Sweet Rowanberry (Sorbus aucuparia L.)

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Rowan is a fairly common fruit crop in different countries of the world. The orange or reddish fruits of Sorbus aucuparia L. are small (diameter 6–9 mm) and they have been traditionally used as diuretic, laxative, anti-inflammatory, and vasoprotective agents, against rheumatism and kidney diseases as well as for the treatment of various gastrointestinal and respiratory tract-related disorders.

antioxidants polyphenolic compounds rowanberry pomace hybrid cultivars

1. Introduction

According to the recent report by Grand View Research, Inc., the global market of polyphenols is predicted to reach USD 2.08 billion by 2025 [1]. These compounds have demonstrated antioxidant, anti-inflammatory, anti-diabetic, anti-diarrheal, anti-tumor, as well as diuretic and vasodilatory effects. Many fruits and particularly berries are superior sources of polyphenols with a high antioxidant capacity [2][3]. Therefore, fruit-origin raw materials have been growingly utilized to extract bioactive compounds for various applications. In some cases, the processing of fruits generates a substantial number of by-products [4]. For example, fruit pomace, which is a solid residue of juice pressing, consists mainly of skin, seeds, and pulp, and it accounts for approximately 10–35% of the mass of the initial fresh fruit [4]. Moreover, the pomace holds a considerable number of polyphenolic compounds, approximately 28–35% in the skin, 60–70% in seeds, and 10% in pulp, making it a potential source of natural antioxidants [5][6]. Although, many research articles have been published on the valorization of by-products from agro-industry, including fruit pomace [4], juice pressing residues of some fruit remain under-investigated.

Rowan is a fairly common fruit crop in different countries of the world. The orange or reddish fruits of *Sorbus aucuparia* L. are small (diameter 6–9 mm) and they have been traditionally used as diuretic, laxative, anti-inflammatory, and vasoprotective agents, against rheumatism and kidney diseases as well as for the treatment of various gastrointestinal and respiratory tract-related disorders [7].

Although the rowanberries have been used for juice, jams, or jellies [8][9], their application for foods is limited due to their bitter and astringent taste. To overcome this hindrance, the first sweet rowanberry clones were selected from the Sudety Mountains (Czech Republic) already in the 19th century. At the beginning of the 20th century, Russian scientist and plant breeder Michurin started a breeding program of sweet rowanberries for northern conditions and developed the most interesting group of *S. aucuparia* hybrids with *Pyrus, Malus, Aronia,* or *Crataegus* species [10]. The taste of the cultivated hybrid fruits such as Likernaja, Alaja Krupnaja, and Granatnaja (**Figure 1**), is less astringent, and the fruits are usually larger and darker in color than those of wild rowanberries [9][11]. The varieties

Kubovaya, Zheltaya, and Krasnaya were selected from the sweet-fruited form of *S. aucuparia* originated from the village Nevezhino in Russia, while the varieties Rossica and Rosina were bred of the Moravian mountain ash from the Sudety Mountains. Regarding the quality characteristics of rowanberries, Bussinka, Vefed, and Solnechnaja were rich in vitamin C content, while the latter two were also not astringent [12]. Moreover, previous investigations have reported the antioxidant capacity [3] and bacteriostatic effect [13] of both wild and cultivated rowanberry extracts.

Figure 1. Rowanberry cultivars ‘Likernaja’, ‘Alaja Krupnaja’ and ‘Granatnaja’.

2. Total Phenolic Content

The results obtained for TPC are depicted in **Figure 2**a. Accordingly, the pomace fraction has the highest mean value of TPC: compared to the mean value of fruit, it is four-fold, while the mean value of fruit, in turn, is two times higher than the TPC of juice. The standard deviation (SD) bars demonstrate the variety of TPC among the 16 cvs. An especially wide range of TPC is among the pomace part of cvs. These findings prove that the pomace part obtained from specific cvs can provide us a valuable source of polyphenols for food and pharmaceutical purposes [4][14].

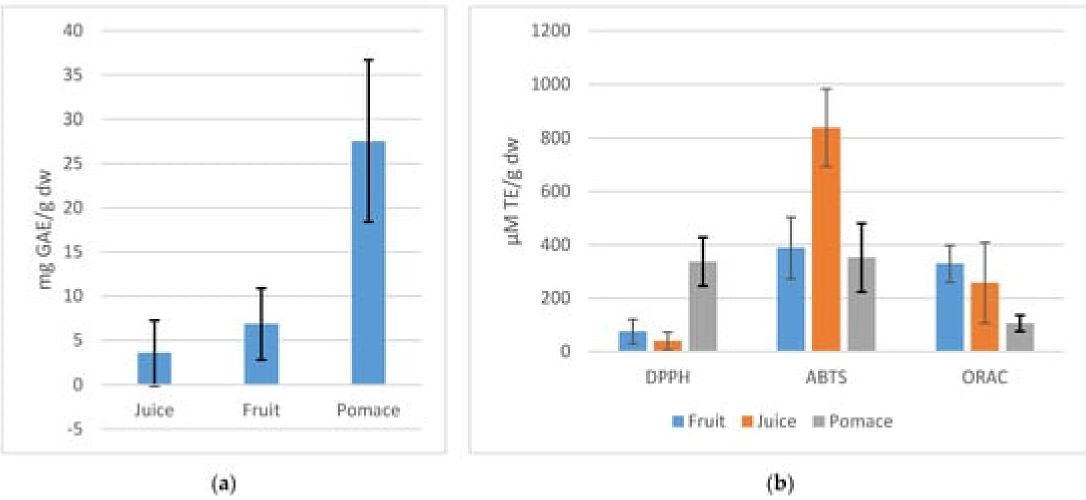

Figure 2. Mean values of TPC (**a**) and antioxidant capacity (**b**) of fruit, juice, and pomace of all cultivars in the current study.

As demonstrated in **Table 2**, the TPC values of 16 sweet rowanberry cvs ranged between 2.53 and 15.05 mg GAE/g dw, 0.53 and 14.8 mg GAE/g dw, and 15.97 and 44.68 mg GAE/g dw for whole fruit, juice, and pomace fractions, respectively. The highest levels were found for all fractions of cvs Likernaja, Burka, Rubinovaja, and Granatnaja. The cvs Likernaja and Burka are the hybrids between rowanberry and chokeberry, S. *aucuparia* × *Aronia melanocarpa,* and *Sorbus aria* × *Aronia arbutifolia*, respectively; while Rubinovaja is × *Sorbopyrus* (S. *aucuparia* × *Pyrus*) and Granatnaja is × *Sorbocrataegus* (S. *aucuparia* × *Crataegus*). The pomace fractions of the hybrids demonstrated the TPC values of 44.68 mg GAE/g dw for cvs Burka and 41 mg GAE/g dw for Likernaja and Rubinovaja. The TPC in the fruit of cv. Likernaja and cv. Burka was 15.05 and 14.78 mg GAE/g dw, respectively, while the contents in the juice of the same hybrids were 14.8 and 9.68 mg GAE/g dw, respectively. These results agree with the TPC values reported by Kampuse et al. [15] who found the highest TPC values for cv. Likernaja (484.9 mg/100 g fw) among the other 8 rowanberry cultivars. Hukkanen [16] tested many rowan cvs and found the highest TPC values for cvs Rubinovaja and Burka, 1014 and 820 mg/100 g of fw of fruit, respectively. In the research performed by Hukkanen et al., cv. Burka had the highest anthocyanin content among the sweet rowanberries. In the current research, the pomace fraction of cv. Moravica and wild rowanberry had very high TPCs, 29.32 and 31.7 mg GAE/g, respectively, while the highest TPCs among Nevezhino rowans were determined in the pomace of cv. Solnechnaja and Krasnaja, at 28.3 and 27.75 mg GAE/g dw, respectively. It may be observed that a significant fraction of polyphenols remains in the pomace, being the valuable part of rowanberries.

Table 2. Total phenolic content, SET- and HAT-type antioxidant activity of fruit, juice, and pomace of 16 rowanberry genotypes and wild rowanberry.

	TPC			DPPH$^\bullet$			ABTS$^{\bullet+}$			ORAC		
	F	J	P	F	J	P	F	J	P	F	J	P
Bur	14.78 ± 1 ^{a}	9.68 ± 1 ^{b}	44.68 ± 2 ^{a}	127.8 ± 9 ^{b}	107.1 ± 4 ^{b}	522.3 ± 36 ^{a}	1010 ± 4 ^{b}	641.4 ± 3 ^{a}	576.8 ± 32 ^{a}	456.5 ± 33 ^{a}	435.7 ± 14 ^{ab}	125.3 ± 8 ^{abc}
Lik	15.05 ± 0 ^{a}	14.8 ± 0 ^{a}	41.31 ± 3 ^{b}	84.38 ± 6 ^{h}	125.61 ± 6 ^{a}	527.6 ± 33 ^{a}	1068 ± 8 ^{a}	615.1 ± 9 ^{a}	508.9 ± 27 ^{b}	416.5 ± 29 ^{ab}	381.9 ± 23 ^{de}	128.5 ± 4 ^{abc}
Gran	11.15 ± 1 ^{b}	5.79 ± 0 ^{c}	38.93 ± 3 ^{c}	177.5 ± 3 ^{a}	63.89 ± 4 ^{c}	402.7 ± 22 ^{c}	855.7 ± 1 ^{d}	500.1 ± 4 ^{b}	511.9 ± 35 ^{b}	399.4 ± 31 ^{cd}	396.8 ± 37 ^{cd}	133.1 ± 10 ^{abc}
Rub	9.51 ± 0 ^{c}	2.23 ± 0 ^{fg}	41.01 ± 4 ^{b}	110.2 ± 9 ^{c}	30.17 ± 2 ^{fg}	451.5 ± 36 ^{b}	990.1 ± 3 ^{b}	453.9 ± 4 ^{d}	584.2 ± 35 ^{a}	375.2 ± 5 ^{d}	335.2 ± 16 ^{e}	150.8 ± 3 ^{a}
Al K	6.46 ± 0 ^{de}	4.6 ± 0 ^{d}	20.73 ± 1 ^{i}	80.35 ± 8 i	58.85 ± 5 ^{d}	329.1 ± 23 ^{efg}	847.9 ± 5 ^{d}	351.3 ± 5 ^{g}	371.5 ± 19 ^{c}	266.4 ± 18 ^{gh}	413.4 ± 23 ^{bc}	66.52 ± 1 ^{gh}

	TPC			DPPH•			ABTS•+			ORAC		
	F	J	P	F	J	P	F	J	P	F	J	P
Mor	6.54 ± 0 ^{de}	0.53 ± 0 ^{i}	29.32 ± 2 ^{e}	87.54 ± 5 ^{g}	18.06 ± 1 ^{i}	330.9 ± 16 ^{efg}	770.1 ± 5 ^{f}	123.2 ± 1 ^{j}	179.9 ± 11 ^{g}	299.3 ± 18 ^{f}	23.81 ± 1 ^{hi}	106.0 ± 2 ^{bcdef}
Kras	2.53 ± 0 ^{h}	1.33 ± 0 ^{h}	27.75 ± 2 ^{f}	39.03 ± 3 ^{l}	14.06 ± 1 ^{j}	268.6 ± 12 ^{hi}	801.4 ± 5 ^{e}	133.9 ± 2 ^{j}	228.1 ± 14 ^{f}	243.8 ± 9 ^{h}	393.7 ± 27 ^{cd}	99.64 ± 6 ^{cdefg}
Kub	2.57 ± 0 ^{h}	1.03 ± 0 ^{hi}	24.81 ± 1 ^{g}	43.71 ± 3 ^{j}	30.52 ± 1 ^{fg}	286.9 ± 24 ^{h}	699.8 ± 5 ^{h}	283.1 ± 4 ^{h}	329.1 ± 29 ^{d}	256.4 ± 15 ^{h}	388.2 ± 34 ^{cd}	80.03 ± 7 ^{efg}
Oranz	2.84 ± 0 ^{gh}	1.16 ± 0 ^{h}	19.76 ± 1 ^{j}	40.67 ± 3 ^{k}	33.08 ± 2 ^{fg}	172.1 ± 12 ^{j}	666.0 ± 1 ^{i}	247.4 ± 4 ^{i}	180.4 ± 5 ^{g}	239.1 ± 9 ^{h}	53.10 ± 3 ^{h}	43.87 ± 1 ^{h}
Sahh	5.77 ± 0 ^{e}	3.58 ± 0 ^{e}	25.37 ± 2 ^{g}	15.10 ± 1 ^{p}	33.32 ± 2 ^{f}	263.2 ± 15 ^{hi}	756.1 ± 5 ^{fg}	260.2 ± 5 ^{hi}	396.0 ± 8 ^{c}	293.85 ± 1 ^{fg}	209.2 ± 16 ^{f}	110.7 ± 10 ^{bcde}
Vef	7.33 ± 0 ^{d}	1.24 ± 0 ^{h}	15.97 ± 1 ^{l}	25.17 ± 1 ^{n}	20.18 ± 1 ^{hi}	317.6 ± 24 ^{fg}	913.7 ± 7 ^{c}	416.0 ± 7 ^{ef}	209.9 ± 16 ^{fg}	313.0 ± 10 ^{e}	19.70 ± 1 ^{i}	75.43 ± 7 ^{fgh}
Ross	4.45 ± 0 ^{f}	2.1 ± 0 ^{g}	18.61 ± 1 ^{k}	109.5 ± 5 ^{d}	6.15 ± 0 ^{k}	244.7 ± 18 ^{i}	813.0 ± 4 ^{e}	395.3 ± 2 ^{ef}	293.1 ± 24 ^{e}	380.4 ± 16 ^{cd}	122.1 ± 2 ^{g}	79.39 ± 2 ^{bcdef}
Soln	8.64 ± 0 ^{c}	3.8 ± 0 ^{e}	28.3 ± 2 ^{f}	91.73 ± 6 ^{f}	32.36 ± 1 ^{g}	324.5 ± 23 ^{efg}	911.5 ± 7 ^{c}	420.9 ± 4 ^{ef}	321.9 ± 23 ^{de}	406.5 ± 8 ^{bc}	443.7 ± 39 ^{a}	146.6 ± 9 ^{a}
Ang	3.77 ± 0 ^{g}	2.65 ± 0 ^{f}	23.02 ± 2 ^{h}	21.89 ± 2 ^{o}	31.64 ± 1 ^{fg}	286.9 ± 23 ^{h}	728.9 ± 3 ^{gh}	470.2 ± 3 ^{cd}	297.2 ± 5 ^{e}	329.4 ± 25 ^{e}	215.5 ± 4 ^{f}	117.5 ± 11 ^{abcd}
Buss	2.81 ± 0 ^{gh}	3.5 ± 0 ^{e}	16.04± 1 ^{l}	108.2 ± 5 ^{e}	37.56 ± 1 ^{e}	297.8 ± 22 ^{g}	756.5 ± 4 ^{fg}	420.2 ± 3 ^{e}	369.6 ± 25 ^{c}	259.4 ± 10 ^{h}	119.6 ± 8 ^{g}	84.62 ± 7 ^{defg}
Rosi	5.29 ± 0 ^{f}	1.1 ± 0 ^{h}	21.12 ± 1 ^{i}	31.60 ± 2 ^{m}	6.03 ± 0 ^{k}	332.5 ± 15 ^{ef}	803.6 ± 8 ^{e}	389.9 ± 2 ^{f}	300.2 ± 14 ^{de}	329.3 ± 28 ^{e}	203.2 ± 12 ^{f}	116.4 ± 8 ^{abcd}
Wild	NA	1.49 ± 0 ^{h}	31.7 ± 2 ^{d}	NA	21.77 ± 1 ^{h}	358.6 ± 24 ^{e}	NA	470.7[17] ± 5 ^{c}	313.2 ± 19 ^{de}	NA	226.9 ± 16 ^{f}	135.2•+ ± 4 ^{ab}

trate the reaction a mixed-mode assay reagent, reacting by both ET (electron-) and HAT (hydrogen atom transfer) mechanisms. The DPPH• is believed to act more like an H- atom acceptor, although the ET mechanism cannot be excluded, depending strongly on phenol-ionizing solvents and at alkaline pH where DPPH• is a stable radical [17][18]. The ORAC assay is based on the HAT reaction mechanism [19].

Results are mean values of four replicate analyses calculated in mg GAE/g dw. NA—data not available; different letters in column mark significant differences at $p \leq 0.05$.

The ABTS$^{\bullet+}$/DPPH$^{\bullet}$ scavenging and ORAC values are presented in **Table 2**. The DPPH$^{\bullet}$ scavenging activity for antioxidant capacity ranged from 15.1 to 177.5 µM TE/g dw, 6.03 to 125.6 µM TE/g dw, and 172.1 to 527.6 µM TE/g dw, for fruit, juice, and pomace, respectively. Using ABTS$^{\bullet+}$ assay the antioxidant capacity values were between 666 and 1068 µM TE/g dw, 123.2 and 641.4 µM TE/g dw, and 179.9 and 584.2 µM TE/g dw for fruit, juice, and pomace, respectively. The results of ORAC assay ranged from 239.1 to 456.5 µM TE/g dw, 19.7 to 443.7 µM TE/g dw, and 43.87 to 150.8 µM TE/g dw, for fruit, juice, and pomace, respectively. All fractions of cvs Likernaja, Burka, Rubinovaja, and Granatnaja had the antiradical capacity values above the average. Comparing the pomace fractions, the cv. Likernaja presented the highest DPPH$^{\bullet}$ value of 527.55 µM TE/g dw, the cv. Burka had the highest ABTS$^{\bullet+}$ value of 576.77 µM TE/g dw, and the cv. Rubinovaja demonstrated the highest ORAC value of 150.75 µM TE/g dw. From previous studies, Jurikova et al. [15] and Kampuse et al. [20] found the highest antioxidant activity of cv. Likernaja which is among the other hybrids. Compared to the other cvs, all fractions of cv. Solnechnaja had very high ORAC values, as well as the DPPH$^{\bullet}$ and ABTS$^{\bullet+}$ values were above the average of 17 pomace samples. While the average ORAC and ABTS$^{\bullet+}$ values raise in the direction: pomace < juice < fruit, the rise of DPPH$^{\bullet}$ values is juice < fruit < pomace, and the average fruit and juice values of ABTS$^{\bullet+}$ are 10-fold compared to DPPH$^{\bullet}$ values. This phenomenon can be explained by the different reaction mechanisms in ABTS$^{\bullet+}$, DPPH$^{\bullet}$, and ORAC assays.

4. Identification and Quantification of Individual Phenolic Compounds in Different Fractions of Sweet Rowanberry Cultivars

The extracts recovered with acidified ethanol from fruit, juice, and pomace fractions were analyzed by UHPLC-DAD-MS/MS. The results (**Figure 3** and **Table 3**) revealed that sweet rowanberry cvs are rich in caffeoylquinic acids, especially chlorogenic and neochlorogenic acids, ranging between 1.07 and 4.59 mg/g dw and between 0.75 and 6.13 mg/g dw, respectively. In our experiment, the highest contents of neochlorogenic acid were found in the fruit and juice samples of cvs Likernaja, Burka, Granatnaja, and Rubinovaja. The highest chlorogenic acid contents were determined in the fruit and juice samples of cvs Sahharnaja, Bussinka, Angri, and wild rowanberry. The neochlorogenic acids followed by chlorogenic acids were the most dominant phenolic acids in pomace samples (**Figure 3**). These findings were similar to the previous study of Bobinaitė et al. [21]. In the current study, the highest contents of neochlorogenic acid were tested in cvs Likernaja and Solnechnaja, but relatively high contents were determined also in cvs Burka, Bussinka and Granatnaja. Comparative data were reported by Jurikova et al., who found the highest content of chlorogenic acid in cvs Likernaja (100.9 mg/100 g fw) and Granatnaja (90.62 mg/100 g fw) [15]. While testing the chlorogenic acid content of the pomace samples, the highest values were found for wild rowanberry and cvs Bussinka and Sahharnaja, at 4.79 mg/g dw, 3.64 mg/g dw, and 3.62 mg/g dw, respectively. Mikulic-Petkovsek et al. [22] also reported cv. Bussinka to be rich in neochlorogenic acid.

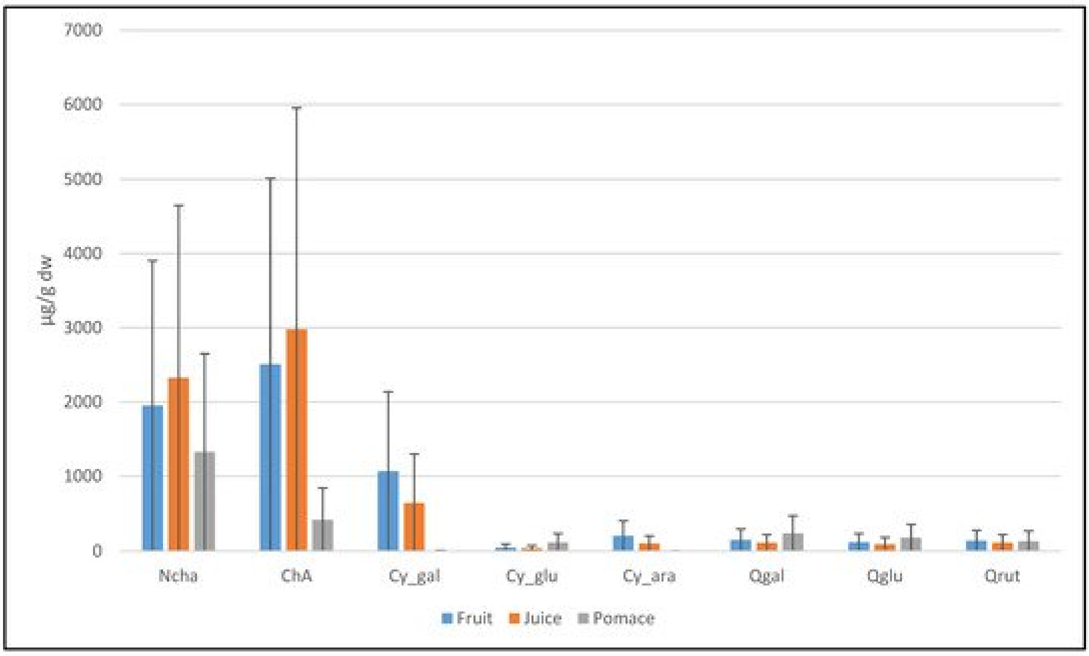

Figure 3. The mean contents of major polyphenolic compounds for all cultivars in current study.

Table 3. The distribution of individual phenolic compounds (μg/g dw) in fruit, juice, and pomace extracts of 17 sweet rowanberry cultivars.

		Bur	Lik	Gran	Rub	Al_K	Mor	Kras	Kub	Oranz	Sahh	Vef	Ross	Soln	Ang	Buss	Rosi	Wild
NCha	F	3086 ± 781	4955 ± 323	2553 ± 182	2441 ± 231	1991 ± 132	1677 ± 131	1014 ± 164	991 ± 0.82	0.944 ± 0.073	1891 ± 141	1779 ± 162	1181 ± 103	2541 ± 182	1241 ± 122	1850 ± 183	1518 ± 142	1531 ± 101
	J	3930 ± 123	6127 ± 108	3497 ± 42	3402 ± 133	2475 ± 46	1830 ± 28	1122 ± 19	1176 ± 42	1023 ± 46	2122 ± 55	1963 ± 122	1289 ± 14	2040 ± 692	1461 ± 29	2297 ± 27	1942 ± 28	1813 ± 41
	p	1681 ± 61	2172 ± 182	1621 ± 50	1453 ± 92	1181 ± 43	1171 ± 21	862 ± 35	752 ± 21	713 ± 12	1281 ± 43	1472 ± 32	901 ± 12	2021 ± 44	981 ± 22	1641 ± 21	1204 ± 42	1392 ± 11
ChA	F	2013 ± 502	2269 ± 83	2011 ± 2.1	2440 ± 72	1052 ± 43	2662 ± 61	2636 ± 12	2700 ± 121	2448 ± 41	3789 ± 83	1982 ± 41	2692 ± 52	2028 ± 32	3031 ± 63	3142 ± 102	2450 ± 52	3312 ± 44
	J	2213 ± 59	2640 ± 59	2731 ± 102	3368 ± 140	1265 ± 60	2834 ± 216	3139 ± 145	3186 ± 126	2625 ± 122	4595 ± 106	2202 ± 147	3064 ± 126	2515 ± 129	3459 ± 76	3843 ± 209	3359 ± 95	3591 ± 154
	p	1564 ± 28	1620 ± 102	1994 ± 64	2261 ± 135	1070 ± 18	2745 ± 115	3232 ± 27	2782 ± 216	2669 ± 69	3622 ± 59	2205 ± 31	2894 ± 91	2477 ± 81	3161 ± 123	3639 ± 93	3024 ± 23	4782 ± 181

		Bur	Lik	Gran	Rub	Al_K	Mor	Kras	Kub	Oranz	Sahh	Vef	Ross	Soln	Ang	Buss	Rosi	Wild
Cygal	F	5526 ± 602	4775 ± 263	2661 ± 122	2077 ± 73	716 ± 12.	274 ± 14	137 ± 20	158 ± 12	81 ± 1	118 ± 12	290 ± 13	132 ± 21	109 ± 12	147 ± 1	506 ± 22	279 ± 12	183 ± 1
	J	2627 ± 184	2704 ± 413	1884 ± 63	1288 ± 92	497 ± 13	235 ± 10	115 ± 4	146 ± 7	51 ± 12	94 ± 7	227 ± 20	126 ± 5	113 ± 8	134 ± 7	460 ± 13	273 ± 8	72 ± 12
	p	28 ± 2	26 ± 2	17 ± 2	9 ± 0	5 ± 0	2 ± 0	1 ± 0	1 ± 0	0	1 ± 0	2 ± 0	1 ± 0	1 ± 0	1 ± 0	3 ± 0	1 ± 0.0	2 ± 0
Cyglu	F	217 ± 42	175 ± 32	119 ± 11	141 ± 13	10 ± 2	18 ± 2	0	1 ± 0	0	0	10	1 ± 0	1 ± 0	1 ± 0	121 ± 2	25 ± 2	1 ± 0
	J	126 ± 4	127 ± 2	78 ± 1	110 ± 2	6 ± 0	18 ± 0	1 ± 0	1 ± 0	0	1 ± 0	1 ± 0	32 ± 2	1 ± 0	0	113 ± 2	23 ± 2	1 ± 0
	p	600 ± 31	554 ± 21	323 ± 53	362 ± 32	18 ± 2	27 ± 1	2 ± 0	66 ± 2	1 ± 2	1 ± 0	5 ± 0	2 ± 0	2 ± 0	2 ± 0	6 ± 0	36 ± 2	14 ± 2
Cyara	F	1538 ± 21	1380 ± 74.	424 ± 2.	60 ± 2	13 ± 2	5 ± 0	6 ± 0	6 ± 0	2 ± 0	4 ± 0	14 ± 1	5 ± 0	3 ± 0.0	6 ± 1	11 ± 2	5 ± 0	6 ± 0
	J	668 ± 57	690 ± 130	288 ± 8	37 ± 2	8 ± 0	3 ± 0	4 ± 0	5 ± 0	1 ± 0	3 ± 0	11 ± 2	4 ± 0	3 ± 0	5 ± 0	9 ± 0	4 ± 0	2 ± 0
	p	9 ± 0	8 ± 0	4 ± 0	1 ± 0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ecat	F	27 ± 1	31 ± 2	27 ± 2	26 ± 2	22 ± 2	17 ± 1	28 ± 3	35 ± 2	27 ± 6	20 ± 2	13 ± 2	44 ± 2	13 ± 2	38 ± 6	13 ± 0	15 ± 2	33 ± 2
	J	10 ± 1	14 ± 1	16 ± 1	12 ± 1	11 ± 1	8 ± 1	16 ± 1	24 ± 1	14 ± 1	13 ± 0.1	8 ± 0.1	23 ± 0.1	8 ± 0.1	20 ± 0.1	07 ± 0	10 ± 0	12 ± 0
	p	59 ± 3	62 ± 3	69 ± 1	65 ± 3	65 ± 3	59 ± 2	70 ± 7	102 ± 3	84 ± 5	96 ± 3	65 ± 5	103 ± 1	54 ± 6	100 ± 2	53 ± 2	60 ± 3	111 ± 3
Cat	F	9 ± 2	9 ± 2	11 ± 2	26 ± 2	17 ± 2	19 ± 2	18 ± 2	22 ± 02	30 ± 2	19 ± 2	5 ± 2	23 ± 2	22 ± 2	25 ± 02	92	16 ± 2	17 ± 2
	J	5 ± 0	6 ± 0	8 ± 1	13 ± 2	8 ± 2	10 ± 1	12 ± 1	014 ± 1	016 ± 1	14 ± 1	3 ± 1	12 ± 1	14 ± 1	12 ± 1	6 ± 1	12 ± 1	8 ± 1
	p	21 ± 2	22 ± 2	37 ± 2	65 ± 2	48 ± 2	69 ± 2	44 ± 2	54 ± 2	82 ± 2	90 ± 2	22 ± 2	59±	93 ± 2	56 ± 0	29 ± 2	66 ± 2	52 ± 0
Coum	p	12 ± 1	9 ± 1	8 ± 1	24 ± 1	4 ± 0	5 ± 0	7 ± 1	9 ± 1	7 ± 1	6 ± 1	15 ± 1	15 ± 1	9 ± 1	17 ± 1	12 ± 1	8 ± 1	21 ± 1

		Bur	Lik	Gran	Rub	Al_K	Mor	Kras	Kub	Oranz	Sahh	Vef	Ross	Soln	Ang	Buss	Rosi	Wild
Fer	p	10 ± 0	11 ± 0	8 ± 0	28 ± 0	4 ± 0	5 ± 0	7 ± 0	9 ± 0	5 ± 0	6 ± 0	23 ± 0	16 ± 0	7 ± 0	20 ± 0	25 ± 0	8 ± 0	10 ± 0
Q	F	50 ± 1	9 ± 1	9 ± 1	9 ± 1	5 ± 0	8 ± 1	6 ± 1	7 ± 1	5 ± 0	4 ± 0	8 ± 1	6 ± 1	9 ± 1	10 ± 1	7 ± 1	10 ± 1	12 ± 1
	J	14 ± 1	29 ± 1	28 ± 1	30 ± 1	23 ± 1	22 ± 1	23 ± 1	23 ± 1	18 ± 1	33 ± 1	22 ± 1	36 ± 1	37 ± 1	40 ± 1	25 ± 1	26 ± 1	17 ± 1
	p	58 ± 1	41 ± 1	73 ± 1	82 ± 1	37 ± 1	45 ± 1	35 ± 1	29 ± 1	30 ± 1	55 ± 1	131 ± 1	69 ± 1	64 ± 1	84 ± 1	63 ± 1	75 ± 1	121 ± 1
Qgal	F	268 ± 34	199 ± 7	220 ± 8	89 ± 11	119 ± 12	94 ± 6	48 ± 1	63 ± 1	40 ± 4	426 ± 36	185 ± 7	68 ± 1	238 ± 10	108 ± 4	53 ± 5	91 ± 1	232 ± 1
	J	199 ± 6	163 ± 18	202 ± 8	87 ± 5	89 ± 4	51 ± 1	45 ± 1	31 ± 1	23 ± 1	357 ± 26	129 ± 15	46 ± 1	207 ± 9	75 ± 1	47 ± 1	85 ± 1	63 ± 1
	p	338 ± 6	627 ± 18	270 ± 8	138 ± 5	187 ± 9	133 ± 1	111 ± 3	69 ± 1	64 ± 3	619 ± 4	345 ± 2	708 ± 1	361 ± 8	129 ± 1	72 ± 4	155 ± 4	741 ± 1
Qglu	F	289 ± 13	222±	200 ± 7	115 ± 9	188 ± 23	78 ± 3	28 ± 1	35 ± 3	34 ± 3	27,838	62 ± 3	37 ± 1	617 ± 17	53 ± 3	20 ± 1	74 ± 1	143 ± 3
	J	226 ± 17	191 ± 20	200 ± 5	125 ± 0	146 ± 1	47 ± 0	25 ± 1	18 ± 2	20 ± 9	231 ± 1	46 ± 1	27 ± 4	132 ± 1	34 ± 3	17 ± 4	74 ± 2	43 ± 1
	p	344 ± 15	277 ± 37	240 ± 21	183 ± 44	300 ± 13	115 ± 7	61 ± 4	41 ± 1	55 ± 9	403 ± 18	12,418	42 ± 0	241 ± 5	63 ± 6	33 ± 1	125 ± 25	431 ± 71
Qrut	F	246 ± 27	240 ± 14	166 ± 5	224 ± 15	242 ± 15	91 ± 1	82 ± 1	122 ± 7	95 ± 7	0	195 ± 13	115 ± 1	242 ± 6	165 ± 5	23 ± 0	84 ± 1	73 ± 1
	J	232 ± 6	245 ± 13	164 ± 3	229 ± 10	205 ± 5	60 ± 2	57 ± 2	47 ± 2	50 ± 2	0	135 ± 6	64 ± 1	214 ± 2	84 ± 2	19 ± 1	83 ± 2	18 ± 2
	p	819 ± 10	225 ± 8	118 ± 3	202 ± 7	255 ± 20	70 ± 1	124 ± 5	73 ± 4	84 ± 4	1 ± 0	221 ± 6	61 ± 3	25,715	100 ± 5	21 ± 1	74 ± 1	221 ± 1
Ka	F	7 ± 1	5 ± 0	5 ± 0	6 ± 1	6 ± 1	6 ± 1	2 ± 0	4 ± 0	30	15 ± 1	2 ± 0	3 ± 0	8 ± 1	5 ± 0	1 ± 0	61	9 ± 1
	J	50	60	6 ± 0	70	5 ± 0	3 ± 0	2 ± 0	2 ± 0	2 ± 0	12 ± 0	1 ± 0	2 ± 0	6 ± 0	3 ± 0	1 ± 0	4 ± 0	2 ± 0
	p	3 ± 0	3 ± 0	4 ± 0	7 ± 0	2 ± 0	5 ± 0	4 ± 0	4 ± 0	3 ± 0	4 ± 0	7 ± 0	9 ± 0	4 ± 0	10 ± 0	4 ± 0	7 ± 0	10 ± 0
Isor	p	7 ± 0	7 ± 0	5 ± 0	21 ± 0	5 ± 0	1 ± 0	1 ± 0	0	0	0	2 ± 0	1 ± 0	1 ± 0	1 ± 0	1 ± 0	1 ± 0	1 ± 0
PCA	p	46 ±	27 ±	40 ±	128	8 ± 0	4 ± 0	4 ± 0	5 ± 0	5 ± 0	4 ± 0	17 ± 0	11 ±	4 ± 0	15 ±	18 ±	13 ±	17 ±

nstance, of total anatnaja, ng/g dw, to 91% ucosides [22] [13] [16] reported s) in the ng/g dw. Interestingly, in the case of rowanberry pomace, cyanidin-3-glucoside was the major part (up to 97%) of ACYs. Zymone et al. [23] and Mikulic-Petkovsec et al. [22] found cyanidin-3-galactoside to be the predominant anthocyanin in rowanberry pomace powder fruits. In our study, the highest total content of ACYs was found in pomace of cvs Burka and Likernaja, followed by cvs Rubinovaja and Granatnaja. The latter two are hybrid cultivars, originating from sweet rowanberries with intense dark colors.

The average content of ACYs was found up to 10-fold in the fruit and juice samples compared to that in pomace samples. At the same time, the average content of flavanols in the pomace samples was up to 4.8 times higher than that in the juice and fruit samples. In addition, the average contents of flavanols were lower in the fruit and juice samples than in the pomace samples.

A principal component analysis (PCA) of eight major phenolic compounds (Ncha, ChA, Cygal, Cyglu, Cyara, Qgal, Qglu, and Qrut) was conducted for the rowanberry fruit, juice, and pomace samples (**Figure 4**). All three (a, b, c)

		Bur	Lik	Gran	Rub	Al_K	Mor	Kras	Kub	Oranz	Sahh	Vef	Ross	Soln	Ang	Buss	Rosi	Wild
		6	4	3	± 10								0		0	2	1	0
Caf	p	24 ± 1	18 ± 2	24 ± 3	67 ± 7	13 ± 1	16 ± 1	20 ± 1	23 ± 3	21 ± 1	21 ± 2	34 ± 1	51 ± 2	17 ± 1	51 ± 2	44 ± 2	34 ± 2	38 ± 2
P_B1	F	8 ± 1	10 ± 1	16 ± 1	40 ± 4	22 ± 1	26 ± 1	24 ± 5	28 ± 5	40 ± 2	26 ± 5	6 ± 1	31 ± 1	30 ± 1	32 ± 1	12 ± 1	21 ± 1	22 ± 1
	J	3 ± 0	5 ± 0	8 ± 1	18 ± 1	10 ± 1	14 ± 1	16 ± 1	18 ± 1	21 ± 1	19 ± 1	4 ± 0	18±	22 ± 1	17 ± 1	6 ± 0	14 ± 1	10 ± 1
	p	24 ± 1	25 ± 2	42 ± 4	75 ± 3	51 ± 2	72 ± 3	49 ± 2	60 ± 1	98 ± 9	99 ± 7	24 ± 3	68 ± 7	100 ± 10	61 ± 4	32 ± 3	68 ± 5	57 ± 1
P_B2	F	79 ± 1	94 ± 0	4 ± 7	80 ± 8	66 ± 8	49 ± 4	75 ± 1	97 ± 1	78 ± 1	60 ± 1	41 ± 1	118 ± 1	36 ± 1	107 ± 2	42 ± 5	44 ± 1	92 ± 1
	J	28 ± 5	40 ± 7	49±	42 ± 1	33 ± 5	23 ± 6	47 ± 1	71 ± 2	36 ± 1	42 ± 3	24 ± 1	66 ± 2	28 ± 1	62 ± 3	25 ± 4	29 ± 3	33±
	p	162 ± 7	172 ± 7	186 ± 7	185 ± 10	176 ± 16	150 ± 14	188 ± 13	259 ± 6	209 ± 12	255 ± 18	174 ± 10	293 ± 7	139 ± 22	271 ± 19	145 ± 4	164 ± 3	306 ± 1
P_C1	F	93 ± 1	105 ± 1	88 ± 1	96 ± 1	78 ± 1	53 ± 1	77 ± 1	100 ± 1	83 ± 1	70 ± 1	40 ± 1	142 ± 1	49 ± 1	124 ± 1	39 ± 2	55 ± 1	103 ± 2
	J	34 ± 1	44 ± 10	53 ± 11	38 ± 11	36 ± 12	26 ± 0	41 ± 1	66 ± 1	43 ± 1	41 ± 1	26 ± 10	69 ± 12	26 ± 13	67 ± 11	20 ± 11	40 ± 12	41 ± 11
	p	187 ± 24	201 ± 7	222 ± 24	234 ± 11	202 ± 18	163 ± 3	187 ± 14	267 ± 32	240 ± 25	273 ± 5	189 ± 9	308 ± 44	188 ± 0	282 ± 24	150 ± 5	185 ± 4	312 ± 23

NCha—neochlorogenic acid; ChA—chlorogenic acid; Cy_gal—cyanidin-3-galactoside; Cy_glu—cyanidin-3-O-glucoside; Cy_ara—cyanidin-3-arabinoside; Ecat—epicatechin; Cat—catechin; Coum—p-coumaric acid; Caf—caffeic acid; Fer—ferulic acid; Ka—kaempferol; Isor—isorhamnetin; Q—quercetin; Qgal—quercetin-3-O-galactoside; Qglu—quercetin 3-glucoside; Qrut—quercetin-3-O-rutinoside; P_B1, P_B2, and P_C1—procyanidins B1, B2, and C1.

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Figure 4. PCA score plots of different Sorbus fruit (**a**), juice (**b**), and pomace (**c**) samples.

Selecting the cvs with the best yield (years 2019 and 2021) and antioxidant capacity, four potential cvs among sixteen emerged. Therefore, hybrid cvs Likernaja and Burka, as well as Nevezhino rowans Sahharnaja and Solnechnaja, but also the wild rowanberry will be used in the further studies.

5. Correlation Analysis

The correlation analysis demonstrated the significant correlations between the ORAC, ABTS$^{\bullet+}$, and DPPH$^{\bullet}$ scavenging values and the main phenolic groups in the *Sorbus* fruit, juice, and pomace fractions. As presented in **Table 4**, relatively strong positive correlations were found between all antioxidant assays using the pomace, fruit, and juice extracts and their TPC (0.40 < R^2 < 0.95) and ACY contents (0.48 < R^2 < 0.89). The correlations between ORAC, ABTS$^{\bullet+}$, and DPPH$^{\bullet}$ scavenging values and FLAVO contents of three extracts was moderate (0.47 < R^2 > 0.66), except the correlation between DPPH$^{\bullet}$ and FLAVO of fruit, which was weak (R^2 = 0.28).

Table 4. Correlation coefficients (R^2) between the content of different groups of polyphenolic compounds and the antioxidant capacity of 16 *Sorbus* fruit, juice, and pomace extracts.

	TPC			HCA			ACY			FLAVO		
Part	F	J	P	F	J	P	F	J	P	F	J	P
ABTS	0.872	0.723	0.749	0.537	0.558	0.105	0.751	0.751	0.820	0.658	0.591	0.491

	TPC			HCA			ACY			FLAVO		
DPPH	0.547	0.948	0.810	0.221	0.616	0.188	0.527	0.893	0.886	0.278	0.658	0.514
ORAC	0.822	0.493	0.708	0.512	0.265	0.289	0.685	0.476	0.517	0.652	0.567	0.466

uice, and

TPC—total phenolic content, HCA—hydroxycinnamic acids, ACY—anthocyanins, FLAVO—flavanols, F—fruit, J—juice, P—pomace.

In the case of pomace extracts, the weak correlations were found between the radical scavenging values determined by ORAC, ABTS$^{•+}$, and DPPH$^{•}$ methods and the contents of HCA; however, there was a moderate correlation between the ORAC and ABTS$^{•+}$ scavenging values and HCA content in the fruit, as well as between ABTS$^{•+}$ and DPPH$^{•}$ scavenging values and HCA content in juice extracts. The differences in correlations with polyphenolic groups and various radical scavenging methods, while using the same extracts, can be explained by the different reaction mechanisms in ORAC, ABTS$^{•+}$, and DPPH$^{•}$ assays, as described earlier.

The correlations between antioxidant assays and phenolic groups are different while using the whole fruit, pressed juice, or pomace for the analysis. In the current study working with 16 *Sorbus* cultivars and wild rowanberry, the major part (on average 85%) of the weight of fresh rowanberries comprised juice; therefore, it is expected that the fruit and juice could have comparable composition. The correlation analysis demonstrated comparable correlations between the antioxidant assays and polyphenolic groups of fruit and juice. The antioxidant activity of pomace samples, which consist mainly of peel and seeds, is influenced by TPC and ACY contents and moderately by FLAVO content in the samples, while in the case of the fruit and juice samples, HCA contents have an additional effect on radical scavenging values. Compared to the fruit and juice extracts, pomace extracts hold higher concentrations of protocatechuic acid and isorhamnetin, but also epicatechin, catechin, and procyanidins B1, B2, and C1, making the pomace fraction a considerable source of natural antioxidants.

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