Pembina' in turn is described by Canadian researchers as a large shrub that is typically grown for its edible qualities, although it does have ornamental merits as well. It produces small, blue, round berries, which are usually ready for picking from late spring to early summer. The berries have a sweet taste and 'Martin' is a prairie hardy shrub. The berries have a large size and a delicious taste. This species has a consistent yield, making it great for both orchards and small gardens. The berries ripen uniformly, making them convenient for machine harvesting [19].

The aim of the study was to compare the yield, fruit quality, and content of some bioactive compounds of three popular Saskatoon berry cultivars in Poland.

We hypothesize that the evaluated cultivars are suitable for cultivation under the climatic and soil conditions of east Poland.

2. Materials and Methods

The plant material used consisted of three Canadian Saskatoon berry (*Amelanchier alnifolia*) cultivars: 'Honeywood', 'Pembina' and 'Martin' The research was conducted at the Warsaw University of Life Sciences in 2017 and 2018.

The plants were planted in 2014 in the southeastern part of Poland, in the area of Biala Podlaska (Lubelskie Province: 52°02′ N, 23°07′ E; 158 m a.s.l.). The region where the experimental plantation is located has a colder climate than other climatic regions in

Poland. There are fewer warm days with precipitation and usually more frosty, sunny and precipitation-free days [20].

All bushes were of the same age, planted at the experimental site as two-year-old seedlings. The pre-crop was mustard, grown for green fertilizer, additionally in the year before planting, applied 30 $t \cdot ha^{-1}$ of manure. The bushes grew in a compact spacing with 3×1 m. After planting, the bushes are cut in order to encourage growth. The rows of plants were mechanically kept in black fallow, with turf between the rows. No diseases or pests were observed in the experiment, therefore no chemical plant protection was carried out. The plantation was not irrigated. The soil in which the plants grow was sandy–loamy with a slightly acidic pH_{KCl} 6.0–6.5, classified in the IV discount class. The evaluation was carried out on five selected bushes in repetition, with five repetitions used for each cultivar (25 bushes/each cultivar).

2.1. Phenological Phases

During the experiment, observations of the following selected phenological phases of all of the tested cultivars were conducted: beginning and end of flowering, as well as the fruit ripening phase. The beginning of flowering was considered to be the moment when 5% of the flowers on the bushes were open, and the end of flowering—the moment when 90% of the flowers had dropped their petals. The fruit was harvested manually at the stage of consumption maturity, which was determined by typical coloring (dark purple), size (depending on the cultivar from about 8 mm in diameter) and fruit flavor (sweet and tasty) [21]. All the fruits picked for the study were at the same stage of maturity, without signs of any disease or pest infestation, and were similar in size and shape within the varieties.

2.2. Meteorological Conditions

Accurate meteorological data from the area of the Saskatoon berry plantation for a given year were obtained from the portal Meteoblue: https://www.meteoblue.com/ (accessed on 27 August 2021). data from 2017—the 10th of January 2018, data from 2018—the 8th of January 2019.

2.3. Analytical Methods

Yield: The yield was recorded from each bush and was converted into a kilograms per bush ratio. The fruit from the bushes assessed for their phenological phases were used to assess yield.

Fruit quality: 30 fruits were taken at random from each replication of every cultivar in order to evaluate the fruit quality factors—in total, 150 fruits of each cultivar were used (30 fruits $\times$ 5 replications).

- Average fruit mass (g)—measured on a TP 200 (OHAUS Europe GmbH, Nänikon, Switzerland) analytical balance.
- Fruit diameter (mm)—immediately after the harvest, the diameter of the fruit was measured in two directions with a caliper. Then, the obtained results from each fruit were averaged.
- Soluble solid content (SSC) (Brix degrees)—measured, according to the Polish PN-EN 012143: 2000 standard [22], in juice squeezed from 30 fruits per replication. The SSC was determined using an Atago PR-32 digital refractometer (Atago, Tokyo, Japan).
- Fruit firmness (FF) was determined as a value of the force necessary for penetration the fruit by 4.5 mm diameter punch probe. Determinations were made using an Instron type 5542 tester (Instron, High Wycombe, UK). FF was determined on 20 fruits in 3 replications. Each fruit was subjected one times (in the horizontal plane), with compression speed 240 mm^{-1} during penetration to 3 mm depth. FF was expressed in newton (N).

- Content of pro-health components: All reagents were of analytical purity gradients or of HPLC grade purchased from Sigma-Aldrich (Poznań, Poland) or Merck (Warsaw, Poland).
- Analysis of the total polyphenol content: According to the Waterhouse method [23], the total polyphenol level was measured with a Marcel s330 PRO spectrophotometer (Marcel S.A., Warsaw, Poland) using Folin–Ciocalteau reagent. 5 g of material crushed in liquid nitrogen were extracted with 50 mL of 100% methanol. The extraction process was repeated twice collecting the extracts into a 100 mL flask. Successively, 1 mL of extract was collected into a 50 mL flask, 35 mL of H_2O, 2.5 mL of Folin–Ciocalteau reagent, and 7.5 mL of 10% $NaCO_3$ were added. H_2O was made up and incubated for 20 min at 25 $\pm$ 2 °C. All measurements were performed at a wavelength of 750 nm. Gallic acid was used as the standard at different concentrations: 0.00, 0.05, 0.15, 0.20, 0.25, and 0.3 g/L. The contents of total polyphenols is given in milligrams of gallic acid per 100 g of fresh weight.
- Analysis of the flavonoid content: Determined according to the modified method of Marinova et al. [24]. For the determination of flavonoids, 5 g of fruit ground in liquid nitrogen was used. The samples were mixed with 25 mL of 80% methanol and extracted for 15 min. Extractions were carried out two times. Distilled water, 5% $NaNO_2$, 10% $AlCl_3$, and 1M NaOH were added to the obtained samples successively at fixed time intervals. Measurement was performed using a Marcel s330 PRO spectrophotometer (Marcel S.A., Warsaw, Poland) at 510 nm. Total flavonoid content of fruits was expressed as mg catechin equivalents (CE) per 100 g of fresh weight of fruit.
- Analysis of the total anthocyanin content: Determined spectrophotometrically according to the method of Fuleki and Francis [25]. The method developed consists of extracting the anthocyanins with ethanol-1.5 N hydrochloric acid (85:15). 5 g of fruit crushed in liquid nitrogen was extracted in the extraction mixture for 12 h in the dark. Total anthocyanins were determined by performing two measurements at varying pH. In the first 25 mL flask, 5 mL of extract and 20 mL of pH 4.5 buffer were mixed. In the second flask (25 mL), 5 mL of extract, 5 mL of HCL and 15 mL of H_2O (pH 1.0) were combined. Absorbance measurement was carried out on a Marcel spectrophotometer (Marcel S.A., Warsaw, Poland), and determinations were made at a wavelength of 535 nm. The results were expressed in mg of cyanidin-3-glucosid equivalent (AAE) per g of fresh weight.
- Qualitative and quantitative analysis of anthocyanins: The fruit homogenate was extracted with 25 mL of mixture (acetone;methanol;water = 35:35:30) acidified with 1 mL of HCl at 36%. The solution was then drained, and the clear filtrate was evaporated under vacuum at 40 °C until the acetone and methanol evaporated. The remaining solution was poured into a 25 mL flask, made up with distilled water, and the resulting sample was cleaned on a 0.45 µm Millex HV filter (Millipore, Warsaw, Poland). The identification and quantitative analysis of anthocyanins were conducted separately using the HPLC technique described by Szpadzik et al. [26], performed by means of a PerkinElmer series 200 HPLC with a Diode Array Detector (Perkin Elmer, Krakow, Poland), using a LiChroCART® 125-3 (Merck KGaA, Darmstadt, Germany) column with a 1.0 mL/min flow rate, detected at 520 nm. The mobile phase was a mixture: water (A): 20% formic acid (B): acetonitrile (C) with variable parameters of the gradient A and C. The anthocyanin content is given milligrams per 100 g of fresh weight of fruit as cyanidin-3-glucosid equivalent.

2.4. Statistical Analysis

The data collected during the study period were statistically analyzed with the ANOVA program, using a one-way analysis of variance. To compare the averages, the Tukey group test was used with a α = 0.05 significance level.

3. Results

3.1. Phenological Phases and Meteorological Conditions during the Experiment

In each year of the study, the bushes of all cultivars bloomed at a similar time (Table 1). In 2017, the blooming phase started a few days earlier than in 2018. In both study seasons, the earliest flowering was experienced by "Honeywood". Interestingly, this cultivar reached harvest maturity the latest in both years. The other two cultivars ("Pembina" and "Martin") in both years of the study flowered and matured at a similar time.

Table 1. The time of bloom and harvest of the tested cultivars in 2017 and 2018.

Variety	2017		2018	
	Blooming Time	**Harvest Time**	**Blooming Time**	**Harvest Time**
Honeywood	19–27 April	19 June	22–29 April	17 June
Pembina	22–30 April	14 June	24 April–1 May	11 June
Martin	21–29 April	13 June	24 April–3 May	12 June

In Poland, 2017 was a difficult year for fruit crops in terms of meteorological conditions. The year was characterized by a short, smooth, and almost snow-free winter period. The vegetation began in early spring. All phenological phases started earlier, and the weather during blooming time was not convenient for the pollination and fertilization of plants. Spring frosts with a temperature decrease to −3 °C were recorded during the flowering phase (late April), and to −6 °C a few days after the end of blooming—in the early phase of bud growth (early May) (Figure 1a). The average daily temperature at the time of bloom was only approximately 10 °C. In addition, during this period, there were mostly rainy days—also not favorable for the pollination of flowers.

Compared to 2017, 2018 was a much more favorable year in terms of weather conditions. There was no decrease in temperature below 0 °C during blooming time (Figure 1b). During the whole flowering period, the meteorological conditions were favorable for good pollination and fruit setting. The average daily temperature during blooming was quite high, approximately 20 °C, and there was no rain.

3.2. Yield

The results show that the yield depended on cultivar (Figure 2a,b). In 2017, 'Honeywood' achieved a much better yield compared to the other cultivars (about 0.15 kg/bush). However, in the second year, 'Honeywood' was the least yielding cultivar; a much higher yield was obtained from 'Martin'—approximately 0.3 kg/bush. The best yielding cultivar was 'Pembina' with approximately 0.4 kg of fruit per bush.

A strong seasonal influence on yields can also be seen in the data presented (Figure 2a,b). Although no statistical analysis was carried out between the research seasons, it is clear that the plants studied in 2018 yielded much better than in 2017.

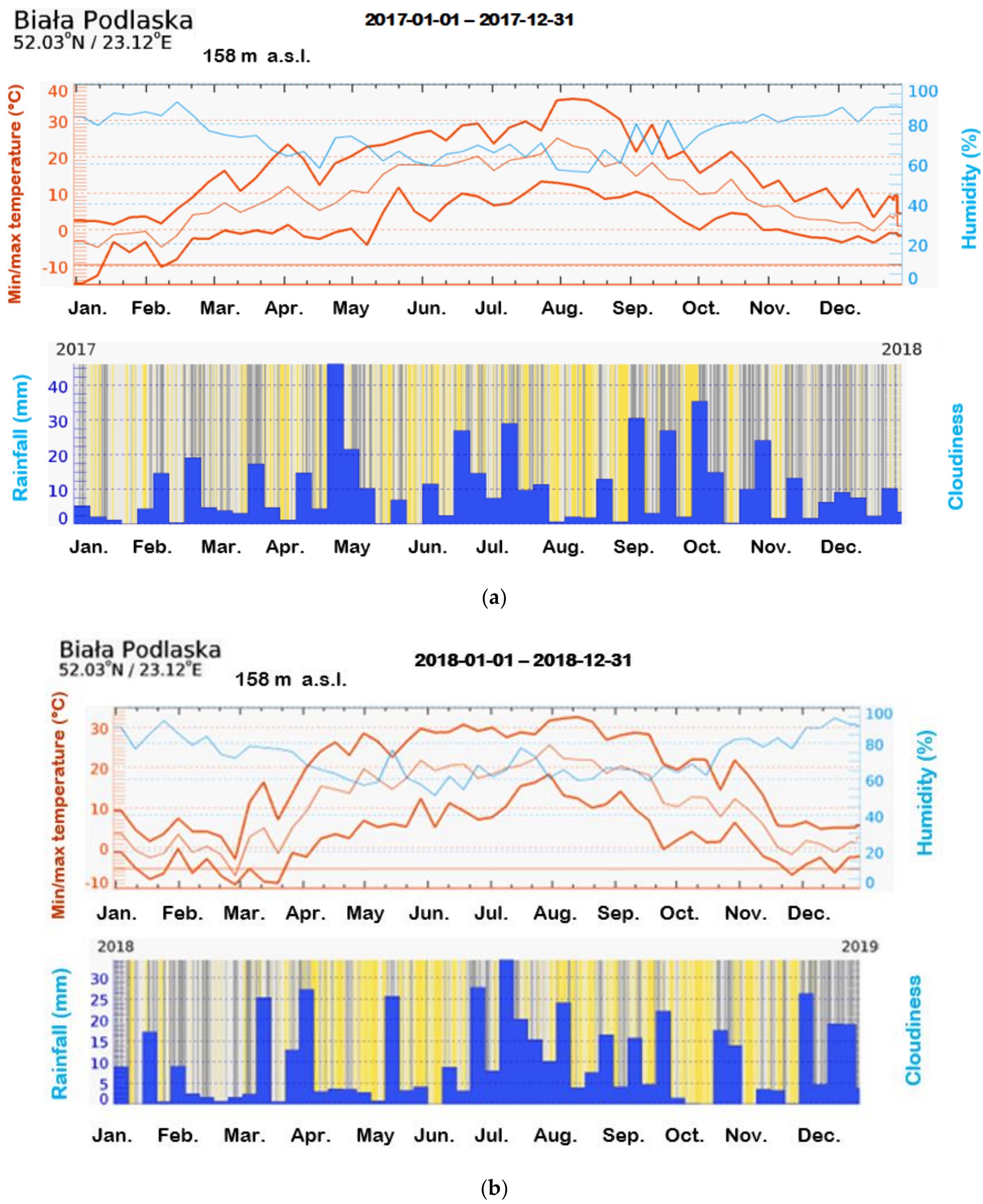

Figure 1. Meteorological conditions in Biala Podlaska during (**a**) the first and (**b**) second year of the experiment. Data shown are from the Meteoblue website: https://www.meteoblue.com/ (accessed on 27 August 2021). data from 2017—the 10th of January 2018, data from 2018—the 8th of January 2019.

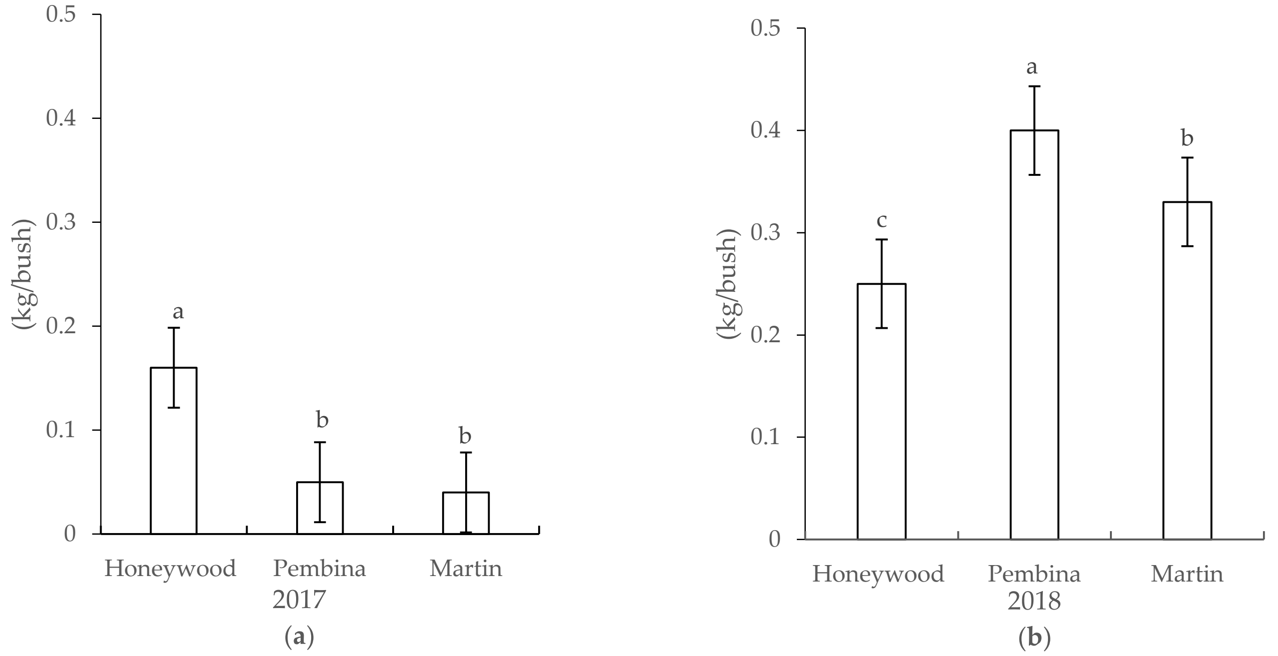

Figure 2. Yield of the studied cultivars in (**a**) 2017 and (**b**) 2018. Values with different letters are significantly different within a year.

3.3. Fruit Mass

The mass of the fruit also depended on the cultivar (Figure 3a,b). In both years of the study, it was found that 'Honeywood' produced fruits with a lower mass than the other two cultivars. In both 2017 and 2018, the fruits of 'Pembina' and 'Martin' had an approximately 0.3 g greater mass than the 'Honeywood' fruits.

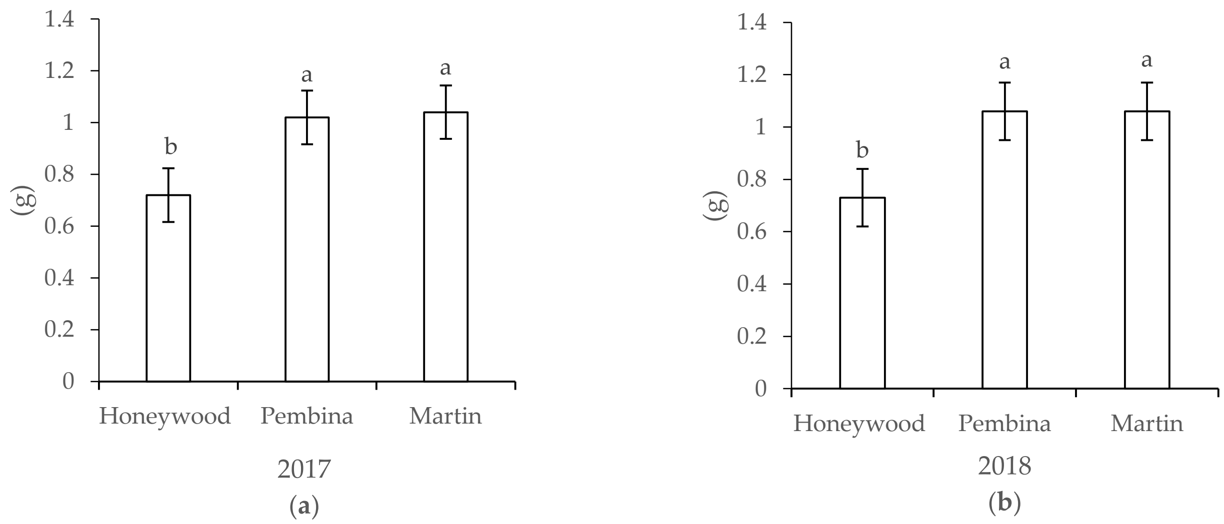

Figure 3. Fruit mass of the studied cultivars in (**a**) 2017 and (**b**) 2018. Values with different letters are significantly different within a year.

3.4. Fruit Diameter

The fruit diameter of 'Honeywood' was the smallest of the tested cultivars—approximately 8 mm in both years (Figure 4a,b). In both 2017 and 2018, 'Martin' had the largest fruit diameter (approximately 12 mm). The diameter of 'Pembina' fruits was significantly smaller than that of 'Martin' but was above 10 mm.

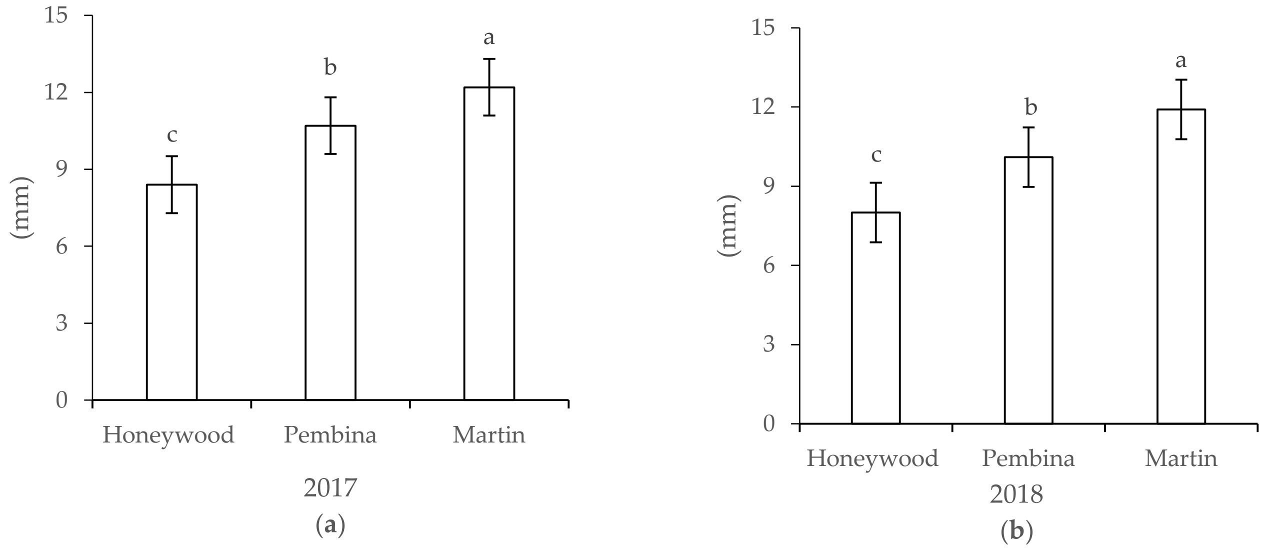

Figure 4. Fruit diameter of the studied cultivars in (**a**) 2017 and (**b**) 2018. Values with different letters are significantly different within a year.

3.5. Soluble Solid Content (SSC)

The tested cultivars differed in fruit soluble solid content. In 2017, 'Pembina' had a significantly higher SSC (above 20° Brix) compared to the other two cultivars, in which the value of this parameter did not exceed 17° Brix (Figure 5a).

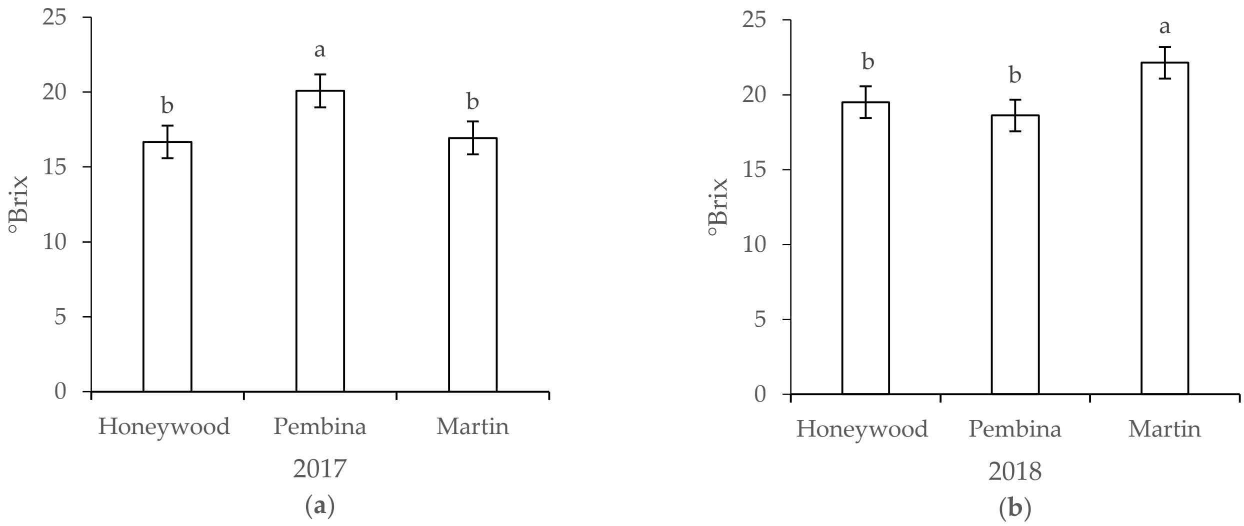

Figure 5. Soluble solid content (SSC) of the studied cultivars in (**a**) 2017 and (**b**) 2018. Values with different letters are significantly different within a year.

In 2018, 'Martin' had a much higher SSC (above 22° Brix) than 'Honeywood' (below 20° Brix) and 'Pembina' (approximately 18.5° Brix) (Figure 5b).

3.6. Fruit Firmness

In both years of the study, significant differences in fruit firmness were found between the cultivars (Figure 6a,b). In 2017, the highest firmness was found for 'Pembina' (above 3 N), while the fruits of 'Honeywood' had the lowest firmness (approximately 2 N). In 2018, the values of the examined parameter were lower than in the first year of study and ranged from approximately 1.5 N in 'Honeywood' fruits to approximately 2 N in 'Pembina' fruits. Significant differences were noted only between the two mentioned cultivars.

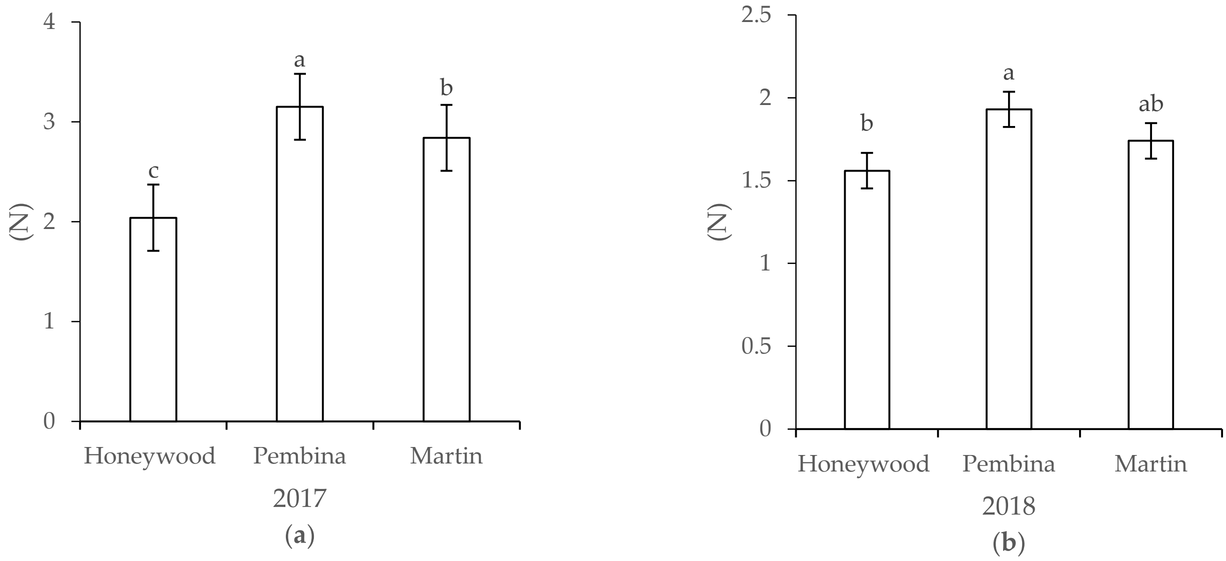

Figure 6. Fruit firmness of the studied cultivars in (**a**) 2017 and (**b**) 2018. Values with different letters are significantly different within a year.

3.7. Total Polyphenol Content

The tested cultivars differed in terms of health-promoting compound content (Figure 7a,b). In the first and second year of tests, 'Honeywood' had more polyphenols in comparison to the other cultivars, but only in 2017 was this statistically proven. In 2018, 'Honeywood' had a statistically higher polyphenol content only in comparison to 'Pembina' fruits; there were no significant differences between 'Honeywood' and 'Martin'.

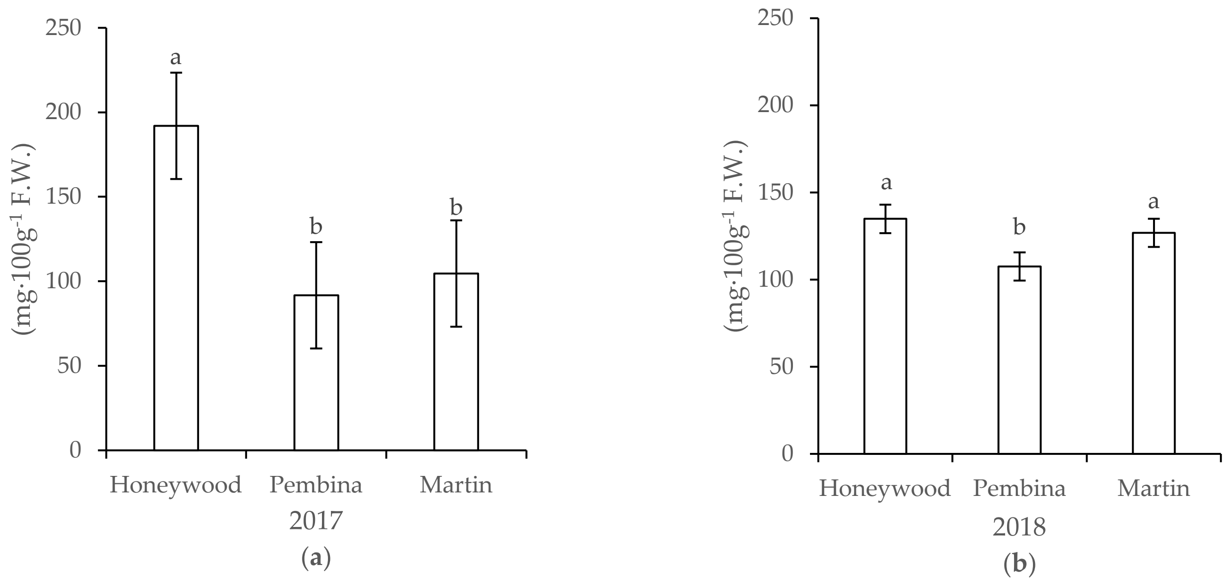

Figure 7. Total polyphenol content in the fruits of the studied cultivars in (**a**) 2017 and (**b**) 2018. Values with different letters are significantly different within a year.

3.8. Total Flavonoid Content

It was proven that 'Honeywood' had the lowest flavonoid content in both years, with less than 300 mg·100 g^{-1} F.W. (Figure 8a,b). In the first year of study, 'Martin' had the highest content of the mentioned compounds (above 415 mg·100 g^{-1} F.W.) of all three cultivars. During the second test season, significant difference were observed only between the fruits of 'Honeywood' and the other two cultivars, in which the total flavonoid content was approximately 170 mg·100 g^{-1} F.W. higher compared to 'Honeywood'.

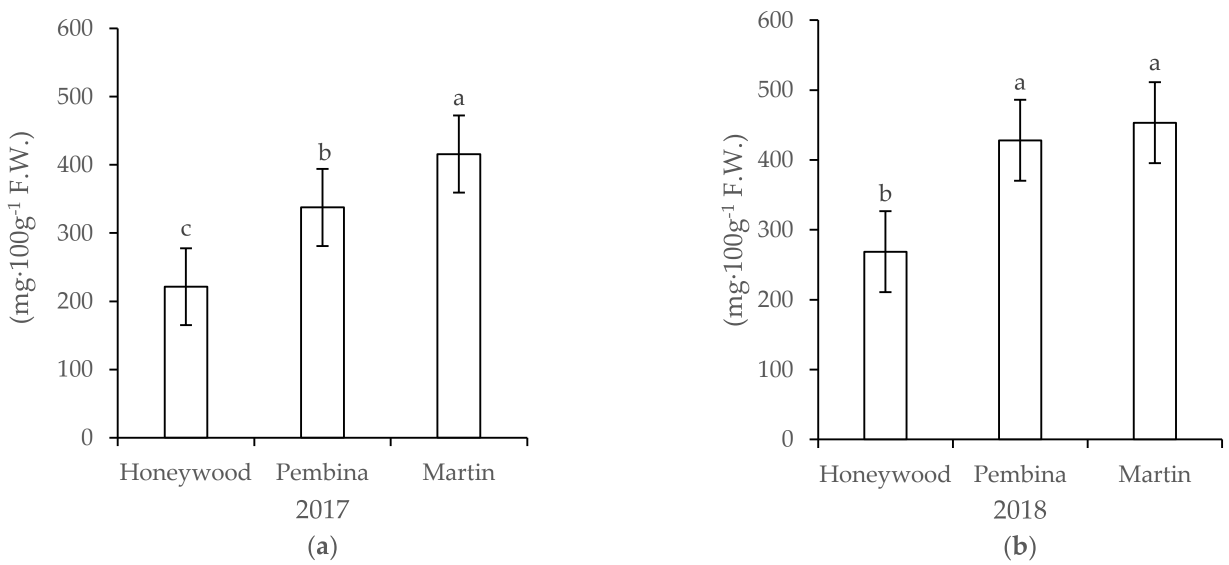

Figure 8. Total flavonoid content in the fruits of the studied cultivars in (**a**) 2017 and (**b**) 2018. Values with different letters are significantly different within a year.

3.9. Anthocyanin Content

The anthocyanin content of the fruits depended on the cultivar (Figure 9a,b). In the first year of study, 'Pembina' was poorer in anthocyanins than the other two cultivars. The anthocyanin content in "Honeywood" and 'Martin' on average, was approximately 165.5 mg·100 g^{-1} F.W., whereas in 'Pembina' this parameter was approximately 40 mg·100 g^{-1} F.W. lower. In the next year, the fruits of 'Honeywood' proved to be the least abundant in anthocyanins—slightly above 108 mg·100 g^{-1} F.W. 'Pembina' and 'Martin' had approximately 160 mg·100 g^{-1} F.W. of anthocyanins.

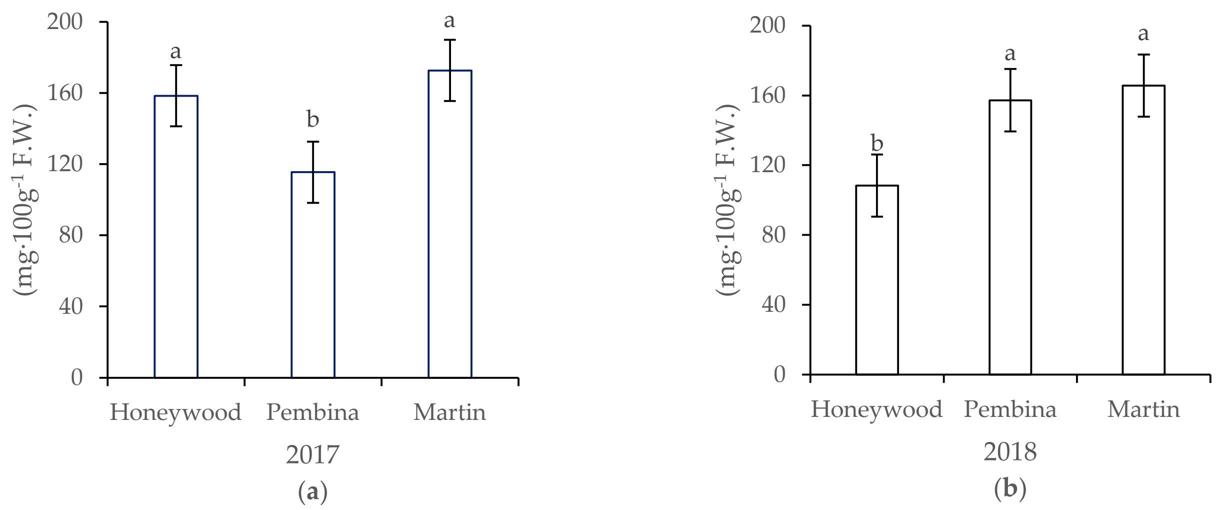

Figure 9. Total anthocyanin content in the fruits of the studied cultivars in (**a**) 2017 and (**b**) 2018. Values with different letters are significantly different within a year.

3.10. Contents of Individual Anthocyanin Compounds

Considering the individual anthocyanin compound contents, an influence of the cultivar on the examined trait was also observed (Table 2). In 2017, 'Pembina' had a significantly lower content of cyanidin-3-galactoside (approximately 71 mg·100 g^{-1} F.W.) compared to the other two cultivars (both higher than 100 mg·100 g^{-1} F.W.). In the case of cyanidin-3-glucoside and cyanidin-3-arabidoside, 'Honeywood' had a lower content of these substances than 'Martin'. 'Pembina' had contents of these compounds not significantly different from 'Honeywood' and 'Martin'. Regarding the cyanidin-3-xyloside content, no differences were found between the tested cultivars. Meanwhile, in 2018, only for cyanidin-3-galactoside content was no significant difference found between the tested cultivars. For the other three compounds, generally 'Honeywood' had a lower content compared to the remaining cultivars.

Table 2. Contents of the individual anthocyanin compounds depending on cultivar (mg·100 g^{-1} F.W.).

Year	Cultivar	Cyanidin-3-galactoside		Cyanidin-3-glucoside		Cyanidin-3-arabidoside		Cyanidin-3-xyloside	
2017	Honeywood	122.75	±3.7 a *	18.02	±0.8 b	8.91	±2.2 b	8.82	±0.9 a
	Pembina	71.80	±4.8 b	21.65	±1.8 ab	12.21	±3.1 ab	9.87	±0.7 a
	Martin	110.00	±4.1 a	31.87	±3.4 a	17.23	±1.6 a	13.62	±4.0 a
	Average for Cultivars	**101.51 A ˆ**		**23.84 B**		**12.78 C**		**10.77 C**	
2018	Honeywood	83.21	±2.1 a	13.00	±4.2 b	5.83	±1.9 b	6.22	±1.4 b
	Pembina	95.00	±3.7 a	30.00	±1.2 a	18.11	±2.5 a	13.60	±0.5 a
	Martin	93.10	±4.4 a	39.20	±1.5 a	19.30	±1.6 b	15.11	±0.8 a
	Average for Cultivars	**90.43 A**		**27.40 B**		**14.41 C**		**11.64 C**	

* Values marked with the same lower letter are not significantly different in each column within a year. ˆ Values marked with the same capital letter are not significantly different within the row.

Moreover, in both years, it was found that the examined fruits had the highest cyanidin-3-galactoside content (above 100 mg·100 g^{-1} F.W. in 2017 and approximately 90 mg · 100 g^{-1} F.W. in 2018) and the lowest cyanidin-3-arabidoside (above 12 mg·100 g^{-1} F.W. in both years) and cyanidin-3-xyloside (approximately 11 mg·100 g^{-1} F.W.) contents (Table 2).

4. Discussion

The Saskatoon berry is a very valuable ingredient in the production of many valued products, including medicinal ones. This is why it is so important that the fruits should be of the highest quality and have a high health value.

This study presents the yield, fruit quality, and content of some biologically active compounds of three Saskatoon berry cultivars under the East Poland conditions. The quite large variation in the results between the individual years of the experiment may indicate a large influence of the external factors present in a given season on the yield, as well as on the physicochemical quality of the fruits. It is worth taking into account that the study seasons differed considerably in terms of meteorological conditions, especially during and shortly after flowering, a key moment for fruit set. The poor yield of the plants in the first year of the study was mainly due to unfavorable meteorological conditions during and just after blooming. Many flowers were damaged by spring frost, and therefore, the bushes did not yield well. In addition, rainy and cool weather during this period limited the activity of pollinating insects. Therefore, it is difficult to relate these results to the data presented in the available literature. However, it can be concluded that the cultivar that best tolerated the difficult temperature conditions during blooming was 'Honeywood', as it was the cultivar with the highest yield. In 2018 it was Pembina that proved to be the best yielding of the cultivars tested. In Canadian experiments, 'Honeywood' was shown to yield better than "Pembina" and 'Martin' [27,28]. On the contrary, in experiments conducted in North Dakota, USA, the yield of 'Honeywood' was much poorer than 'Pembina' and

'Martin' [29]. An experiment by Polish researchers evaluating the yield of seven-year-old cultivars and breeding clones of *Amelanchier alnifolia* in north-eastern Poland, showed that yields averaged 1.33 kg per shrub [4]. In an earlier experiment conducted in central Poland, after two years of yielding of a few cultivars of Saskatoon berry, the highest yield was found in the case of 2 clones and was 2.5–2.8 kg, while the lowest yield was observed in the cultivar 'Pembina' −0.4 kg/bush [30]. This indicates that environmental and climatic factors have a strong influence on the yield of individual cultivars. It is worth noting that the mentioned results of both Canadian and Polish researchers come from typical conventional cultivation, whereas in our experiment plants were grown without any synthetic protection products. This may have been the reason for the better yields in the cited studies.The results also indicate fruit differentiation among the studied years and the effect of the cultivar on all examined parameters. It is worth noting that cultivar is one of the primary factors determining the selected fruit characteristics [4,12].

The size of the fruit is a cultivar feature, but to a great extent, it also depends on the growing conditions. In the case of our study—as mentioned—no chemical treatments were used on the plantation, which could also have resulted in fruit not always reaching the expected diameter and mass. In an experiment carried out by Canadian researchers, fruits of 'Martin' cultivar reached significantly higher weight than those of 'Pembina' ('Martin'—1.66 g, 'Pembina'—0.86 g) [13]. In our experiment, on the other hand, fruits of these two cultivars were characterized by a similar weight both in the first and in the second year of the study, which was on average about 1.04 g. However, taking into account the fruit size, in the presented experiment the fruit of 'Martin' had a larger diameter than those of 'Pembina'.

Canadian experiments have also shown that 'Pembina' is characterized by quite a high soluble solid content (20.1° Brix) compared to 'Honeywood' (15.8° Brix) and 'Martin' (15.3° Brix) [28]. The results obtained in the present experiment partially confirm the abovementioned reports. In the first year of study, 'Pembina' had a higher SSC than the other cultivars, while in the second year, 'Martin' did. In another experiment conducted in Poland by Lachowicz et al. [2], it was 'Honeywood' that had the highest SSC. The results of the described studies show that the SSC of fruit may be determined by various factors, e.g., meteorological conditions during fruit ripening, as well as by the maturity of the fruit, which is associated with the activity of the enzymes that cause the degradation of starch and with a reduced level of monosaccharaides in the respiration process [31,32]. The soil conditions can also have a significant impact on the value of the described characteristics.

Firmness is also very important fruit quality attributes. It may indicate their resistance to mechanical damage, as well as their shelf life. As well as the SCC, it can depend on climatic, soil, and maturity factors. The most important factor, however, is the cultivar effect. In the present experiment, 'Pembina' exhibited the highest fruit firmness in both study seasons, although this was statistically proven in 2017 only.

There is no doubt about the antioxidant and highly health-promoting properties of the Saskatoon berry. These fruits are rich in antioxidants, especially flavonoids, anthocyanins, and proanthocyanidins. This affords them anticancer and antifungal properties [9]. A study by Heinonen et al. [33] indicated that the Saskatoon berry has higher antioxidant levels than blueberries, strawberries, and raspberries. In addition, Lachowicz et al. proves that *A. alnifolia* is a species extremely rich in antioxidants [34]. Whereas Ochmian et al. report that the flavonoid and anthocyanin content in the species *A. alnifolia* is similar to *A. spicata*. However, significantly more of these compounds are found in *A. ovalis* [35]. The results obtained in the present experiment show that all of the studied cultivars are rich in polyphenols, flavonoids, and anthocyanins. 'Honeywood' demonstrated a higher polyphenol content than the other cultivars. However, in terms of flavonoid and anthocyanin contents, these were lower than in 'Pembina' and 'Martin'. In the case of total anthocyanin content, the results were quite diverse and the influence of testing season on this parameter was evident in the individual cultivars. Jin et al. [36], in their study, obtained a similar content of total anthocyanins in the case of 'Pembina' to those obtained in the present experiment in 2018 (approximately 154 mg·100 g^{-1} F.W.).

In the detailed analysis of anthocyanins, four basic chemical compounds were identified, i.e., cyanidin-3-galactoside, cyanidin-3-glucoside, cyanidin-3-arabinoside, and cyanidin-3-xyloside. The same compounds were also shown by Jin et al. [36] and Lavola et al. [12]. In spite of quite different results obtained for the contents of particular cyanidins, as well as between years and cultivars, it can be stated that 'Honeywood' usually had lower contents of the discussed compounds in relation to the other two cultivars. However, this relationship was not regular and could not always be proven statistically.

Among the factors that influence flavonoid, polyphenol, and anthocyanin contents, researchers typically focus on the genotype, cultivar, cultivation method, plant age, availability of water and minerals, degree of maturity during harvest, and atmospheric conditions—mainly light and temperature [12,37,38]. Therefore, it is difficult to clearly compare the results obtained to those from other climatic regions. In addition, the nutraceutical content of fruit can be determined by many other factors, including growing conditions, genotype, the use of pesticides and the maturity at harvest [21,39,40].

5. Conclusions

It cannot be clearly stated that the tested varieties are without a doubt suitable for cultivation in the difficult climatic conditions of eastern, so the research hypothesis cannot be proven at this stage of the research. Despite relatively high resistance to frost, Saskatoon berry cultivars in eastern Poland can be damaged by spring frosts as it was in the 2017 season—which resulted in very low yields of the experimental plants. Among the varieties tested 'Martin' seems to be the most stable in terms of nutraceutical content among the tested cultivars, and showed the lowest differences in content of biologically active compounds between the study seasons.

However, it can be confirmed that all tested cultivars have a high level of the bioactive compounds. "Honeywood" cultivar has a higher total polyphenol content than 'Pembina' and 'Martin' but has a lower anthocyanin content than the other cultivars.

Although, further research is needed to confirm the data obtained.

Author Contributions: Conceptualization, E.S., T.K.; methodology, E.S., T.K., formal analysis, E.S., T.K.; investigation, E.S., T.K.; resources, E.S., T.K.; data curation, E.S., T.K.; writing—original draft preparation, E.S., T.K.; writing—review and editing, E.S., T.K.; supervision, E.S., T.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Pluta, S.; Seliga, Ł.; Lewandowski, M.; Żurawicz, E. Wstępna ocena wzrostu i plonowania dwóch genotypów świdośliwy olcholistnej (*Amelanchier alnifolia* Nutt.) posadzonych w różnej rozstawie. *Zesz. Nauk. Inst. Ogrod.* **2017**, *25*, 95–104. Available online: http://www.inhort.pl/.../08_Pluta.pdf (accessed on 18 May 2021).
2. Lachowicz, S.; Oszmiański, J.; Seliga, Ł.; Pluta, S. Phytochemical Composition and Antioxidant Capacity of Seven Saskatoon Berry (*Amelanchier alnifolia* Nutt.) Genotypes Grown in Poland. *Molecules* **2017**, *22*, 853. [CrossRef] [PubMed]
3. Bieniek, A.; Dragańska, E.; Pranckietis, V. Assessment of climatic conditions for Actinidia arguta cultivation in north-eastern Poland. *Zemdirb. Agric.* **2016**, *103*, 311–318. [CrossRef]
4. Bieniek, A.; Markuszewski, B.; Kopytowski, J.; Pluta, S.; Markowski, J. Yielding and fruit quality of several cultivars and breeding clones of Amelanchier alnifolia grown in north-eastern Poland. *Zemdirb. Agric.* **2019**, *106*, 351–358. [CrossRef]
5. Zhao, L.; Huang, F.; Hui, A.L.; Shen, G.X. Bioactive Components and Health Benefits of Saskatoon Berry. *J. Diabetes Res.* **2020**, *2020*, 3901636. [CrossRef] [PubMed]

6. Lachowicz, S.; Seliga, Ł.; Pluta, S. Distribution of phytochemicals and antioxidative potency in fruit peel, flesh, and seeds of Saskatoon berry. *Food Chem.* **2020**, *305*, 125430. [CrossRef]
7. Estruch, R. Primary prevention of cardiovascular disease with a Mediterranean diet. *N. Engl. J. Med.* **2013**, *368*, 1279–1290. [CrossRef] [PubMed]
8. Shahidi, F.; Ambigaipalan, P. Phenolics and polyphenolics in foods, beverages and spices: Antioxidant activity and health effects—A review. *J. Funct. Foods* **2015**, *18*, 820–897. [CrossRef]
9. Męczarska, K.; Cyboran-Mikołajczyk, S.; Włoch, A.; Bonarska-Kujawa, D.; Oszmiański, J.; Kleszczyńska, H. Polyphenol content and bioactivity of saskatoon (*Amelanchier alnifolia* Nutt.) leaves and berries. *Acta Pol. Pharm.* **2017**, *74*, 660–669.
10. Schieber, A. Side streams of plant food processing as a source of valuable compounds: Selected examples. *Annu. Rev. Food Sci. Technol.* **2017**, *8*, 97–112. [CrossRef] [PubMed]
11. Ozga, J.A.; Saeed, A.; Wismer, W.; Reinecke, D.M. Characterization of cyanidin- and quercetin-derived flavonoids and other phenolics in mature saskatoon fruits (*Amelanchier alnifolia* Nutt.). *J. Agric. Food Chem.* **2007**, *55*, 10414–10424. [CrossRef]
12. Lavola, A.; Karjalainen, R.; Julkunen-Tiitto, R. Bioactive polyphenols in leaves, stems, and berries of Saskatoon (*Amelanchier alnifolia* Nutt.) cultivars. *J. Agric. Food Chem.* **2012**, *60*, 1020–1027. [CrossRef]
13. Zatylny, A.M.; Ziehl, W.D.; St-Pierre, R.G. Physicochemical properties of fruit of 16 saskatoon (*Amelanchier alnifolia* Nutt.) cultivars. *Can. J. Plant Sci.* **2005**, *85*, 933–938. [CrossRef]
14. Baiano, A. Recovery of biomolecules from food wastes—A review. *Molecules* **2014**, *19*, 14821–14842. [CrossRef] [PubMed]
15. Galanakis, C.M. Recovery of high added-value components from food wastes: Conventional, emerging technologies and commercialized applications. *Trends Food Sci. Technol.* **2012**, *26*, 68–87. [CrossRef]
16. Kowalska, H.; Czajkowska, K.; Cichowska, J.; Lenart, A. What's new in biopotential of fruit and vegetable by-products applied in the food processing industry. *Trends Food Sci. Technol.* **2017**, *67*, 150–159. [CrossRef]
17. Kumar, K.; Yadav, A.N.; Kumar, V.; Vyas, P.; Dhaliwal, H.S. Food waste: A potential bioresource for extraction of nutraceuticals and bioactive compounds. *Bioresour. Bioprocess.* **2017**, *4*, 18. [CrossRef]
18. Coman, V.; Teleky, B.E.; Mitera, L.; Martau, G.A.; Szabo, K.; Calinoiu, L.F.; Vodnar, D.C. Chapter Five—Bioactive potential of fruit and vegetable wastes. *Adv. Food Nutr. Res.* **2020**, *91*, 157–225. [CrossRef] [PubMed]
19. Spencer, R.; Matthews, L.; Bors, B.; Peters, C.; Saskatoon, B. *Production Manual*; Kaulbars, C., Ed.; Alberta Agriculture and Rural Development: Edmonton, AB, Canada, 2013. Available online: https://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/agdex14362/$FILE/238_20-2.pdf (accessed on 27 June 2021).
20. Woś, A. Regiony Klimatyczne Polski w Świetle Częstości Występowania Różnych Typów Pogody (Climatic Regions of Poland in the Light of the Frequency of Various Weather Types). Zeszyty Instytutu Geografii i Przestrzennego Zagospodarowania PAN (Institute of Geography and Spatial Organization of the Polish Academy of Sciences), IGiPZ PAN: Warszawa, Poland. 1993; Volume 20, p. 42. Available online: https://rcin.org.pl/dlibra/doccontent?id=33464 (accessed on 21 June 2021).
21. Rogiers, S.Y.; Knowles, N.R. Physical and chemical changes during growth, maturation, and ripening of Saskatoon (Amelanchier alnifolia) fruit. *Can. J. Bot.* **1998**, *75*, 1215–1225. [CrossRef]
22. PN-EN 12143. *Soki Owocowe i Warzywne—Oznaczanie Zawartości Substancji Rozpuszczalnych Metoda Refraktometryczną*; Polish Committee of Standardization: Warsaw, Poland, 2000. (In Polish)
23. Waterhouse, A. Determination of total phenolics. In *Current Protocols in Food Analytical Chemistry*; Wrolstad, R.E., Acree, T.E., Decker, E.A., Eds.; John Wiley and Sons, Inc.: Hoboken, NZ, USA, 2002; pp. I1.1–I1.1.8. [CrossRef]
24. Marinowa, D.; Ribarova, F.; Atanassova, M. Total phenolics and total flavonoids in Bulgarian fruits and vegetables *J. Univ. Chem. Technol. Metall.* **2005**, *40*, 255–260. Available online: https://dl.uctm.edu/journal/node/j2005-3/Marinova.pdf (accessed on 1 June 2021).
25. Fuleki, F.T.; Francis, F.J. Quantitative Methods for Anthocyanins. II. Determination of Total Anthocyanin and Degradation Index for Cranberry Juice. *J. Food Sci.* **1968**, *33*, 78–83. [CrossRef]
26. Szpadzik, E.; Krupa, T.; Niemiec, W.; Jadczuk-Tobjasz, E. Yielding and fruit quality of selected sweet cherry (*Prunus avium*) cultivars in the conditions of central Poland. *Acta Sci. Pol. —Hortorum Cultus* **2019**, *18*, 117–126. [CrossRef]
27. Zatylny, A.; St-Pierre, R.G. Revised International Registry of Cultivars and Germplasm of the Genus Amelanchier. *Small Fruits Rev.* **2003**, *2*, 51–80. [CrossRef]
28. St-Pierre, R.G.; Zatylny, A.M.; Tulloch, H.P. Evaluation of growth and fruit production characteristics of 15 saskatoon (*Amelanchier alnifolia* Nutt.) cultivars at maturity. *Can. J. Plant Sci.* **2005**, *85*, 931. [CrossRef]
29. Ardayfio, N.K.; Hatterman-Valenti, H. Juneberry Cultivar Evaluation in North Dakota. *HortTechnology* **2015**, *25*, 747–751. [CrossRef]
30. Seliga, Ł.; Pluta, S. Assessment of growth and yielding of some Saskatoon berry (*Amelanchier alnifolia* Nutt.) genotypes in central Poland. *Zesz. Nauk. Inst. Ogrod.* **2016**, *24*, 109–119. (In Polish)
31. Hajagos, A.; Model, P.; Spornberger, A.; Végvári, G. The effect of rootstocks on the development of fruit quality parameters of some sweet cherry (*Prunus avium* L.) cultivars, 'Regina' and 'Kordia', during the ripening process. *Acta Univ. Sapientiae Agric. Environ.* **2012**, *4*, 59–70. Available online: http://www.acta.sapientia.ro/acta-agrenv/C4/agr4-7.pdf (accessed on 15 May 2021).
32. Gjamovski, V.; Kiprijanovski, M.; Arsov, T. Evaluation of some cherry varieties grafted on Gisela 5 rootstock. *Turk. J. Agric. For.* **2016**, *40*, 737–745. [CrossRef]

33. Heinonen, I.M.; Meyer, A.S.; Frankel, E.N. Antioxidant Activity of Berry Phenolics on Human Low-Density Lipoprotein and Liposome Oxidation. *J. Agric. Food Chem.* **1998**, *46*, 4107–4112. [CrossRef]
34. Lachowicz, S.; Oszmiański, J.; Wiśniewski, R.; Pluta, S. Chemical parameters profile analysis by liquid chromatography and antioxidative activity of the Saskatoon berry fruits and their components. *Eur. Food Res. Technol.* **2019**, *245*, 2007–2015. [CrossRef]
35. Ochmian, I.; Kubus, M.; Dobrowolska, A. Description of plants and assessment of chemical properties of three species from the *Amelanchier* genus. *Dendrobiology* **2013**, *70*, 59–64. [CrossRef]
36. Jin, A.L.; Ozga, J.A.; Kennedy, J.A.; Koerner-Smith, J.L.; Botar, G.; Reinecke, D.M. Developmental Profile of Anthocyanin, Flavonol, and Proanthocyanidin Type, Content, and Localization in Saskatoon Fruits (*Amelanchier alnifolia* Nutt.). *J. Agric. Food Chem.* **2015**, *63*, 1601–1614. [CrossRef] [PubMed]
37. Faniadis, D.; Drogoudi, P.D.; Vasilakakis, M. Effects of cultivar, orchard elevation, and storage on fruit quality characters of sweet cherry (*Prunus avium* L.). *Sci. Hortic.* **2010**, *125*, 301–304. [CrossRef]
38. Popescu, S.; Velciov, A.B.; Rivis, A.; Costescu, C.; Petolescu, C. Antioxidant Activity and Phenolic Content of Sweet Cherries (*Prunus avium* L.) from West and SouthWest of Romania. *Bull. UASVM Food Sci. Technol.* **2014**, *71*, 215–217. [CrossRef]
39. Eisele, T.A.; Drake, S.R. The partial compositional characteristics of apple juicefrom 175 apple varieties. *J. Food Compos. Anal.* **2005**, *18*, 213–221. [CrossRef]
40. Ozga, J.A.; Saeed, A.; Reinecke, D.M. Anthocyanins and nutrient components of saskatoon fruits (*Amelanchier alnifolia* Nutt.). *Can. J. Plant Sci.* **2006**, *86*, 193–197. [CrossRef]