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EVALUATION OF CHEMICAL COMPOSITION OF FRESH AND FROZEN BLUEBERRY FRUIT (*Vaccinium corymbosum* L.)

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Abstract. Blueberries are tasteful fruits and are widely believed to be the source of health beneficial compounds, especially phenolics. Freezing is one of the methods of prolonging their supply beyond vegetative season.

The aim of the study was to estimate fruit chemical composition of four blueberry cultivars ('Spartan', 'Bluecrop', 'Jersey' and 'Blueray'). Dry weight, total sugar, total acidity, vitamin C and total polyphenol content were determined in fresh berries and after 6 and 12 months of freeze-storage at –25 ^{0}C.

In generally, 'Bluecrop' berries showed the most stabile chemical composition (dry weight, total sugar, total acid content) whereas 'Spartan' ones the least. Considering the all storage period the least pronounced changes occurred in total acid content (increase by 0.1 g citric acid · 100g^{-1}) while the most substantial in vitamin C content, decrease by 57% ('Bluecrop') – 72% ('Jersey').

Key words: highbush blueberry, fruit chemical composition

INTRODUCTION

Highbush blueberries (*Vaccinium corymbosum* L.) among other berries of *Vaccinium* genus have been known for indigenous inhabitants of North America for centuries. They were used both as a food and remedy [Pliszka 2000]. In Poland, a growing interest has been observed in blueberry cultivation [Mitek et al. 2001].

Recently, dietary and therapeutic properties of blueberries are widely highlighted in a lay-press and scientific journals. Blueberries are excellent table fruits with a wide range of biological effects including antioxidant, anticarcinogenic and cardiovascular disorders reducing activities. Beneficial influence of berry consumption on human health has been attributed especially to phenolic compounds like flavonoids and pheno-

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lic acids [Zheng and Wang 2003] as well as resveratrol and piceatannol [Rimando et al. 2004].

The purpose of the study was to investigate fruit chemical composition of four blueberry cultivars, and estimate the changes in nutritive and biologically active components after 6 and 12 months of freeze-storage.

MATERIAL AND METHODS

The fruits of four highbush blueberry cultivars: 'Spartan', 'Bluecrop', 'Jersey' and 'Blueray' were obtained from commercial plantation in 2001–2003. In 2001 'Bluecrop' and 'Jersey' shrubs were 11 years old while 'Spartan' 8 years old and ''Blueray' 7 years old. Except of 'Bluecrop' cultivar (*in vitro*) other bushes originated from hardwood cuttings. The plants were cultivated according to the recommendations for this species [Smolarz 2000]. The plantation was established on typical forest soil with natural humus horizon (30 cm) where ground water level was ca 1 m. Additionally, conifer sawdust to mulch as well as drip irrigation and acidifying by means of drop-sulphur were used. The ripe berries of 'Exstra' class (PN-R-75507) were manually collected in the first ten days of August. The bulk sample for each cultivar was ca 2 kg. After harvest the fresh fruit were kept at 10°C for 16 hs. Berries destinated for storage were packed into food-freezing polyethylene bags (three replicates of 250–300 g each), de-aerated by means of Clatronic 777 vacuum-welder, and preserved at ca -25°C for 6 and 12 months. Chemical analyses of fresh and frozen blueberries prior to de-freezing [Małolepszy 1985] were performed. Total sugar content was estimated with the Loof-Schoorl method [Drzazga 1997]. Organic acid content was determined by titration of fruit tissue water extract of with 0.1 N NaOH to end point 8.1 (measured with Orion 720A pH meter, Orion Research Incorporated, Boston, AM, USA) according to PN-90/A-75101/04. Vitamin C content was estimated with iodometric method [Sapožnikova and Dorofiejeva 1966]. Total polyphenol content was estimated in the methanol (70%) extracts according to Singleton and Rossi [1965] with the Folin-Ciocalteu reagent. The data were expressed as mg of gallic acid equivalents (GAE) per 100 g of fruit tissue. Dry weight content was determined with a gravimetric method (drying ~5 g aliqout of fruit tissue at 105°C to the constant weigh), according to Krełowska-Kułas [1993]. Statistical analysis was done by two-factor analysis of variance (I factor – cultivar, II factor – storage time) for each year and then subjected to three years constant model synthesis. The data were evaluated by the Tukey multiple comparison test at $P < 0.05$.

RESULTS AND DISSCUSSION

Water content in blueberries as reported by Adams [1975] is 83.2%. Ostrowska and Ściążko [1996] determined lower dry matter content in blueberry cultivars (12.80–15.09%) related to the results obtained in this study (14.94–15.79%). Regarding fresh fruit, 'Bluecrop' and 'Jersey' berries showed higher dry weight content than 'Blueray' and 'Spartan' ones (fig. 1). After 6 months of freezing-preservation 'Spartan', 'Jersey' and 'Blueray' fruit exhibited reduction in dry weight content while that of 'Bluecrop' increase. Further storage caused decrease in dry weight content in all studied cultivars. From practical point of view, the alterations observed, though in some cases statistically significant, with exception of 'Spartan' berries, were not substantial. They may have resulted mainly from the differences between the samples. After 12 months of storage the strongest dry weight decline was found for 'Spartan' berries (by 7.3%). 'Jersey' by 2.8%, 'Blueray' 1.4% and the least for 'Bluecrop' berries by 0.8%. The results obtained for these cultivars confirm usability of polyethylene welded bags for blueberries freezing preservation.

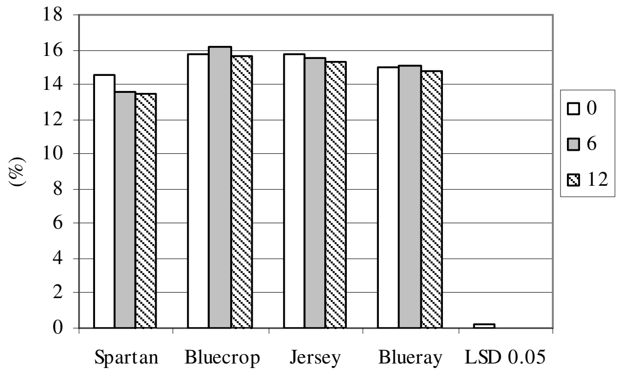

Fig. 1. Mean dry weight content in blueberries: fresh, after 6, and 12 months of freezing preservation

Rys. 1. Średnia zawartość suchej masy w świeżych i mrożonych borówkach po 6 i 12 miesiącach przechowywania

According to Andrzejewski [1975] the scope of saccharose content in blueberries is 0.15–1.77 and invert sugar 5.28–11.70 g · 100 g^{-1}. Total sugar content in these berries determined by Ostrowska and Ściążko [1996] ranged from 8.36 ('Bluecrop') to 9.57 g · 100 g^{-1} ('Jersey') and was lower to that obtained in the reported study for fresh berries (10.87–11.83 g · 100 g^{-1}). On average, within 1-year storage 'Bluecrop' berries showed the highest and 'Spartan' ones the lowest total sugar content (tab. 1). After 6 months of storage significant decrease of mean sugar content was found for all the cultivars. Considering the whole period of storage, the greatest reduction in total sugar was observed in 'Spartan' berries (by 10.8%) what was similar to dry weight content. Fruit of 'Bluecrop', 'Blueray' and 'Jersey' showed some decline in sugar content by 1%, 2.2% and 6.1%, respectively.

Total titratable acid estimated for blueberries by Prior et al. [1998] ranged from 0.22 to 0.73 mequiv/g of dry weight. According to Andrzejewski [1975] total acid content in blueberries is 0.51–1.77 g · 100 g^{-1} of fresh weight. In this experiment on the basis of fresh fruit and the mean values for each cultivar, 'Blueray' berries exhibited the highest total acid content whereas 'Spartan' ones the lowest (tab. 1). After 6 months of freezing preservation of blueberries (regarding mean values for period factor) no significant changes in fruit acidity were noted. On the other hand after next 6 months significant increase in total acidity was recorded. ‘Blueray’ berries displayed the most stabile acidity during the experiment. After 12 months total acid content in fruit of this cultivar was higher only by 0.7% compared to their initial value. ‘Spartan’ berries showed the greatest augmentation of total acid content by 3.2% towards fresh fruit. Acidity increase in ‘Bluecrop’ and ‘Jersey’ berries was by 1.1% and 1.7%, respectively.

Table 1. Total sugar and total acid content in fresh fruits of selected highbush blueberry cultivars and after 6 and 12 months of freezing preservation (means of 2001–2003)
Tabela 1. Zawartość cukrów ogółem i kwasów ogółem w świeżych owocach wybranych odmian borówki wysokiej oraz po 6 i 12 miesiącach przechowywania w stanie zamrożonym (średnie z lat 2001–2003)

Cultiva Odmiana	Total sugar ($g \cdot 100 g^{-1}$) Cukry ogółem ($g \cdot 100 g^{-1}$)				Titratable acidity (g citric acid $\cdot 100 g^{-1}$) Kwasowość miareczkowa (g kwasu cytrynowego $\cdot 100 g^{-1}$)			
	storage time – okres przechowywania							
	0	6	12	mean średnia	0	6	12	mean średnia
‘Spartan’	10.87	9.30	9.70	9.96	0.54	0.56	0.55	0.55
‘Bluecrop’	11.83	11.53	11.71	11.69	0.80	0.79	0.81	0.80
‘Jersey’	11.22	10.80	10.53	10.85	0.81	0.80	0.82	0.81
‘Blueray’	11.53	11.17	11.28	11.33	0.87	0.86	0.88	0.87
Mean – Średnia	11.36	10.70	10.81	-	0.76	0.75	0.77	-
$LSD_{0.05}$ I $NIR_{0.05}$ I	0.135				0.008			
$LSD_{0.05}$ II $NIR_{0.05}$ II	0.105				0.006			
$LSD_{0.05}$ I × II $NIR_{0.05}$ I × II	0.210				0.012			

Organic acids and sugars are regarded to be stabile compounds in native conditions and do not undergo striking changes neither during freezing nor after de-freezing [Gruda and Postolski 1999]. In the present study all examined cultivars after 1-year of storage maintained excellent taste and quantitative alterations in total sugar and total acid content did not influence their sensory attributes.

‘Blueberries’ are not considered to be a rich source of vitamin C. Ścibisz et al. [2003] estimated very low ascorbic acid content in these berries 1.4–3.2 mg $\cdot$ 100 g^{-1}. However Łata et al. [2005] determined similar to this report results. For ‘Darrow’ cultivar the authors obtained 16.6 and 30.6 mg $\cdot$ 100 g^{-1} and for ‘Bluecrop’ 16.2 and 25.2 mg $\cdot$ 100 g^{-1}, respectively in 2001 and 2002 year. The scope of this antioxidant content surveyed in present study ranged from 22.7 to 16.5 mg $\cdot$ 100 g^{-1} (tab. 2). Referring to fresh fruit stage and mean values for the cultivars within all storage period ‘Bluecrop’ berries had the highest vitamin C level while that of ‘Spartan’ the lowest. During freezing preservation considerable decline of vitamin C occurred after first 6 months. Further storage did not cause any appreciable changes. After 1-year, the strongest reduction was found in ‘Jersey’ berries (by 72%) and the least in ‘Blueray’ fruit (by 57%). As stated by Zadernowski and Oszmiański [1994] substantial influence on preservation of vitamin C in berries exerts the method of fruit freezing and the freeze-storage length-time.

Table 2. Vitamin C and total polyphenol content in fresh fruits of selected highbush blueberry cultivars and after 6 and 12 months of freezing preservation (means of 2001–2003)

Tabela 2. Zawartość witaminy C i polifenoli ogółem w świeżych owocach wybranych odmian borówki wysokiej oraz po 6 i 12 miesiącach przechowywania w stanie zamrożonym (średnie z lat 2001–2003)

Cultivar Odmiana	Vitamin C ($mg \cdot 100 g^{-1}$) Witamina C ($mg \cdot 100 g^{-1}$)				Total polyphenol ($mg \cdot 100 g^{-1}$) Polifenole ogółem ($mg \cdot 100 g^{-1}$)			
	storage time – okres przechowywania							
	0	6	12	mean średnia	0	6	12	mean średnia
‘Spartan’	19.9	6.5	7.1	11.2	258.8	236.4	294.1	263.1
‘Bluecrop’	22.7	9.1	9.1	13.6	306.9	290.8	307.5	301.7
‘Jersey’	15.2	4.1	4.2	7.8	194.1	189.6	218.7	200.8
‘Blueray’	16.5	5.4	7.1	9.7	205.9	221.2	252.1	226.4
Mean – Średnia	18.6	6.3	6.9	-	241.4	234.5	268.1	-
$LSD_{0.05}$ I $NIR_{0.05}$ I	0.84				27.52			
$LSD_{0.05}$ II $NIR_{0.05}$ II	0.65				21.35			
$LSD_{0.05}$ I × II $NIR_{0.05}$ I × II	1.30				n.s. – r.n.			

n.s. – not signnificant
r.n. – różnica nieistotna

Cultivated highbush blueberries are copious sources of phenolics that are believed to have health beneficial activity. Total polyphenol content as scrutinized by Ehlenfeldt and Prior [2001] was only 179 $mg \cdot 100 g^{-1}$ (average for 87 cultivars) whereas Zheng and Wang [2003] determined much higher values for ‘Serra’ cultivar berries amounted to 412 $mg \cdot 100 g^{-1}$. In this experiment similarly to vitamin C content, the highest total polyphenol content was estimated in ‘Bluecrop’ berries and the lowest in ‘Blueray’ and ‘Jersey” (as regards fresh fruit and the means for cultivar factor) (tab. 2). For the first 6 months of storage a slight lowering of phenolics in all the cultivars but ‘Blueray’ (slight increase) was observed. However, according to statistical estimation of the means for period factor no significant alterations were found. In comparison to initial data ‘Bluecrop’ berries after 12 months had the least increase of total polyphenol by 0.2% only. ‘Jersey’ and ‘Spartan’ cvs showed increase by 14 and 13%, respectively. The greatest increase was recorded in ‘Blueray’ fruit by 22%. The changes of phenolic compounds content in frozen fruits are difficult for unequivocal interpretation. According to Häkkinen and Törrönen [2000] freeze-storage of berries may influence phenolic content in these fruits. The authors noticed quercetin content decreased by 40% in bilberries and increased by 32% in strawberries during 9 months of storage at -20°C. Schmidt et al. [2005] found that both cultivated (*Vaccinium corymbosum* L.) and wild lowbush (*Vaccinium angustifolium* Ait.) fresh and individually quick frozen (IQF) blueberries, had the highest total phenols, antioxidant activity, and antiproliferation activity compared to such fruit products as spray-dried, heat-dried, cooked, juice concentrate, pie filling, and jam.

CONCLUSIONS

Three-year observation of blueberry (*Vaccinium corymbosum* L.) fruit chemical composition either fresh or under applied freeze-preservation (at -25°C, after 6 and 12 months) revealed significant differences between selected cultivars.

1. 'Spartan' cv berries showed the strongest lowering of dry weight and total sugar content followed by the highest increase of total acid content.
2. Blueberries of 'Bluecrop' cv were characterized by the most stabile chemical composition, especially dry weight, total sugar and total polyphenol content.
3. 'Blueray' cv berries exhibited negligible alteration of total acid content and the least decline of vitamin C content. On the other hand these fruits presented the highest increase of total polyphenol content.
4. Blueberries of 'Jersey' cv displayed the greatest losses of vitamin C.
5. Regarding the all storage period the least pronounced relative changes in chemical composition of blueberries occurred in total acidity while the most considerable in vitamin C content.

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OCENA SKŁADU CHEMICZNEGO ŚWIEŻYCH I MROŻONYCH OWOCÓW BORÓWKI WYSOKIEJ (*Vaccinium corymbosum* L.)

Streszczenie. Jagody borówki wysokiej są smacznymi owocami powszechnie uznawanymi za źródło cennych dla zdrowia substancji, zwłaszcza związków polifenolowych. Mrożenie, oprócz innych metod, jest sposobem na przedłużenie ich podaży poza sezon wegetacyjny. Celem badań było określenie składu chemicznego owoców czterech odmian borówki wysokiej ('Spartan', 'Bluecrop', 'Jersey' i 'Blueray'). W owocach świeżych oraz po 6 i 12 miesiącach przechowywania w stanie zamrożonym w temp. -25°C oznaczano zawartość suchej masy, cukrów ogółem, kwasowość ogólną, zawartość witaminy C i polifenoli ogółem. Stwierdzono, że jagody odmiany 'Bluecrop' miały najbardziej stabilny skład chemiczny (zawartość suchej masy, cukrów ogółem i kwasowość), natomiast borówki odmiany 'Spartan' najmniej. Mając na uwadze cały okres przechowywania borówek, najmniejsze zmiany nastąpiły w kwasowości ogólnej owoców (wzrost o 0,1 g kwasu cytrynowego $\cdot 100\ g^{-1}$) , a największe w zawartości witaminy C (spadek o 57% u odmiany 'Bluecrop' – 72% 'Jersey').

Słowa kluczowe: Borówka wysoka, skład chemiczny owoców

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