Effect of dried powder preparation process on polyphenolic content and antioxidant activity of blue honeysuckle berries (*Lonicera caerulea* L. *var. kamtschatica*)

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ABSTRACT

The aim of the study was to evaluate different methods used for the preparation of powders from blue honeysuckle (*Lonicera caerulea* L. *var. kamtschatica*) cv. 'Wojtek', and the effects of these methods on chemical composition and antioxidant activity of lyophilized powders and pomace. The analyzed samples were evaluated for their basic chemical composition dry weight, pH, total acidity, sugars (glucose, fructose and sucrose), and antioxidant capacity (FRAP, ABTS). Polyphenolic compounds were identified and quantified by UPLC-PDA-MS/MS. Thirty eight polyphenolic compounds, including eight phenolic acids, eight anthocyanins, five flavan-3-ols, twelve flavonols and five flavones were identified in blue honeysuckle products. The highest content of bioactive compounds was detected in juice pressed from peels, as compared with fresh berries and other products. The study showed that peel-based pomace of blue honeysuckle is a better material for the production of dried product rich in bioactive compounds than the pomace obtained from whole berries.

1. Introduction

Blue honeysuckle is a variety of honeyberry (*Lonicera caerulea*), a shrub belonging to Caprifoliaceae family (Juss.). It is native to northeastern Russia, China, Japan and Canada. In Russia, the only cultivated varieties are hybrids of *L. caerulea* var. kamtschatica Sevast. and other varieties of honeyberry, particularly *L. kamtschatica* var. edulis. In Japan (Hokkaido), this variety was crossbred with *L. kamtschatica* var. emphyllocalyx, and in Canada with native *L. kamtschatica* var. villosa. In the wild, blue honeysuckle is found in wetlands along rivers, marshes or on forest clearings (Miyashita, Ohashi, Shibata, Araki, & Hoshino, 2009; Plekhanova, 2000; Szot & Lipa, 2012).

The fruit is a fleshy, elongated, purple-black, wax-coated berry, 2—3 cm long and about 1 cm in diameter. A single berry may weigh up to 3 g. As stone fruit, they contain up to 20 soft seeds imperceptible during consumption. The berries have a characteristic pleasant taste with a hint of bitterness. Contrary to bilberry, a ripe berry is dark in entire cross-section (Plekhanova, 2000). Currently, blue honeysuckle (*L. caerulea* L.) is becoming increasingly popular mainly due to its health promoting properties. Its fruit, similarly to elderberry and bilberry, may be a valuable component of medicinal products or food supplements as they contain many beneficial ingredients (Thompson & Chaovanalikit, 2003). Dark colored berries contain more polyphenols than strawberries or raspberries. They produce considerable amounts of vitamins, minerals and polyphenols that positively affect human health and make blue honeysuckle an attractive plant in terms of disease prevention and nutritional value (Skupień, Oszmiański, Ochmian, & Grajkowski, 2007; Wojdyło, Jáuregui, Carbonell-Barrachina, Oszmiański, & Golis, 2013).

Polyphenols present in blue honeysuckle berries have anti-inflammatory properties, and they mitigate the risk of metabolic diseases such as obesity or diabetes (Jin et al., 2005; Palikova, Valentova, Oborna, & Ulrichova, 2009). They reduce oxidation of LDL cholesterol responsible for increased risk of cardiovascular diseases, and positively affect hypertension by lowering blood pressure. Thanks to their detoxifying properties, the berries are often used to alleviate drug or heavy metal poisoning or to treat cardiovascular diseases. Blue honeysuckle berries exhibit strong antibacterial and antiviral activity (Celli, Ghanem, & Brooks, 2014). Therefore, fruit-derived compounds may be used in the prevention of oral cavity diseases. They also prevent urinary tract infections by

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limiting bacteria penetration into the urinary tract. They protect tissues against detrimental UV radiation that accelerates aging processes and induces skin and DNA damage (Jin et al., 2005; Skupień et al., 2007). Blue honeysuckle is recommended for alleviating food allergies. Its juice may be used for treating lichens and ulcers, and a decoction is recommended for rinsing the throat and oral cavity in gum diseases, tonsilitis and inflammation of the mucous membranes (Li & Li, 2005).

Blue honeysuckle berries are currently used for making jams, jellies, wine, candies, gelatin, puffed snacks (Liu, Zheng, Jia, Ding, & Gao, 2009; Liu et al., 2010), juice, juice-concentrate, tea, canned and frozen fruit, medicinal products as an antioxidant and healthy food (Skupień et al., 2007). Dried berries are a durable and convenient blue honeysuckle product that can be easily crushed and used as a raw material for the production of dietary supplements in the form of capsules and tablets. Drying procedure should not induce degradation of thermolabile substances, which is why lyophilization is one of the best ways of obtaining this type of product (Kozłowska, & Troszyńska, 1999).

It is difficult to lyophilize small berries by prolonging the freeze-drying time due to their thick peel that impedes water removal. Wax covering the peel protects the berries from water, insects and fungi. This way, the peel limits water transport from the interior of a food product to its surface, slowing the drying process. Since the berry peel is thick and has low porosity, a pre-treatment stage was considered before drying in order to facilitate water diffusion. There are mechanical pre-treatment methods that reduce the peel resistance and promote water transport. The berries are often processed to make fruit juice and various fruit drinks (Vattem, Ghaedian, & Shetty,2005). About 80–85% of the berry mass is transferred to the juice, while 15–20% remains in a pomace that is a waste material. Berry pomace is a by-product of the fruit juice processing industry. It is composed of pulp, peel and seeds of the fruit left after the juice and water are pressed from the fruit. Traditionally, the pomace has been used in animal feeding, however, due to its poor nutritional value it is disposed of into landfills causing considerable economic loss and environmental problems. Food technologists have recently developed a technology for preparing a powder from berry pomace that contains all the essential bioactive compounds (White, Howard, & Prior, 2010).

The aim of the study was to investigate the possibility of preparing a dry powder with high content of bioactive compounds from the pomace instead of whole berries. The berries contain considerable amounts of acids and sugars, are hygroscopic and difficult to dry. Juice pressing removes about 80% of water and most of sugars and acids and some polyphenolic compounds. The study compared the chemical composition (dry weight, pH, total acidity, sugars (glucose, fructose and sucrose), polyphenolic composition and antioxidant activity (FRAP, ABTS)) pomace obtained in a standard way from crushed fruit with the pomace resulting from pressing the whole berries, and peels and flesh separately.

2. Materials and methods

2.1. Reagents and standards

Acetonitrile, formic acid, methanol, ABTS (2,2'-azinobis-(3-ethylbenzothiazoline-6-sulphonic acid), Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), TPTZ (2,4,6-Tri(2-pyridyl)-s-triazine), acetic acid and phloroglucinol were purchased from Sigma–Aldrich (Steinheim, Germany). (−)-Epicatechin, (+)-catechin, chlorogenic acid, neochlorogenic acid, 3,5-dicaffeoylquinic acid and procyanidins B, *p*-coumaric acid, isoquercetin, caffeic acid, luteolin-3-*O*-glucoside, pelargonidin-3-*O*-glucoside, peonidin-3-*O*-glucoside, cyanidin-3-*O*-glucoside, and

isorhamnetin-3-*O*-rutinoside were purchased from Extrasynthese (Lyon, France).

2.2. Plant materials

Fruits of 'Wojtek' blue honeysuckles (~15 kg) were obtained from horticultural farm in Piotrowice, near Wrocław. The raw material was collected at optimum ripening stage recommended for consumption. The juice was pressed from crashed, whole fruits, hand speared skins and flesh on a laboratory press Zodiak. The pomaces and fruits were dried with the use of freeze dryer Alpha 1–4 LSC (Christ, Osterode, Germany). The homogeneous powders were obtained by crushing the dried tissues using a closed laboratory mill (IKA A.11, Germany) to avoid hydration, and the powder was passed through a strainer (1 mm). The powders were kept in a refrigerator (−80 °C) until extract preparation. The basic parameters of the chemical composition: dry matter, and acidity were determined in fruit, pomaces and blue honeysuckle dry powders according by Wojdyło, Jáuregui, et al. (2013). Results are reported as the arithmetic mean of three independent repetitions, taking into account the standard deviation (SD).

2.3. Extraction procedure

The fresh and dried samples of fruits and pomace were extracted with methanol acidified with 2.0% formic acid. The extraction was performed twice by incubation for 20 min under sonication (Sonic 6D, Polsonic, Warsaw, Poland) and with occasional shaking. Next, the slurry was centrifuged at 19,000 × g for 10 min, and the supernatant was filtered through a Hydrophilic PTFE 0.20 μm membrane (Millex Samplicity Filter, Merck) and used for analysis. The content of polyphenols in individual extracts was determined by means of the ultra-performance liquid chromatography-photodiode array detector-mass spectrometry (LC−PDA−MS) method. All extractions were carried out in triplicate.

2.4. Identification and quantification of polyphenols by the LC−PDA−MS method

Identification and quantification of polyphenol of blue honeysuckle extracts was carried out with the use of an ACQUITY Ultra Performance LC system equipped with a photodiode array detector with a binary solvent manager (Waters Corporation, Milford, MA) series with a mass detector G2 Q/Tof Micro mass spectrometer (Waters, Manchester, U.K.) equipped with an electrospray ionization (ESI) source operating in negative and positive modes. The content of polyphenols (anthocyanin, flavanolos, flavonol and phenolic acid) was measured by protocol described previously by Wojdyło, Jáuregui, et al. (2013).

2.5. Analysis of proanthocyanidins by phloroglucinolysis

Direct phloroglucinolysis of freeze-dried samples was performed as described by Kennedy and Jones (2001) on reverse-phase HPLC (RP-HPLC) analysis and phloroglucinol products were separated on a Cadenza CD C18 (75–4.6 mm, 3 μm) column (Imtakt, Japan) (Wojdyło, Oszmiański, Milczarek, & Wietrzyk, 2013).

2.6. Antioxidant activity

The extracts for analysis of antioxidant activity was prepared as described previously by Wojdyło, Jáuregui, et al. (2013). The free radical scavenging activities were determined using two methods, ABTS and FRAP (ferric reducing antioxidant power). The ABTS and FRAP assays were conducted as previously described by Re,

Pellegrini, Proteggente, Pannala, and Yang (1999) and Benzie and Strain (1996), respectively. Determinations by ABTS and FRAP methods were performed using a UV-2401 PC spectrophotometer (Shimadzu, Kyoto, Japan). The antioxidant activity was evaluated by measuring the variation in absorbance at 734 nm after 6 min for ABTS, and at 593 nm after 10 min for FRAP. All antioxidant activity analyses were done in triplicate, and results were expressed as μmol of Trolox per 1 g of sample.

2.7. Analysis of sugar by the HPLC-ELSD method

Analysis of sugars by the HPLC-ELSD method was performed as described by Valliyodan, Shi, and Nguyen (2015) with modification. The samples of blue honeysuckle fruits (1–2 g) were diluted with redistilled water (50 ml). The extraction was performed by incubation for 15 min under sonication (Sonic 6D, Polsonic, Warsaw, Poland) and with occasional shaking, and then incubation in 90 °C for 30 min. Next, the slurry was centrifuged at 19000g for 10 min, and the supernatant was filtered through a Sep-Pak C-18 Cartridges (Waters Milipore), and through a Hydrophilic PTFE 0.20 μm membrane (Millex Samplicity Filter, Merck) and used for analysis. All extractions were carried out in triplicate.

Chromatographic analysis was carried out with a Merck-Hitachi L-7455 liquid chromatograph with an evaporative light scattering detector (ELSD; Polymer Laboratories PL-ELS 1000) and quaternary pump L-7100 equipped with D-7000 HSM Multisolvent Delivery System (Merck-Hitachi, Tokyo, Japan) and L-7200 autosampler. The separation was performed on a Prevail™ Carbohydrate ES HPLC Column-W 250 × 4.6 mm, 5 μm (Alltech, US) column. Oven temperature was set to 30 °C. The mobile phase was used with an acetonitrile–water (75:25) for isocratic elution, the flow rate was 1 ml/min and injection volume: 10 μl. The ELS detector was optimized for the analyses and following parameters were used: 80 °C for an evaporative temperature, 80 °C for a nebulizer and 1.2 ml/min for a nitrogen gas flow.

The calibration curves ($R^2 = 0.9998$) were created for glucose, fructose and saccharine. Sample concentrations were 1, 2, 3 and 5 mg/ml and each concentration level was injected (10 μl) in triplicate. All sugars analyses were done in triplicate, and results were expressed as g per 100 g of sample.

2.8. Statistical analysis

Results were presented as mean ± standard deviation of three independent determinations. All statistical analyses were performed with Statistica version 10.0 (StatSoft, Tulsa, OK, USA). One-way analysis of variance (ANOVA) by Duncan's test at $p < 0.05$ was used to compare the mean values.

3. Results and discussion

3.1. Quality parameters of berries and their products

Dry matter accounted for 16.02 g/100 g of fresh blue honeysuckle berry mass (Table 1), which was slightly more than in other studies on this species (Szot & Lipa, 2012; Thompson & Chaovanalikit, 2003).

pH of fresh blue honeysuckle berries was 2.65, and total acidity was 3.60 g citric acid/100 g (Table 1). Ochmian, Skupień, Grajkowski, Smolik, and Ostrowska (2012) reported titratable acidity in 'Wojtek' cv. from 3.4 to 4.4 g citric acid/100 g, depending on fruit maturity In general, honeysuckle berries are rich in organic acids. High amounts of acids impart a specific taste resembling bilberries with a distinct hint of acidity.

Sugar content of the berries was 6.48 g/100 g, with glucose as a dominant sugar (3.64 g/100 g) and fructose (2.80 g/100 g) and sucrose (0.04 g/100 g) as less abundant ones. Palikova et al. (2009) showed that honeysuckle fruit contained 7.20 g/100 g of saccharides and that free saccharides included 3.2 g/100 g glucose and 2.9 g/100 g fructose. Szot and Lipa (2012) estimated total sugar content to be 5.50 g/100 g in fresh honeysuckle berries.

Fresh pomace made of whole or crushed berries or from peels or flesh had pH ranging from 2.60 to 2.78, and total acidity (2.94–3.54 g citric acid/100 g) was almost stable except for the products obtained from whole berry pomace (2.94 g citric acid/100 g). The content of sugars in these products was significantly ($p < 0.05$) higher compared to fresh berries, except for the fresh product prepared from flesh-based pomace (5.44 g/100 g). The lowest content of dry mass was determined for the fruit (16.02 g/100 g). The pomace left after juice pressing included more dry matter, from 19.72 g/100 g after pressing the whole berries to 32.11 g/100 g after pressing the flesh. Therefore, obtaining dry berries from pomace is not only easier but it also requires less effort to remove water than from fruit. The final content of dry matter in dried berries after 24 h of lyophilization was 91.27 g/100 g, and in the dry product obtained from pomace it was up to 93.83 g/100 g for whole berries and 95.96 g/100 g for peels.

3.2. Identification of phenolic compounds in blue honeysuckle berries and their products

Identification of 38 compounds belonging to anthocyanins, hydroxycinnamic acids, flavonols, flavons and flavan-3-ols was based on a comparison of their retention times, MS and MS/MS data with available standards and published data. The identification results are presented in Table 2. Structures of all these compounds were identified by comparison of their spectral and MS and/or MS/MS data to those reported in previous studies (Chaovanalikit,

Table 1
Chemical composition of samples prepared from honeysuckle berries.

Type of products	Samples	Dry matter [g/100 g]	Total acidity [g/100 g]	pH	Sugars [g/100 g]			
					Fructose	Glucose	Saccharose	Total sugars [g/100 g]
Fresh	Berries	16.02 ± 0.32	3.60 ± 0.07	2.65 ± 0.05	2.80 ± 0.06	3.64 ± 0.07	0.04 ± 0.00	6.48
	Pomace from whole berries	19.72 ± 0.39	2.94 ± 0.06	2.60 ± 0.07	5.16 ± 0.10	6.80 ± 0.14	0.00 ± 0.00	11.96
	Pomace from crashed berries	23.94 ± 0.49	3.27 ± 0.07	2.62 ± 0.05	3.72 ± 0.07	5.00 ± 0.10	0.04 ± 0.01	8.76
	Pomace from skin	28.60 ± 0.57	3.02 ± 0.06	2.78 ± 0.06	3.96 ± 0.08	5.60 ± 0.11	0.04 ± 0.02	9.60
	Pomace from flesh	32.11 ± 0.64	3.54 ± 0.07	2.75 ± 0.06	2.20 ± 0.04	3.24 ± 0.06	0.00 ± 0.00	5.44
Dried	Berries	91.27 ± 1.83	23.93 ± 0.48	2.70 ± 0.08	19.56 ± 0.39	24.04 ± 0.48	0.20 ± 0.03	43.80
	pomace from whole berries	93.83 ± 1.88	12.51 ± 0.25	2.77 ± 0.05	23.28 ± 0.47	26.36 ± 0.52	0.20 ± 0.05	49.84
	Pomace from crashed berries	94.74 ± 1.90	11.69 ± 0.23	2.76 ± 0.06	12.56 ± 0.25	15.56 ± 0.31	0.12 ± 0.00	28.24
	Pomace from skin	95.96 ± 1.92	11.00 ± 0.22	2.82 ± 0.09	14.96 ± 0.30	17.72 ± 0.35	0.16 ± 0.03	32.84
	Pomace from flesh	95.41 ± 1.91	8.07 ± 0.16	2.82 ± 0.06	5.68 ± 0.11	7.88 ± 0.16	0.12 ± 0.01	13.68

Means ± SD followed by different letters within the same line represent significant differences (P < 0.05). Data are the averages of triplicates.

Table 2
LC-QTOF/MS analysis of phenolic compounds in blue honeysuckle berries.

Compound	T_R (min)	λ_{max} (nm)	MS[M−H]⁻ (m/z)	MS/MS[M−H]⁻ (m/z)
Neochlorogenic acid	2.80	325	353	191
Procyanidin dimer	3.16	278	577	289
Cyanidin-3,5- diglucoside	3.49	525	611⁺	449/287⁺
(+)-Catechin	3.57	278	289	245
Chlorogenic acid	3.74	325	353	191
Cryptochlorogenic acid	3.80	325	353	191
Caffeic-quinic acid	3.86	325	353	191
Procyanidin dimer	3.96	279	577	289
Peonidin-3,5-dihexoside	4.08	523	625⁺	301⁺
Luteolin-3-dihexoside-7-hexoside	4.10	346	771	609/447/285
Cyanidin-3-O-glucoside	4.29	525	449⁺	287⁺
Cyanidin-3-O-rutinoside	4.51	525	595⁺	449/287⁺
(−)-Epicatechin	4.60	278	289	245
Caffeic-quinic acid	4.65	325	353	191
Procyanidin trimer	4.70	279	865	557/289
Pelargonidin-3-O-glucoside	4.82	515	433⁺	271⁺
Peonidin-3-O-glucoside	5.13	525	463⁺	301⁺
Peonidin-3-O-rutinoside	5.21	525	609⁺	449/301⁺
Quercetin-dihexoside	5.54	353	625	301
Quercetin-vicianoside	5.81	353	595	433/301
Quercetin-3-hexoside-pentoside	5.94	353	595	449/301
Cyanidin-3-hexoside-ethyl-catechin	6.06	525	765⁺	603/475/313/287⁺
Quercetin-3-O-rutinoside	6.10	352	609	301
Quercetin-3-O-rhamnosiy-hexoside	6.24	352	609	301
Quercetin-3-O-rhamnoside-hexoside	6.32	352	609	301
Luteolin-O-hexose-O-deoxyhexoside	6.40	347	593	285
Quercetin-3-O-glucoside	6.44	352	463	301
Luteolin-3-O-glucoside	6.56	347	447	285
Quercetin-pentoside	6.69	352	433	301
Isorhamnetin -hexosylpentoside	6.77	350	609	315
Luteolin-3-O-rutinoside	6.99	347	593	285
3,5-dicaffeoylquinic acid	7.14	326	515	353/191
Isorhamnetin-3-O-rutinoside	7.18	350	623	315
Quercetin- acetyl -hexoside	7.44	352	505	301
Diosmetin-rhamnosylglucoside	7.66	340	607	299
Dicaffeoylquinic acid	7.74	326	515	353/191
Dicaffeoylquinic acid	7.99	326	515	353/191
Quercetin-pentoside	8.43	352	433	301

Thompson, & Wrolstad, 2004; Ochmian et al., 2012; Skupień et al., 2007; Wojdyło, Jáuregui, et al. 2013; and Kusznierewicz et al., 2012).

3.3. Quantification of phenolic compounds in blue honeysuckle fresh berries and pomace

The content of phenolics is one of the most important parameters for appraising blue honeysuckle berries with respect to their nutraceutical value and potential use for different technological purposes. The content of polyphenolic compounds in fresh berries and pomace that were the raw material for the production of dry powders is presented in Table 3 and Fig. 2.

Major polyphenolic groups in the berries were mono, di, tri-, and polymers of flavan-3-ols (61% of total phenolic compounds, TPC), and the next group were anthocyanins (29% of TPC). The third group were phenolic acids (7%), and the last were flavonols + flavons that constituted only 3% of TPC. The type and content of polyphenolic compounds detected in blue honeysuckle berries were similar to those previously reported by Wojdyło, Jáuregui, et al. (2013) for different cultivars of blue honeysuckle berries. Other researchers (Chaovanalikit et al., 2004; Ochmian et al., 2012) reported lower content of total phenolic groups but they investigated only catechin monomer as a representative of flavan-3-ols without any quantification of polymeric procyanidins.

Flavan-3-ols were the major group of blue honeysuckle polyphenols amounting to 690.77 mg/100 g fw with polymeric procyanidins as dominant compounds (87% of total flavan-3-ols).

(+)-Catechin concentration was 80.42 mg/100 g fw, while (−)-epicatechin concentration was 3.19 mg/100 g fw. The content of flavan-3-ols was similar to that of black currant but higher than that of red currant (Wojdyło, Oszmiański, et al., 2013).

Anthocyanins belong to phenolic compounds that contribute to red, blue, and/or purple color of many fruit, including blue honeysuckle berries. These compounds are also well known for their antioxidant activity and health-promoting properties (Palikova et al., 2009). The content of total anthocyanins in blue honeysuckle was 335.24 mg/100 g fw with cyanidin-3-O-glucoside (295.3 mg/100 g fw) as a major anthocyanin, and much lower content of the other seven anthocyanins (below 30 mg/100 g fw). The presence of this type of anthocyanins and (+)-catechin confirmed earlier findings (Chaovanalikit et al., 2004; Ochmian et al., 2012; Wojdyło, Jáuregui, et al., 2013).

Phenolic acid level was 79.73 mg/100 g fw, and predominating phenolic acids in blue honeysuckle berries were chlorogenic acid (66.44 mg/100 g fw) and neochlorogenic acid (9.65 mg/100 g fw). The content of other phenolic acids was lower than 2 mg/100 g fw (Table 5). Concentration of phenolic acids is very important, especially of chlorogenic acid, because they are precursors of flavor (Guyot, Marnet, Laraba, Sanoner, & Drilleau, 1998) not only in fruit but also in fruit-based products (see Table 3).

Total concentration of flavonol + flavon derivatives was 31.15 mg/100 g fw, and flavonols accounted for 95% of total flavonols + flavons. The amount of these compounds in blue honeysuckle berries was similar to blue honeysuckle berries grown in Oregon (Thompson & Chaovanalikit, 2003). Quercetin derivatives

Table 3
Polyphenol content in the blue honeysuckle fruits and fresh pomaces [mg/100 g fw].

Compound	Fruits	Pomace from			
		Whole fruits	Crashed fruits	Skins	Flesh
Neochlorogenic acid	9.65 ± 0.19d	30.08 ± 0.60b	32.74 ± 0.65b	45.84 ± 0.91a	19.85 ± 0.40c
Procyanidin dimer	7.05 ± 0.14d	20.13 ± 0.40c	23.81 ± 0.48c	32.41 ± 0.65a	28.89 ± 0.58 ab
Cyanidin-3,5- diglucoside	7.39 ± 0.15d	28.46 ± 0.57c	32.59 ± 0.65b	49.15 ± 0.98a	7.59 ± 0.15d
(+)-Catechin	80.42 ± 1.61d	336.90 ± 6.74c	385.01 ± 7.70b	512.96 ± 10.26a	366.33 ± 7.33c
Chlorogenic acid	66.44 ± 1.33d	190.95 ± 3.18b	198.56 ± 3.97b	277.26 ± 5.55a	155.07 ± 3.10bc
Cryptochlorogenic acid	0.87 ± 0.02e	3.11 ± 0.06b	2.79 ± 0.06c	4.65 ± 0.09a	1.92 ± 0.04d
Caffeic-quinic acid	0.44 ± 0.01c	1.45 ± 0.03b	1.33 ± 0.03b	1.99 ± 0.04a	0.58 ± 0.01c
Procyanidin dimer	0.17 ± 0.00c	0.34 ± 0.01b	0.40 ± 0.01b	0.44 ± 0.01b	0.74 ± 0.01a
Peonidin-3,5-dihexoside	0.44 ± 0.01c	1.84 ± 0.04b	1.63 ± 0.03b	2.36 ± 0.05a	0.45 ± 0.01c
Luteolin-3-dihexoside-7-hexoside	0.57 ± 0.01c	1.73 ± 0.03b	1.76 ± 0.04b	2.72 ± 0.05a	0.54 ± 0.01c
Cyanidin-3-*O*-glucoside	295.30 ± 5.91d	1010.15 ± 20.20b	1401.98 ± 28.04b	2171.96 ± 43.44a	557.17 ± 11.14c
Cyanidin-3-*O*-rutinoside	27.02 ± 0.54d	82.35 ± 1.65c	120.54 ± 2.41b	183.73 ± 3.68a	35.42 ± 0.71d
(−)-Epicatechin	3.19 ± 0.06d	12.56 ± 0.25a	8.29 ± 0.17c	14.80 ± 0.30a	11.20 ± 0.22 ab
Caffeic-quinic acid	1.14 ± 0.02d	3.16 ± 0.06b	2.86 ± 0.06c	4.95 ± 0.10a	2.18 ± 0.04c
Procyanidin trimer	0.68 ± 0.01d	3.82 ± 0.08bc	4.33 ± 0.09b	6.52 ± 0.13a	4.00 ± 0.08b
Pelargonidin-3-*O*-glucoside	0.76 ± 0.02e	2.75 ± 0.06c	3.35 ± 0.07b	5.42 ± 0.11a	1.42 ± 0.03d
Peonidin-3-*O*-glucoside	3.55 ± 0.07d	17.98 ± 0.36b	19.28 ± 0.39b	30.19 ± 0.60a	6.19 ± 0.12c
Peonidin-3-*O*-rutinoside	0.61 ± 0.01d	2.10 ± 0.04b	2.84 ± 0.06b	4.80 ± 0.10a	1.24 ± 0.03c
Quercetin-dihexoside	0.78 ± 0.02d	2.41 ± 0.05c	3.79 ± 0.08b	5.02 ± 0.10a	0.72 ± 0.01c
Quercetin-vicianoside	2.95 ± 0.06e	12.13 ± 0.24c	17.52 ± 0.35b	22.33 ± 0.45a	3.20 ± 0.06d
Quercetin-3-hexoside-pentoside	0.24 ± 0.00d	1.14 ± 0.02c	1.58 ± 0.03b	2.02 ± 0.04a	0.20 ± 0.00d
Cyanidin-3-hexoside-ethyl-catechin	0.17 ± 0.00c	0.24 ± 0.00c	0.34 ± 0.01b	0.67 ± 0.01a	0.30 ± 0.01b
Quercetin-3-*O*-rutinoside	0.21 ± 0.00d	0.71 ± 0.01c	1.11 ± 0.02b	1.40 ± 0.03a	0.36 ± 0.01d
Quercetin-3-*O*-rhamnosyl-hexoside	23.74 ± 0.47d	83.90 ± 1.68c	129.63 ± 2.59b	162.29 ± 3.25a	21.73 ± 0.43d
Quercetin-3-*O*-rhamnoside-hexoside	0.19 ± 0.00d	0.87 ± 0.02c	1.19 ± 0.02b	1.64 ± 0.03a	0.56 ± 0.01c
Luteolin-*O*-hexose-*O*-deoxyhexoside	0.20 ± 0.00d	1.57 ± 0.03b	1.39 ± 0.03b	3.38 ± 0.07a	0.69 ± 0.01c
Quercetin-3-*O*-glucoside	1.84 ± 0.03e	9.00 ± 0.18c	12.57 ± 0.25b	16.97 ± 0.34a	3.54 ± 0.07d
Luteolin-3-*O*-glucoside	0.13 ± 0.00d	2.98 ± 0.06a	0.86 ± 0.02c	1.39 ± 0.03b	0.31 ± 0.01d
Quercetin-pentoside	0.29 ± 0.01d	1.37 ± 0.03c	2.05 ± 0.04b	3.09 ± 0.06a	0.53 ± 0.01d
Isorhamnetin -hexosylpentoside	0.16 ± 0.00d	0.53 ± 0.01c	0.74 ± 0.01b	0.97 ± 0.02a	0.18 ± 0.00d
Luteolin-3-*O*-rutinoside	0.30 ± 0.01d	0.93 ± 0.02c	1.49 ± 0.03b	2.06 ± 0.04a	0.34 ± 0.01d
3,5-dicaffeoylquinic acid	1.09 ± 0.02d	14.14 ± 0.28c	20.63 ± 0.41b	20.65 ± 0.41b	45.22 ± 0.90a
Isorhamnetin-3-*O*-rutinoside	1.15 ± 0.02e	4.08 ± 0.08c	5.99 ± 0.12b	9.13 ± 0.18a	1.87 ± 0.04d
Quercetin- acetyl -hexoside	1.00 ± 0.02e	5.46 ± 0.011c	7.40 ± 0.15b	10.33 ± 0.21a	2.08 ± 0.04d
Diosmetin-rhamnosylglucoside	0.33 ± 0.01d	1.31 ± 0.03c	2.26 ± 0.05b	7.04 ± 0.14a	1.61 ± 0.03c
Dicaffeoylquinic acid	0.15 ± 0.00d	0.47 ± 0.01c	0.93 ± 0.02b	1.94 ± 0.04a	1.06 ± 0.02b
Dicaffeoylquinic acid	0.15 ± 0.00d	0.82 ± 0.02b	0.83 ± 0.02b	1.15 ± 0.02a	0.59 ± 0.01c
Quercetin-pentoside	0.07 ± 0.00d	0.58 ± 0.01c	0.76 ± 0.02b	1.13 ± 0.02a	0.38 ± 0.01c
Procyanidin polymers	599.26 ± 11.99d	542.59 ± 10.85d	654.53 ± 13.09c	1244.77 ± 24.90a	720.58 ± 14.41b
Total	**1140.06e**	**2437.12c**	**3111.71b**	**4871.57a**	**2006.82d**

Means ± SD followed by different letters within the same line represent significant differences ($p < 0.05$). Data are the averages of triplicates.
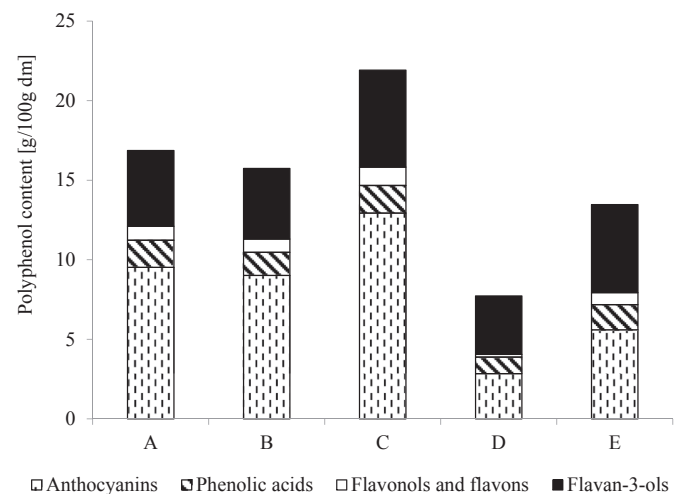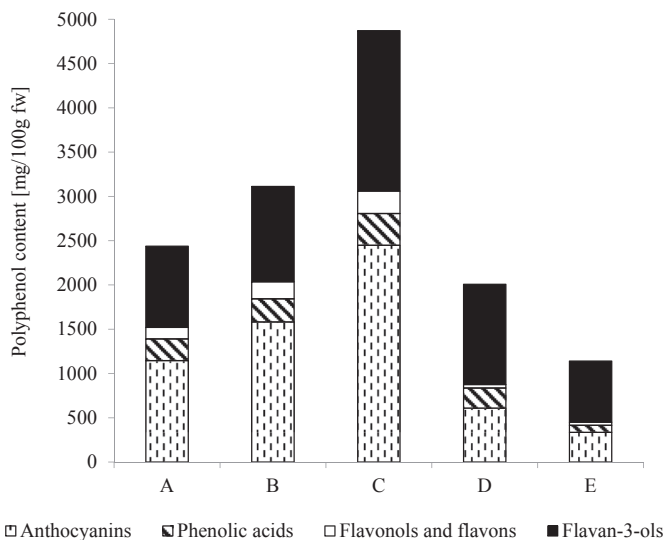

Fig. 1. Polyphenol group content in the blue honeysuckle fresh fruits and pomaces [mg/100 g fw]. Abbreviations: **A-**pomace after pressing of uncrushed fruits; **B**- pomace after pressing of crushed fruits; **C**- pomace after skin pressing; **D-**pomace after flesh pressing; **E-**fresh fruits.

Fig. 2. Polyphenol group content in the blue honeysuckle powder from dried fruits and pomaces [g/100 g dm]. Abbreviations: **A-**pomace after pressing of uncrushed fruits; **B**- pomace after pressing of crushed fruits; **C**- pomace after skin pressing; **D-**pomace after flesh pressing; **E-**dried fruits.

Table 4
Polyphenol content in the dried blue honeysuckle powders from fruits and pomaces [mg/100 g dw].

Compound	Fruits	Pomace from			
		Whole fruits	Crashed fruits	Skin	Flesh
Neochlorogenic acid	169.26 ± 3.39b	211.11 ± 4.22a	172.25 ± 3.45b	224.91 ± 4.50a	83.25 ± 1.67c
Procyanidin dimer	113.54 ± 2.27b	119.65 ± 2.39a	121.26 ± 2.43a	121.26 ± 2.43a	115.28 ± 2.31b
Cyanidin-3,5-diglucoside	101.27 ± 2.03d	186.69 ± 3.73b	155.44 ± 3.11c	240.24 ± 4.80a	36.34 ± 0.73e
(+)-Catechin	1804.71 ± 36.09b	2013.13 ± 40.26a	1696.98 ± 33.94d	1733.85 ± 34.68c	1368.21 ± 27.36e
Chlorogenic acid	1286.78 ± 25.74c	1303.52 ± 26.07b	1109.80 ± 22.20d	1377.14 ± 27.54a	647.72 ± 12.95e
Cryptochlorogenic acid	13.47 ± 0.27c	19.82 ± 0.40b	15.58 ± 0.31c	24.09 ± 0.48a	8.10 ± 0.16d
Caffeic-quinic acid	5.98 ± 0.12b	9.42 ± 0.19a	5.78 ± 0.12b	9.85 ± 0.20a	2.01 ± 0.04c
Procyanidin dimer	5.01 ± 0.10c	7.52 ± 0.15b	5.31 ± 0.11c	8.18 ± 0.16a	1.11 ± 0.02d
Peonidin-3,5-dihexoside	7.79 ± 0.16d	11.00 ± 0.22c	14.56 ± 0.29b	18.61 ± 0.37a	3.36 ± 0.07e
Luteolin-3-dihexoside-7-hexoside	8.23 ± 0.16b	12.33 ± 0.25a	8.49 ± 0.17b	12.59 ± 0.25a	2.08 ± 0.04c
Cyanidin-3-O-glucoside	5011.56 ± 100.23c	8499.57 ± 169.99b	8107.39 ± 162.15b	11,610.45 ± 232.21a	2574.95 ± 51.50d
Cyanidin-3-O-rutinoside	415.71 ± 8.31d	708.47 ± 14.17b	603.78 ± 12.08c	897.85 ± 17.96a	151.90 ± 3.04e
(−)-Epicatechin	58.57 ± 1.17b	80.55 ± 1.61a	52.22 ± 1.04b	59.00 ± 1.18b	35.17 ± 0.70c
Caffeic-quinic acid	22.89 ± 0.46a	5.55 ± 0.11d	18.88 ± 0.38b	13.20 ± 0.26c	14.52 ± 0.29c
Procyanidin trimer	39.33 ± 0.79a	11.13 ± 0.22cd	16.53 ± 0.33b	12.22 ± 0.24c	17.21 ± 0.34b
Pelargonidin-3-O-glucoside	12.28 ± 0.25d	18.89 ± 0.38b	15.74 ± 0.31c	22.36 ± 0.45a	5.21 ± 0.10e
Peonidin-3-O-glucoside	45.68 ± 0.91d	95.28 ± 1.91c	112.57 ± 2.25b	134.98 ± 2.70a	30.77 ± 0.62e
Peonidin-3-O-rutinoside	1.14 ± 0.02c	4.50 ± 0.09b	3.77 ± 0.08b	17.97 ± 0.36a	0.56 ± 0.01d
Quercetin-dihexoside	14.07 ± 0.28c	19.07 ± 0.38b	16.77 ± 0.34bc	23.02 ± 0.46a	2.96 ± 0.06d
Quercetin-vicianoside	66.96 ± 1.34cd	86.06 ± 1.71b	77.03 ± 1.54c	104.37 ± 2.09a	13.43 ± 0.27e
Quercetin-3-hexoside-pentoside	6.12 ± 0.12b	6.93 ± 0.14b	6.38 ± 0.13b	8.03 ± 0.16a	0.82 ± 0.02c
Cyanidin-3-hexoside-ethyl-catechin	1.90 ± 0.04b	0.83 ± 0.02e	1.57 ± 0.03c	1.23 ± 0.02d	2.15 ± 0.04a
Quercetin-3-O-rutinoside	3.44 ± 0.07c	6.02 ± 0.12a	3.69 ± 0.07c	4.13 ± 0.08b	1.13 ± 0.02d
Quercetin-3-O-rhamnosyl-hexoside	513.08 ± 10.26bc	577.21 ± 11.54b	575.78 ± 11.52b	764.72 ± 15.29a	92.50 ± 1.85d
Quercetin-3-O-rhamnoside-hexoside	4.80 ± 0.10b	6.23 ± 0.12a	4.12 ± 0.08b	3.92 ± 0.08b	2.41 ± 0.05c
Luteolin-O-hexose-O-deoxyhexoside	6.15 ± 0.12b	7.13 ± 0.14b	5.85 ± 0.12c	16.72 ± 0.33a	4.49 ± 0.09c
Quercetin-3-O-glucoside	49.40 ± 0.99b	61.86 ± 1.24a	53.21 ± 1.60b	66.75 ± 1.34a	15.11 ± 0.30c
Luteolin-3-O-glucoside	1.92 ± 0.04d	6.13 ± 0.12a	3.08 ± 0.06c	5.20 ± 0.10 ab	1.59 ± 0.03d
Quercetin-pentoside	7.74 ± 0.15b	8.61 ± 0.17b	7.69 ± 0.15b	11.14 ± 0.22a	1.84 ± 0.04c
Isorhamnetin -hexosylpentoside	2.70 ± 0.05b	3.28 ± 0.07a	1.76 ± 0.004c	3.03 ± 0.06a	0.75 ± 0.02d
Luteolin-3-O-rutinoside	5.83 ± 0.12bc	6.26 ± 0.13b	6.50 ± 0.13b	9.43 ± 0.19a	1.70 ± 0.03d
3,5-dicaffeoylquinic acid	101.91 ± 2.04c	152.98 ± 3.06b	142.99 ± 2.86b	83.01 ± 1.66d	281.39 ± 5.63a
Isorhamnetin-3-O-rutinoside	23.02 ± 0.46b	26.54 ± 0.53b	26.07 ± 0.52b	42.63 ± 0.85a	5.38 ± 0.11c
Quercetin-acetyl-hexoside	28.33 ± 0.57bc	32.04 ± 0.64b	30.92 ± 0.62b	41.65 ± 0.83a	8.95 ± 0.18d
Diosmetin-rhamnosylglucoside	7.83 ± 0.16bc	8.70 ± 0.17b	8.33 ± 0.17b	33.38 ± 0.67a	9.66 ± 0.19b
Dicaffeoylquinic acid	4.19 ± 0.08a	4.82 ± 0.70a	3.98 ± 0.08 ab	3.74 ± 0.07b	2.96 ± 0.06c
Dicaffeoylquinic acid	0.47 ± 0.01b	0.40 ± 0.01b	0.34 ± 0.01b	0.60 ± 0.01a	0.38 ± 0.01b
Quercetin-pentoside	2.90 ± 0.06b	3.53 ± 0.07a	2.71 ± 0.05b	3.44 ± 0.07a	1.43 ± 0.03c
Procyanidin polymers	3740.71 ± 74.81b	2751.45 ± 55.03c	2734.06 ± 54.68c	4352.33 ± 87.05a	2244.09 ± 44.88d
Total	**13716.65d**	**17094.20b**	**15949.15c**	**22120.24a**	**7792.86e**

Means ± SD followed by different letters within the same line represent significant differences ($p < 0.05$). Data are the averages of triplicates.

Table 5
Effect of pre-treatment of blue honeysuckle berries and they products on antioxidant activity (μmol/1 g).

Type of products	Samples	ABTS	FRAP
Fresh	Berries	0.30 ± 0.01ef	0.23 ± 0.01f
	Pomace from whole berries	0.48 ± 0.01e	0.66 ± 0.02e
	Pomace from crashed berries	0.71 ± 0.02e	0.84 ± 0.03e
	Pomace from skin	1.31 ± 0.04d	1.54 ± 0.05d
	Pomace from flesh	0.52 ± 0.02e	0.37 ± 0.01f
Dried	Berries	4.45 ± 0.13c	4.01 ± 0.12b
	Pomace from whole berries	5.47 ± 0.16b	5.78 ± 0.17b
	Pomace from crashed berries	5.37 ± 0.16b	5.09 ± 0.15b
	Pomace from skin	6.46 ± 0.19a	8.30 ± 0.25a
	Pomace from flesh	4.03 ± 0.12c	3.21 ± 0.10c

ABTS, 2,2′-azinobis-(3-ethylbenzothiazoline-6-sulphonic acid); FRAP, ferric reducing antioxidant power; a-d Means ± SD followed by different letters within the same column represent significant differences ($p < 0.05$). Data are the averages of triplicates.

are not only the major polyphenolic components in this berry, but they are also very important for human health (Knekt et al., 2000). Furthermore, flavonols are effective antioxidants that due to their 3′,4′-dihydroxy substitution in B-ring and conjugation between the A- and B-rings have a high antioxidant potential. Flavones, in general, have higher antioxidant activity than anthocyanins with

the same hydroxylation pattern measured with the ORAC assay (Wang, Chen, Sciarappa, Wang, & Camp, 2008).

Considerable qualitative and quantitative differences were found in the content of these compounds in fruit and pomace depending on their type (Table 3, Fig. 1).

Total polyphenol content in all types of pomace was higher than in fruit. The greatest difference of over 4.2 times was detected in the peel-based pomace, and the smallest of over 1.7 times in the flesh-based pomace. The content of individual groups of compounds varied in different samples. Anthocyanins dominated in peel containing pomace obtained either from whole and crushed berries or from peels, while flavan-3-ols prevailed in the pomace obtained from fruit and flesh. Similarly to anthocyanins, flavonol content was significantly higher in pomace-based dry products, and the peel-based pomace contained over 7 times more of these compounds than the fruit. These results confirm that fruit anthocyanins and flavonols are located mainly in the peel. Peel-derived pomace is a good source of these biologically active compounds and a useful material for obtaining dry powders rich in anthocyanin derivatives such as cyanidine-3-O-glucoside and flavonols such as quercetine-3-O-rhamnoside-hexoside. The content of phenolic acids was less variable in the investigated samples. The lowest concentration of phenolic acids was detected in fresh fruit and it was 2.8 times lower than in flesh-based pomace and up to 4.4 times lower than in peel-

Table 6
Correlation matrix between antioxidant activity method and the key bioactive compounds of blue honeysuckle berries and they products.

Type of products		Anthocyanins	Flavan-3-ols	Flavonols + flavons	Phenolic acid	TP
fresh	ABTS	**0.822**	**0.851**	0.722	0.665	**0.840**
	FRAP	**0.932**	**0.851**	0.782	**0.905**	**0.895**
dried	ABTS	**0.990**	0.581	**0.882**	0.681	**0.952**
	FRAP	**0.990**	0.645	**0.851**	0.668	**0.937**

TP- total polyphenolic compounds.
Bold values are significant at p.

based pomace. Pomace, especially the peel-derived one, was much more abundant in polyphenolic compounds than fruit and might serve as a natural concentrated source of these compounds for dry powder production.

3.4. Effects of technological pre-treatment of berries on the content of phenolic compounds in final products

Fig. 2 and Table 4 show the differences among total phenolics determined by UPLC-PDA and HPLC-FL in the final products prepared from blue honeysuckle berries.

Total phenolic content in fruit was 12.29 g/100 g dm. In different blue honeysuckle products TPC ranged from 7.27 g/100 g dm for products prepared from flesh-based pomace to 21.03 g/100 g dm for products prepared from peel-based pomace. TPC was significantly ($p < 0.05$) affected by technological aspects of berry pre-treatment. The greatest effects on polyphenol content were observed the berries pre-treated prior to powder production.

The powder prepared from peel-based pomace contained about 2.9 times more TPC than that prepared from only flesh-based pomace. Additionally, the products made from peel-based pomace comprised significantly ($p < 0.05$) more phenolic compounds, especially of anthocyanins and flavonols + flavons, than the products prepared from flesh-based pomace and products made of berries pre-treated in other ways. The content of anthocyanins in the peel-based and flesh-based powder was 12.42 g/100 g and 2.67 g/100 g dm, respectively, and of flavonols + flavons it was 1.11 g/100 g and 0.16 g/100 g dm, respectively.

It is not surprising to conclude that the powder prepared from peel-based pomace contained the highest concentrations of major anthocyanins and flavonols + flavons, such as quercetin derivatives. These results clearly indicate significantly higher ($p < 0.05$) content of these compounds in the peel than in the flesh of the investigated berries. However, an extraction of anthocyanins from peel into juice or other products depends not only on anthocyanin concentration in berries but also on a tendency of the berry peel to release anthocyanins as a consequence of cellular wall degradation by pectolytic enzymes that make the cell wall pectins permeable during maceration (Ortega-Regules, Romero-Cascales, Ros-Garcia, Lopez-Roca, & Gomez-Plaza, 2006) or pre-treatment. Therefore, a concentration of anthocyanins in the berries and feasibility of their extraction are the main factors affecting their concentration in final products (Romero-Cascales, Ortega-Regules, Lopez-Roca, Fernandez–Fernandez, & Gomez-Plaza, 2005). Anthocyanin pigments are one of the main compounds of the peel, and they are very important due to their dual role. First, they constitute an integral part of sensory attributes because their levels, various forms and derivatives directly affect the coloration of the final product. Second, they possess diverse biological properties, modulate antioxidant power and are considered secondary metabolites with potential nutritional value. This is a very important information, as processing may result in a significant loss of water-soluble phenolics, especially anthocyanins (Lee, Durst, & Wrolstad, 2002; Skrede, Wrolstad, & Durst, 2000).

Another pattern was observed for phenolic acids and flavan-3-ols. The content of phenolic acids, and especially of chlorogenic acid, increased only after processing the peel-based and whole fruit-derived pomace as compared to dried fruit. The content of phenolic acids in these products ranged from 13% for the powder prepared from peel-based pomace to 10% for the powder from whole fruit pomace. It was reported that an increase in phenolic acids, including chlorogenic acid, in the final products correlated with pre-treatment of the berries or green vegetables before processing. Turkmen, Sari, and Velioglu (2005) showed that pre-treatment of green vegetables increased the content of chlorogenic acid. Other powders obtained from flesh-based pomace and crushed berries contained less phenolic acids than dried berries. In the case of flavan-3-ols, only dried peel-based pomace contained about 14% more of these compounds than fried berries.

The pre-treatment step significantly ($p < 0.05$) affected the content of polyphenolic compounds in the final product obtained from pomace increased the content of TPC in the products from whole fruit-derived pomace as compared with crushed fruit-derived pomace. A similar effect was observed in blueberry products (Brownmiller, Howard, & Prior, 2009), and in dried strawberry (Wojdyło, Figiel, & Oszmiański, 2009).

3.5. Effects of technological pre-treatment on antioxidant activity in final products

Considering diverse availability of polyphenolic compounds and phytochemical changes occurring during food product processing and storage, a thorough evaluation of changes in phenolics level and antioxidant activity is important for a consumer, particularly with regard to recommended daily consumption of fruit. This information is also of interest to the manufacturers who wish to retain or possibly boost the concentration of bioactive compounds in their products. A comprehensive evaluation of antioxidant activity of a specific product requires two or more analytical methods. Therefore, two in vitro assays ABTS$^{\bullet+}$ and FRAP were used to properly evaluate the antioxidant activity of blue honeysuckle products (Table 6). ABTS$^{\bullet+}$ method seems less sensitive than FRAP assay to the changes observed in the antioxidant activity of berry-based products. For example, ABTS$^{\bullet+}$ and FRAP values were 0.30 and 0.23 mmol Trolox/100 g dm, respectively. Positive correlations were found for total polyphenol content and antioxidant activity measured by ABTS$^{\bullet+}$ and FRAP assays and total phenolics, anthocyanins, flavan-3-ols, flavonols + flavons, and phenolic acids (Table 4). These correlations showed that the antioxidant activity of blue honeysuckle berries depends mainly on the content of polyphenolic compounds.

In general, pre-treatment of the berries significantly ($p < 0.05$) affected final antioxidant activity. The products obtained from peel > whole berries ≥ crushed berries showed significantly higher antioxidant activity than those obtained from flesh (Table 5). As expected, antioxidant activity was higher in the products prepared from peel as the content of phenolic compounds was higher there than in the rest of the analyzed products. Besides, the use of berries

with intact peel significantly improved the antioxidant activity of the final products.

Additionally, significant differences were found among the final products. Reduced antioxidant activity in these products was probably due to the formation of antioxidant polymers, such as high molecular weight procyanidins, or product degradation and formation of phenolic acid derivatives that also affected antioxidant activity (Brownmiller et al., 2009). This effect on antioxidant activity could be attributable to a matrix effect and/or differences in pH that determined anthocyanin stability. These data are in accordance with those reported by Fracassetti et al. (2013).

The effects of product type, berry pre-treatment and fruit cultivar on antioxidant activity were previously described by other authors and attributed to the product composition (Mena, Gironés-Vilaplana, Martí, & García-Viguera, 2012; Vázquez-Araújo, Rodríguez-Solana, Cortés-Diéguez, & Domínguez, 2013).

4. Conclusions

Bioactive compounds are located mainly in the peel, which is why the pomace obtained this way showed so big differences in their content prior to drying, as compared to fresh berries. The best results were achieved for peel-based pomace that contained 4.3 times more polyphenolic compounds than fresh berries. After juice pressing, the peels contained more dry matter and slightly more sugars and less organic acids than fresh berries. Due to lower water content, lyophilization and crushing of pomace was easier than of fruit. Dried berries contained unfavorably less dry matter and more organic acids and sugars than dried pomace, and favorably more polyphenolic compounds and showed higher antioxidant activity, except for flesh-based pomace. The most valuable product was peel-based dried pomace that contained over 21% of polyphenolic compounds, while in dried berries their share was 12.3% and in flesh-based pomace only about 7.3%. Similar relationships were observed for antioxidant activity that was the highest in dried peel-based pomace and the lowest in dried flesh-based pomace. The study showed that peel-based pomace of blue honeysuckle is a better material for the production of dried product rich in bioactive compounds than the pomace obtained from whole berries.

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