Agronomy Research **18**(S3), 1829–1843, 2020
https://doi.org/10.15159/AR.20.044

The possibility of using microwaves to obtain extracts from berry press residues and jelly products with bioactive characteristics

L. Nilova*, R. Ikramov and S. Malyutenkova

Peter the Great St. Petersburg Polytechnic University, Institute of Industrial Management, Economics and Trade, Graduate School of Service and Trade, Novorossiyskaya street 50, RU194021 Saint-Petersburg, Russia
*Correspondence: nilova_l_p@mai.ru

Abstract. The paper explores the possibility of development a microwave technology for obtaining water extracts from berry press residues (wild bilberries and cranberries as the objects) and jelly products based on them, which will allow using the waste of freshly squeezed juices in business, such as restaurants and catering services. The antioxidant activity (DPPH and FRAP methods), content of phenolic compounds, flavonoids, anthocyanins, ascorbic acid were determined in berries and in berry press residues. The antioxidant activity of bilberry press residues was due to anthocyanins, and the activity of cranberry press residues was due to flavonoids. Using the microwave oven (magnetron power 800 W, frequency 2,450 MHz), water extracts were obtained in the ratio: for cranberries 1.5:10, for bilberries 1:10. The antioxidant activity of extracts depended on the type of berries and was greater in extracts from bilberry press residues. Extracts of bilberries and cranberries and their compositions (sugar-free and sugar-added) with gelatin as a gelling agent were used to produce the jelly products. Combining bilberry and cranberry extracts (70:30) with gelatin makes it possible to obtain jelly products without sugar. Heating of the ready recipe mixture after preliminary swelling of gelatin and without swelling of gelatin was carried out in the microwave oven. The antioxidant activity of jelly products was higher when using bilberry extracts than cranberries. An increase in the antioxidant activity of the extracts led to a slowdown in structure formation, but increased the plasticity of the products.

Key words: bilberries, cranberries, berry press residues, extracts, microwaves, jelly products, antioxidant activity, deformation.

INTRODUCTION

Berries, as sources of biologically active compounds (BAC) that come in an easily digestible form, play a huge role in human nutrition. Compared to other fruits, they contain more phenolic compounds, flavonoids and anthocyanins, which give them a higher antioxidant activity (AOA). Wild berries contain more biologically active compounds compared to their cultivated analogues (Häkkinen et al., 1999; Rupasova et al., 2013; Ruiz-Torralba et al., 2018). Regular consumption of fresh berries and berry juices helps prevent lipid peroxidation, oxidative stress, and reduces the risk of

cardiovascular and oncological diseases (Williams & Hord, 2005; Caillet et al., 2011; Kivimäki et al., 2012; McKay et al., 2015; Cásedas et al., 2018).

The trend of processing fruits and berries in juice production has brought to attention ways to utilize the remaining berry press residue: a valuable product, in which BAC are even more concentrated (Pertuzatti et al., 2012; Aaby et al., 2013; Barakova et al., 2016; Bamba et al., 2018; Klavins et al., 2018). Berry press residues that display high antioxidant and/or antimicrobial properties, can be dried and then used as additives in food products (Nilova et al., 2015; Dubrovskaya et al., 2017; Lorenzo et al., 2018; Nilova & Malyutenkova, 2018; Tian et al., 2018). Seeds that are also contained in press residues, can be used as the source of oils or waxes (Klavins et al., 2016; Klavins et al., 2019).

Extracts from fruits and berry press residues are most often obtained from raw products, since grinding and drying (as in production of powders), leads to the loss of BAC (Klavins et al., 2018; Michalska et al., 2018; Nemzer et al., 2018). Various methods and solvents are used for extraction of BAC. The maximum extraction of biologically active compounds is possible when using acidified methanol, water-ethanol or water-methanol solutions (Vulić et al., 2011; Klavins et al., 2017; Tian et al., 2017; Bamba et al., 2018; Tian et al., 2018) it further intensifies when combined with high pressure processing, irradiation, dense phase carbon dioxide, ultrasonic processing, pulsed electric field, membrane processing technologies, cold plasma, and hydrothermodynamic cavitation (Li et al., 2017; Cvetanović et al., 2018; Khan et al., 2018; Nowacka et al., 2018). Such methods help to decrease processing time and temperature, improve processing efficiency and minimize nutritional losses. However, when using water as the extracting agent, they become less effective (Klavins et al., 2017; Albuquerque et al., 2018).

Water extracts do not require further processing and can be directly used in food production. Microwave extraction is more effective when water environment is used (Albuquerque et al., 2018), even though it can be carried out without a solvent, due to cyclic heating under pressure, which ensures destruction of pathogenic microflora (Michel et al., 2011; Kretova et al., 2018). Microwave extraction allows extracting both free and bound phenolic compounds, which increases their bioavailability in the human body (Dibanda et al., 2020). Temperature and duration of exposure are important factors in terms of BAC preservation. Aaby et al. (2013) have shown that heating the berry press residues diluted in water up to 100 °C for 4 minutes increases the yield of BAC, especially anthocyanins, while heating it to the temperature above 100 °C decreases the yield. At the magnetron power of 600 W, the duration of water extraction can reach 6 minutes, however, the temperature of the extract should not exceed 85 °C (Wei et al., 2018).

Confectionery products, including jelly cups, and other jelly sweets, are very popular in Russia. Traditionally, they were produced on the basis of extracts made from whole fruits or berries, but in recent years, jelly products have been produced from gelatin with the use of artificial food colors, flavors and acids, which reduces their nutritional value. The use of extracts from fruit or berry press residues makes it possible both to enrich jelly products with natural antioxidants (Rasidek et al., 2016), and to stop using artificial food additives.

The purpose of the work is to study the composition of BAC and the antioxidant activity of berry press residues remaining after squeezing juice from them for use in microwave technology as raw materials for water extracts and jelly products based on them with bioactive characteristics.

MATERIALS AND METHODS

Samples of berries and berry press residues

For the purposes of this research, we used Vaccínium genus berries – bilberries and cranberries – collected in the Leningrad Region, Russia, and frozen to minus 18 °C. Before the studies, berries were thawed to the room temperature, and then the juice was squeezed out of them by the method of pressing. Studies were carried out in the whole berries and in the berry press residues.

Extraction with the use of microwave energy

Water extracts were obtained from raw pressed berries in a microwave oven 'Bork', Bork Elektronik GmbH, at the power of 800 W, and the frequency of 2450 MHz, with the range of exposure modes from 144 to 800 W. The microwave power was checked in accordance with IEC 60705:2006 'Household microwave ovens - Methods for measuring performance'. For the extraction used water with a temperature of 20 ± 1 °C. Water extract was obtained in the ratio (hereinafter water ratio): 1:10 and 1.5:10 (berry press residue: water). At the same time, the extract was not allowed to boil, and the process was controlled by the temperature by Infrared Thermometer 'Ouest GM270', China, and the extract volume.

Technology of jelly production

For production of jelly products, we used water extracts of bilberries, cranberries and their mixtures both without sugar and with addition of sugar 2.5 wt%, as well as a building agent (gelatin) 3 wt% (Grade P-11, produced by LLC Russian Grocery Company, Russia). As a control, a water-based jelly product was used and gelatin was added at the same concentration.

Production of jelly products was carried out in two methods. When the first method was applied, all components were mixed together and left to sit for 40 minutes, then mixed again, heated at 800 W in a microwave oven for 1 minute, cooled to the room temperature, and placed in a refrigerator 4 ± 2 °C until solidified. When the second method was used, gelatin was not allowed any time to swell. As the control sample, we used jelly products, produced from similar components according to the traditional technology, which involves giving the gelatin mixture time to swell, boiling and molding the finished product while cooling (Golunova, 2003).

Research Methods

Extractive solids of water extracts of berry press residues were determined by IRF-454 refractometer manufactured by Biomer LLC, Russia.

The determination of ascorbic acid (AA) was made by titrimetric method with a solution of 2,6-dichlorophenolindophenolate sodium. Extraction of ascorbic acid from the raw material was carried out with 2% hydrochloric acid.

Total phenols assay by Folin-Ciocalteau reagent. Ethanol extracts of berries and berry press residues with Folin-Ciocalteau reagent incubated at room temperature in the dark for 30 min. The optical density was measured on a SHIMADZU 1240 spectrophotometer ('SHIMADZU', Japan) at a wavelength of 735 nm. The results are expressed in mg of gallic acid (Rogozhin & Rogozhina, 2015).

The total content of flavonoids was determined spectrophotometrically by reaction with aluminum chloride. The extraction of flavonoids was made using 60% ethyl alcohol. The optical density was measured after 30 minutes, using the SHIMADZU 1240 spectrophotometer ('SHIMADZU', Japan) at a wavelength of 420 nm. The obtained results were denoted in mg of rutin (Rogozhin & Rogozhina, 2015).

The total content of anthocyanins in terms of cyanidin was determined by pH-differential spectrophotometry at pH 1.0 and 4.5 of the samples, at wavelengths of 510 and 700 nm, using SHIMADZU 1240 spectrophotometer ('SHIMADZU', Japan). To prepare the anthocyanin extract, 3 g of berries or raw berry press residues were mixed with 16 mL of reagent (0.1 N hydrochloric acid and 80% ethanol solution (15 : 85 by volume), homogenized and centrifuged for 10 minutes at the speed of 3,000 rpm. (Nowacka et al., 2018).

Methods for assessing the antioxidant activity

Determination of AOA was carried out by two methods: by their reaction to the DPPH-radical, by FRAP method.

A determination of AOA was carried out by use of the Glavind method (Rogozhin & Rogozhina, 2015). Berries, berry press residues and jelly products were ground and extracted with 50% ethanol solution. A total of 0.2 mL of the extract was added to 2 mL of DPPH solution. The resulting solution was incubated in the dark for five minutes, after which the absorbance levels of the resulting solution were measured at a wavelength of 517 nm using a SHIMADZU 1240 spectrophotometer ('SHIMADZU', Japan). The AOA was determined according to the calibration curve and expressed in terms of ascorbic acid (AC).

Determination of the antioxidant activity (chelating ability) using the FRAP method (Rogozhin & Rogozhina, 2015). This method is based on the ability of ferric chloride (III) to oxidize antioxidants. During the process, ferric chloride (III) is reduced to ferric chloride (II), the amount of which is determined by the color intensity when o-phenanthroline is added to it. Berries, raw press residues and jelly products were crushed and extracted with the use of the 50% ethanol. 0.2 mL of the 25 mM solution of o-phenanthroline, 2.4 mL of the 96% ethanol and 0.2 mL of the 12.3 mM FeCl3 solution (added drop by drop) were added to the extract. After stirring, the mixture was kept in a dark place for 10 minutes. The reaction was stopped by adding 1 mL of the 0.4 M HCl solution. The control sample consisted of the original products to which 0.2 mL of the 25 mM *o*-phenanthroline solution, 2.6 mL of the 96% ethanol, 0.2 mL of the 12.3 mM FeCl3 solution, and 1 mL of the 0.4 M HCl solution were added. The light absorption of the extract was measured against the solution of the 96% ethanol with the use of SHIMADZU 1240 spectrophotometer at the wavelength of 505 nm. The specific amount of extract light absorption was subtracted from the amount of light absorption of the control sample. The antioxidant activity was determined according to the calibration curve and expressed in terms of AC.

The strength of the 'Bloom strength' jelly products was determined with the use of 'ST-2 Structometer', manufactured by Quality Laboratory LLC, Russia. This method is based on measuring penetration force by the Bloom indenter, when it penetrates the prepared jelly sample to the depth of 4 mM (at the penetration speed of 1.0 mM s^{-1}, and the touch force of 7 g).

The research was made in triplicate. The reliability of the experimental data was evaluated by methods of mathematical statistics with the use of Microsoft Excel application for Windows 2010. All the results were expressed as means ± standard deviation and the statistical significance was assessed by Student's t test. To establish statistically significant differences between the values of the experimental samples compared to the control in the group, analysis of variance was used (ANOVA). Significant differences were considered when p-value < 0.05.

RESULTS AND DISCUSSION

Bilberries and cranberries collected in the Leningrad Region had a typical biochemical composition comparable with the already published data (Caillet et al., 2011; Aaby et al., 2013). Test samples of whole berries contained total phenolic compounds, total flavonoids, total anthocyanins (which prevailed in bilberries) and vitamin C (which prevailed in cranberries) (Table 1).

Table 1. Composition of biologically active substances, mg 100 g^{-1}, in berries and in berry press residues, ± standard deviation (Student's t-test)

Indicators	Bilberry		Cranberry	
	whole berry	berry press residues	whole berry	berry press residues
Total phenolic compounds	588.9 ± 22.6	682.4 ± 20.9	452.5 ± 18.0	551.6 ± 21.0
Total flavonoids	465.0 ± 18.4	510.2 ± 20.5	358.5 ± 18.5[a]	469.1 ± 20.4
Total anthocyanins	313.0 ± 8.8	514.8 ± 8.5	175.9 ± 9.0[a]	201.7 ± 9.2
Vitamin C	18.34 ± 0.62	6.88 ± 0.53[a,b]	21.20 ± 0.56	7.50 ± 0.39[a,b]

The differences are not statistically significant: [a] – between replicates of experiments; [b] – between raw berry press residues; (p < 0.05).

After squeezing the juice, most of these BAC remain in the raw berry press residues. The exception was vitamin C – its amount could decrease either due to the mechanical destruction of cells during squeezing of the juice, or its contact with atmospheric oxygen. It is known that grinding, as well as thermal processing reduces the content of vitamin C during extraction by the rate of 7%–54%. However, mechanical destruction also stimulates the yield of flavonoids and anthocyanins, which generally raises the AOA of the product (Nowacka et al., 2018). Despite the differences in Vitamin C content in whole bilberries and cranberries, its content in raw berry press residues did not show any statistically significant differences. High content of antioxidants of the phenolic type in berries and press residues caused their high antioxidant properties. Both the antiradical activity (DPPH test) and the chelating ability (FPAP test) showed statistically significantly different results in berries and raw press residues (Fig. 1) with significant predominance in bilberries. Only FPAP values did not differ significantly in bilberries and cranberries.

Dependence of bilberries and cranberries AOA on the content of total phenolic compounds, total flavonoids and total anthocyanins is confirmed by the high relation (R^2) between these indicators (Table 2).

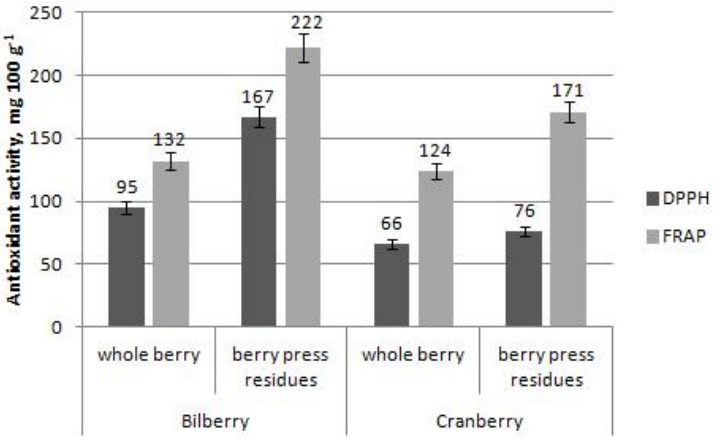

Figure 1. Antioxidant activity (DPPH and FPAP) in bilberries and cranberries, and their respective raw press residues, (mg AC 100 g^{-1}).

Bilberries display AOA due to the high content of anthocyanins (Aaby et al., 2013, Wang et al., 2014, Colak et al., 2016, Tian et al., 2017). Compared to whole bilberries the content of anthocyanins in raw press residues increases from 53% to 75%, i.e. by 22%. Therefore, relation (R^2) between anthocyanins, and DPPH and FPAP tests of bilberries, was 0.998 and 0.991, respectively.

A similar dependence of anthocyanins transition; and their effect on AOA were proved by other authors (Wang et al., 2014, Colak et al., 2016), who experimented both with whole berries from different regions and with different fractions of berries obtained by extraction. Flavonoids displayed lower relation (R^2), since other compounds could also participate in the formation of AOA of bilberries: for example, hydroxycinnamic and hydroxybenzoic acids, and their content could exceed flavonoids (Häkkinen et al., 1999; Aaby et al., 2013).

Table 2. Relation (R^2) between the content of total phenolic compounds, total flavonoids, total anthocyanins and antioxidant activity (DPPH and FPAP)

	AOA	Total phenolic compounds	Total flavonoids	Total anthocyanins	*p*-value
Bilberry	DPPH	0.939	0.769	0.998	< 0.05
	FRAP	0.953	0.803	0.991	< 0.05
Cranberry	DPPH	0.947	0.973	0.874	< 0.05
	FRAP	0.956	0.979	0.888	< 0.05

In cranberries, anthocyanins displayed a less significant role in the formation of AOA. Relation (R^2) were lower than those of phenolic compounds and flavonoids, and amounted to 0.874 for DPPH and 0.888 for FPAP. Feng et al. (2016) did not find a close correlation between the AOA and the content of anthocyanin in red-colored berries (gooseberries (*Ribes procumbens*), strawberries (*Rubus idaeus*), elderberries (*Sambucus williamsii*) and red currants (*Ribes rubrum*)). Flavonoids (R^2 – 0.973 and 0.979) displayed a greater effect, due to their predominance in the composition of cranberry phenolic compounds from 79% in whole berries, to 85% in raw press residues. The

predominance of flavonoids in phenolic compounds has been shown by several authors (Häkkinen et al., 1999; Caillet et al., 2011), but their content may vary depending on the forms of berry cultivation. Optimization of extraction processes from raw press residues can increase the yield of anthocyanins not only in cranberries, but also in other Vaccinium genus berries (Klavins et al., 2018). Regardless of the predominance of phenolic antioxidants in certain berries or raw press residues, on the whole they display a significant effect on their AOA. Therefore, in further studies, DPPH and FPAP tests were used as indicators for evaluating the effectiveness of the extraction conditions.

Water extraction of bilberries and cranberries press residues was carried out in a microwave oven at different capacities. The extracts were not allowed to boil, and were controlled by their temperature and the change of volume. An increase in the duration and power of microwave led to increase in the temperature of the extracts, which did not reach 100 °C. The maximum heating temperature of the extracts reached 95 °C with a microwave power of 800 W for the duration of 180 s (Fig. 2). But under these conditions, we observed a decrease in the extracts' volume by 20%, due to evaporation of the liquid.

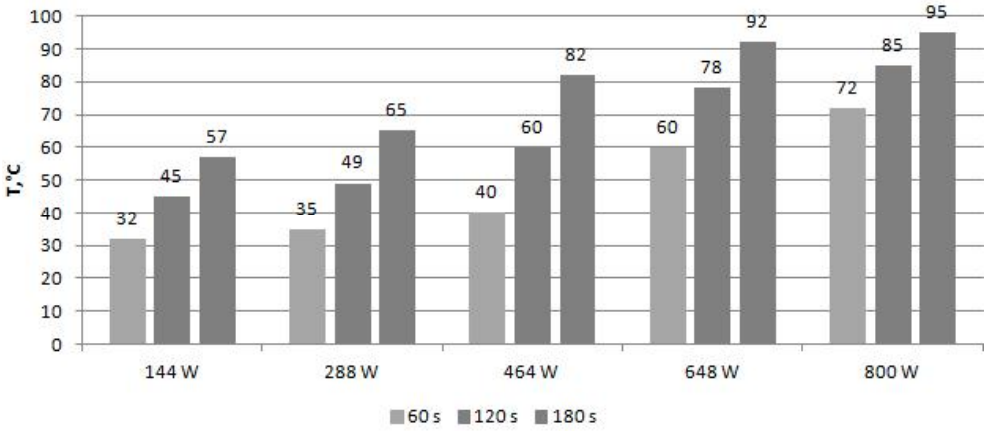

Figure 2. The effect of the microwave exposure conditions (power – W, and duration – s) on the temperature of the extracts.

Reducing the duration of the microwave exposure to 120 s reduced the extract heating by 10 °C, but did not ensure lack of evaporation: as a result the volume of the extract was 6% less, than the initial one. Only when the microwave exposure duration was shortened to 60 s, the extract volume did not change, and its temperature rose to 72 °C. The evaporation of the extract began when it reached the temperature above 76 °C, which happened at the microwave power of 648 W after the duration of 120 s, or at the microwave power of 464 W, after the duration of 180 s.

For further studies, we used the microwave power of 800 W, determining its effect on the yield of the extractive solids and the AOA of the extracts with a water ratio of 1:10, depending on the duration of exposure. Extracts that reduced their volume due to the liquid evaporation, were brought back to their original volume by diluting them with distilled water.

An increase in the duration of the microwave exposure led to increase in the concentration of solids in the extracts. Their sensory properties improved, but their AOA

values decreased. Concentration of the solids during extraction did not show any dependence on the type of berry press residues used, and increased when the duration of the microwave exposure was lengthened (Fig. 3). Thus the microwave exposure for the duration of 180 seconds in comparison to 60 seconds increased concentration of the extractive solids by 12.5%.

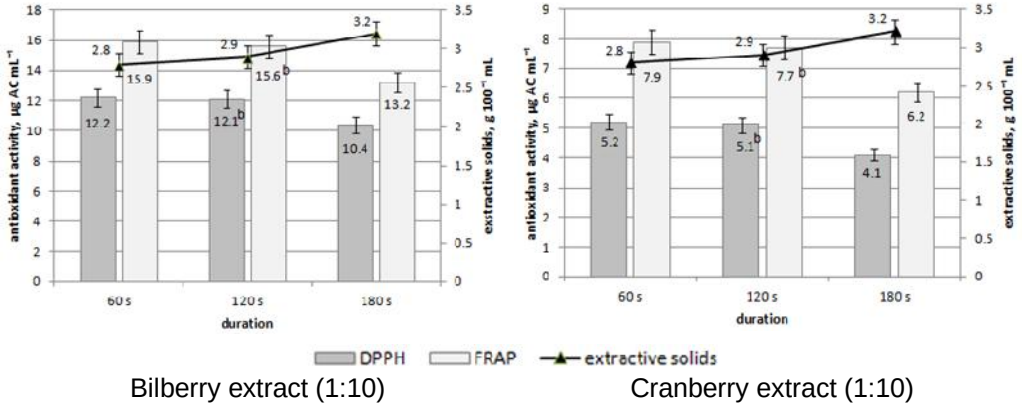

Figure 3. The effect of the duration of the microwave on the concentration of extractive solids and the antioxidant activity (DPPH test and FRAP test) of extracts from berry press residues.

The increase in the duration of the extraction process led to a more pronounced taste, which may have happened due to the transition of acids and sugars into the extract. The bilberry press residues extract had a pronounced bilberry taste after 60 s, while the cranberry press residues extract showed a neutral taste without any pronounced characteristics. The sweet and sour taste, characteristic of cranberries, appeared only after the microwave exposure duration of 180 s.

The AOA of the extracts depended on the type of the used press residues and was higher in the bilberry extracts. In bilberry extracts, obtained by the microwave exposure for the duration of 60 s, DPPH and FRAP values were higher by 2.3 and 2.0 times, respectively, than those of cranberry extracts. The increase in the duration of the microwave exposure led to a decrease in the DPPH and FRAP values in the extracts. When bilberry extracts were exposed for 180 s, their DPPH and FRAP values decreased by 15% and 17%, respectively, compared with the microwave exposure for the duration of 60 s.; similar values decreased in cranberry extracts by 11% and 12% respectively. The increase of the microwave exposure duration from 60 s to 120 s stimulated increase of the concentration of solids in the extract and reduced its AOA, but the results did not show any statistically significant differences. Thus, to obtain extracts from berry press residues, one can use the microwave exposure of 800 W for the duration of 60 s.

To increase the antioxidant and sensory properties of the cranberry press residue extracts, it was decided to change the water ratio to 1.5:10, which led to an increase in the AOA of their DPPH and FRAP tests by 1.5 and 1.3 times respectively (Fig. 4). The taste of the extract became more pronounced, displaying the characteristic acidity.

Extracts from cranberry press residues (water ratio 1.5:10) brought their antioxidant activity values closer to the extracts from bilberry press residues (water ratio 1:10), although they were less by 1.5 and 1.6 times.

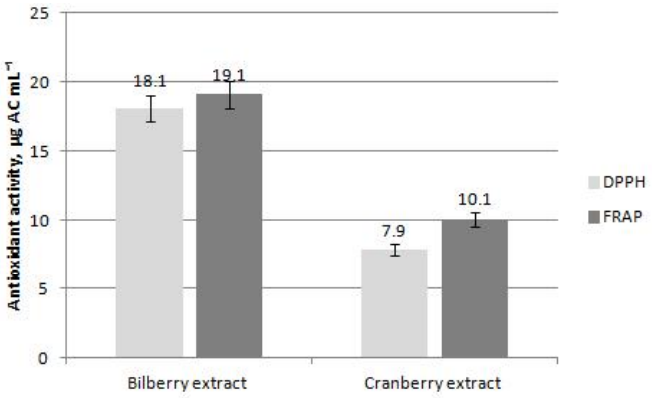

Figure 4. Antioxidant activity, µg AC mL^{-1}, of berry extracts (water ratio 1.5:10).

Staroszczyk et al. (2020) have shown that differences in the AOA of extracts from blueberry and rowanberry press residues differ by 1.5 to 2 times depending on the determination method. The change of the water ratio in bilberry press residues extracts led to an increase in their DPPH and FRAPS values by 1.5 and 1.2 times respectively. The taste of the extracts became more pronounced, but there was no change in the color, which remained dark purple. When using mixed extracts from bilberry and cranberry press residues, it is better to use extracts that have similar antioxidant properties.

Water extracts from bilberry press residues (water ratio 1:10) and cranberries (water ratio 1.5:10) were used alone or in the mixed form to produce jelly products. When mixing the extracts, the optimal sweet and sour taste was achieved in order to exclude sugar from the recipe. It was found out, that extracts from bilberry and cranberry press residues, taken at a ratio of 70:30, display the optimal sensory properties.

For the production of jelly products, the prepared recipe based on extracts from berry press residues after gelatin swelling and without preliminary swelling of gelatin was heated in a microwave oven, after which it was poured into molds. The structure of the product was formed after the mixture was cooled to room temperature and held in a refrigerator with a temperature of 4 ± 2 °C. Product composition and technology influenced the duration of product structure formation. Using traditional technology (control), the formation of the product structure took place after 50–60 minutes. exposure in the refrigerator. Microwave technology with preliminary swelling of gelatin increased the duration of clot formation by 25–30%, with a maximum duration of 75–80 min was in jelly products based on extract from bilberries. The absence of gelatin swelling before microwave treatment slowed down the formation of the product structure by more than 2 times, which amounted to 140–160 min.

Jelly products were distinguished by their consistency from dense for samples using traditional technology to plasticity for products obtained by microwave technology. The strength of jelly products depended not only on the technology, but also on the type of extract and the presence of sugar in the formulation (Table 3). Jelly products obtained by traditional technology were denser in structure. Bloom strength values decreased by 12–23% when using extracts from berry press residues. The formation of the gelatin-based product structure and berry press residues extracts is associated with protein-polyphenol interaction and crosslinking (Wu et al., 2013, Gómez-Mascaraco et al., 2019).

Table 3. Bloom strength of jelly products, g, ± standard deviation (Student's t-test)

Jelly product	Technology					
	traditional		microwave with gelatin swelling		microwave without gelatin swelling	
	without sugar	with sugar	without sugar	with sugar	without sugar	with sugar
Control	106 ± 2	101 ± 2	100 ± 3	93 ± 2	71 ± 3[b]	67 ± 3[b]
Bilberries extracts	82 ± 2	76 ± 2[c]	63 ± 3	58 ± 2	47 ± 3[a,c]	42 ± 3[a,c]
Cranberries extracts	93 ± 2	88 ± 2	83 ± 2	78 ± 2	60 ± 3[b]	55 ± 4[a,b,c]
Bilberries & cranberries extracts	86 ± 3	78 ± 2[c]	71 ± 2	65 ± 2	52 ± 4[a,b,c]	48 ± 3[a,b,c]

The differences are not statistically significant: [a] – between replicates of experiments; [b] – between jelly products without sugar and with sugar; [c] – between jelly products depending on the extracts from berry press residues used ($p < 0.05$).

The physical properties of such a product depend on the amount and composition of the polyphenols. Choi et al. (2018) claim that high concentrations of phenolic compounds due to their molecular mobility and branched structure, leads to a plasticizing effect. However, at high concentrations of phenolic compounds, molecular mobility increased due to grafting/branching reactions resulting in plasticizing effect.

The predominance of anthocyanins in the extract from bilberry press residues led to the formation of a more plasticity product with the lowest Bloom strength values (Fig. 5).

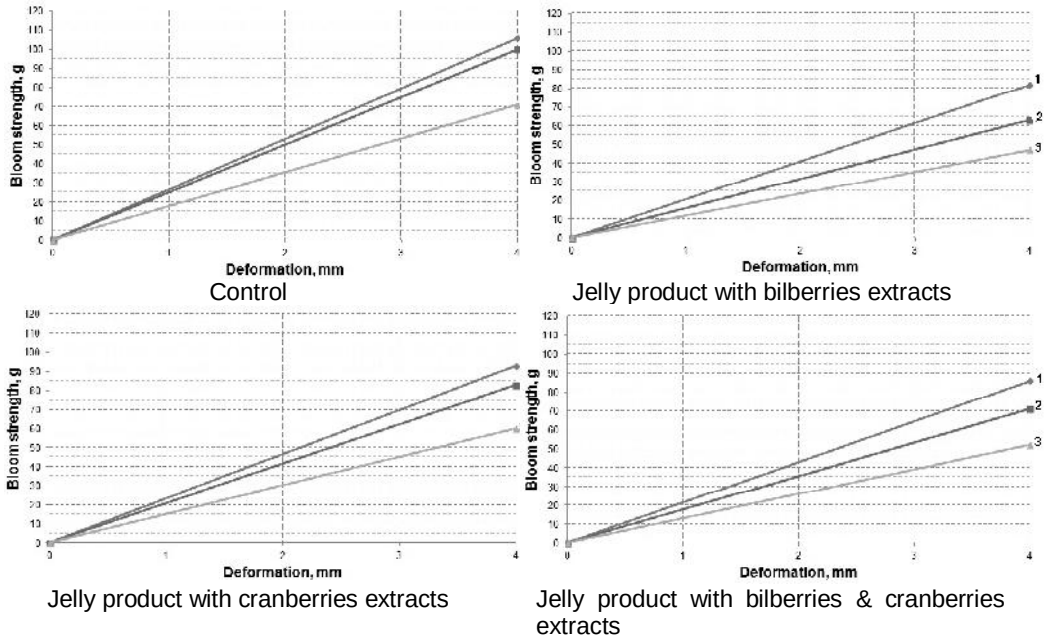

Figure 5. Load force change schedules depending on the depth of implementation of Blume indenter for sugar-free jelly products depending on the technology used (by 'ST-2 Structometer'): 1 – traditional; 2 – microwave with gelatin swelling; 3 – microwave without gelatin swelling.

In jelly products from the composition of extracts and in extracts from cranberry press residues Bloom strength values increased. Many authors point to the influence of anthocyanins in forming the structure of the product with gelatin. Extracts from berry extracts or red cabbage containing anthocyanins contribute to the formation of elastic gelatin films with increased extensibility, which increases with the content of anthocyanins (Nilsuwan et al., 2018; Uranga et al., 2018; Kan et al., 2019; Staroszczyk et al., 2020). For example, films with blueberry extract are 13% more extensible than those with rowanberry extract (Staroszczyk et al., 2020). Yong et al. (2019) have shown on the example of films based on chitosan with sweet potato extract that the formation of structure occurs through the interaction of amino groups of proteins and hydroxyl groups of anthocyanins. The absence of anthocyanins in green tea extract or extract with epigallocatechin gallate form strong gelatine films with reduced stretch (Wu et al., 2013).

The same trend continued with microwave technology, although the Bloom strength values decreased by 6–15%, especially with extracts from berry press residues extracts. The absence of gelatin swelling operation in microwave technology further reduced the Bloom strength values by 25–28%, but there were no statistically significant differences. Regardless of the production technology of jelly products, the introduction of sugar in their composition allowed to produce more stretchy products. Bloom strength values were reduced with the use of the technology: microwave by 6–9%; microwave with gelatin swelling by 6–11%, for traditional by 5–8%.

The use of sugar has not changed the trend of antocyanins influence on the plasticity properties and Bloom strength of jelly products with extracts from berry press residues was aligned the following way: bilberries< bilberries & cranberries< cranberries.

AOA of berry extracts formed them in jelly products with slight losses, which depended on the technology use (Table 4).

Table 4. Antioxidant activity, μg AC g^{-1}, sugar-free jelly products, tandard deviation (Student's t-test)

Jelly product	Technology					
	traditional		microwave with gelatin swelling		microwave without gelatin swelling	
	DPPH	FRAP	DPPH	FRAP	DPPH	FRAP
Control	1.2 ± 0.4 [a,b]	1.4 ± 0.4 [a,b]	1.3 ± 0.3 [a,b]	1.5 ± 0.4 [a,b]	1.2 ± 0.5[a,b]	1.4 ± 0.5 [a,b]
Bilberries extracts	9.2 ± 0.4[c]	12.8 ± 0.6	10.8 ± 0.3[b]	14.6 ± 0.8	10.9 ± 0.4[b]	14.8 ± 0.6[b, c]
Cranberries extracts	6.2 ± 0.3	8.5 ± 0.7 [b]	7.0 ± 0.3[b]	9.8 ± 0.7 [b]	7.3 ± 0.4[a,b]	10.1 ± 0.7 [b]
Bilberries & cranberries extracts	8.6 ± 0.3[c]	11.0 ± 0.6	9.8 ± 0.4[b]	13.0 ± 0.5 [b]	9.5 ± 0.4[b]	13.8 ± 0.6 [b, c]

The differences are not statistically significant: [a] – between replicates of experiments; [b] – between jelly products by different technologies; [c] – between jelly products depending on the extracts from berry press residues used ($p < 0.05$).

The highest DPPH and FRAP values were jelly products obtained by microwave technology. Compared to traditional technology, these values were 13–17% and 14–18% higher, respectively, for DPPH and FRAP, due to lower temperature effects in microwave technology. The increase in temperature above 100°C promotes the loss of

phenolic compounds, and especially anthocyanins (Michalska et al., 2018, Nemzer et al., 2018).

Preliminary swelling of gelatin or its absence in the formulation did not significantly affect the AOA of jelly products. DPPH and FRAP values had no statistically significant differences. AOA of jelly products were formed not only by extracts from berry press residues, but also by gelatin, as evidenced by the DPPH and FRAP values of jelly products without the use of extracts (control). AOA of jelly products, depending on the used extracts from berry press residues extracts, was aligned the following way: bilberry > bilberry and cranberry > cranberry.

CONCLUSIONS

Bilberries and cranberries and berry press residues from them after squeezing juice contain a complex of phenolic antioxidants, which determine their AOA. In bilberry press residues, the AOA is associated with a predominance of anthocyanins, which confirmed the close relation (R^2) with DPPH and FPAP tests, which were 0.998 and 0.991 respectively. AOA of cranberry press residues is associated with flavonoid predominance: R^2 for DPPH and FPAP is 0.973 and 0.979 respectively.

Microwave technology can be used to obtain water extracts from berry press residues. By increasing the microwave power processing time is reduced and the amount of antioxidants in the extract is increased. If it is necessary to use extracts in food technology in order to form the necessary sensory properties, it is necessary to regulate the ratio of berry press residues and water. The ratio of the berry press residues and water to obtain extracts was experimentally found: 1:10 for the extract from bilberry press residues, and from cranberry press residues – 1.5:10. Mixing the extracts with a pronounced sweetish (bilberry) and sour (cranberry) taste can allow their use without sugar in the production of jelly products.

Water extracts from berry press residues were used to produce gelatin-based jelly products. More plasticity jelly products based on extracts are obtained by microwave exposure of the prepared recipe mixture with preliminary swelling of gelatin or with the absence of this operation. The clot formation time is up to 80 min. at a temperature of 4 ± 2 °C. Absence of pre-swelling gelatin increases time to 140–160 minutes. Manufactured jelly products have greater AOA than products by traditional technology. Microwave technology will allow using of press residues after obtaining freshly squeezed juices for production jelly products without sugar and with AOA in such food business, as restaurants and catering services.

Further research should be aimed at transforming microwave technology developed for catering services to industry, for which it is necessary to determine the conditions of microwave exposure (power and duration) depending on the technical characteristics of industrial microwave ovens and the volume of products manufactured per load.

ACKNOWLEDGEMENTS. This paper was financially supported by the ministry of Education and Science of the Russian Federation on the programm to improve the competitiveness of Peter the Great St. Petersburg Polytechnic University (SPbPU) among the world's leading research and education centers in the 2016–2020.

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