Alicja PONDER, Krystyna ŚWIETLIKOWSKA, Ewelina HALLMANN
SGGW w Warszawie, Wydział Nauk o Żywieniu Człowieka i Konsumpcji,
Katedra Żywności Funkcjonalnej, Ekologicznej i Towaroznawstwa, Zakład Żywności Ekologicznej
ul. Nowoursynowska 159c, 02-776 Warszawa, Poland
e-mail: alicja_ponder@sggw.pl
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THE QUALITATIVE EVALUATION OF THE FRUIT OF INDIVIDUAL CULTIVARS *RUBUS* TAKING INTO ACCOUNT THEIR USEFULNESS TO ORGANIC FARMING

Summary

A specific objective of this paper was to evaluate a quality of the fruit of individual cultivars Rubus taking into account their usefulness to organic farming. The berry fruits belong to different botanical groups. Type of the fruits is common feature of those fruits. To this fruit group belongo: raspberry (Rubus idaeus), tayberry (Rubus fruticosus x Rubus idaeus), black raspberry (Rubus occidentalis L.), malina kanadyjska (Rubus canadensis), jeżyna bezkolcowa (Rubus fruticosus). The berry fruits contain a lot of bioactive compounds, which are well known as antioxidants. Those compounds belong mostly to polyphenols group. Polyphenols are characterized by a potent antioxidant and anticancer properties. The experimental material was composed of the fruits of individual cultivars Rubus obtained from Polish Academy of Sciences Botanical Garden, Center for Biological Diversity Conservation in Powsin. The content of dry matter, vitamin C and polyphenols was measured in fruits. The obtained results showed that the cultivar has an impact on the nutritional value and the content of bioactive compounds in the berry fruit. The highest contents of dry matter, total flavonoids and anthocyanins were found in black raspberry fruit. Rubus canadensis fruit contained the highest content of vitamin C. The highest content of total polyphenols was observed in fruits of Rubus idaeus. In contrast, the highest content of total phenolic acids and quercetin was found in tayberry fruit. In conclusion, berry fruits can be used as good sources of antioxidants in diet and may have relevance in the prevention of diseases in which free radicals are implicated. They are easy in cultivation and can be recommended to organic cultivation.
***Keywords**: berry fruit, bioactive compounds, antioxidants, polyphenols, organic farming*

OCENA JAKOŚCIOWA OWOCÓW RÓŻNYCH GATUNKÓW *RUBUS* ZE WZGLĘDU NA ICH PRZYDATNOŚĆ DO UPRAW EKOLOGICZNYCH

Streszczenie

Celem tego badania była ocena jakościowa owoców różnych gatunków Rubus we względu na ich przydatność do upraw ekologicznych. Owoce jagodowe należą do różnych grup botanicznych. Ich wspólną cechą jest rodzaj owoców. Do tej grupy owoców należą: malina, malinojeżyna, czarna malina, jeżyna kanadyjska, jeżyna zwyczajna, jeżyna bezkolcowa. Owoce jagodowe zawierają duże ilości związków biologicznie czynnych o charakterze antyoksydacyjnym, zwłaszcza polifenoli. Polifenole wykazują właściwości przeciwnowotworowe. Materiał do badań stanowiły owoce poszczególnych gatunków Rubus. Owoce były analizowane pod kątem zawartości suchej masy, witaminy C i polifenoli. Uzyskane wyniki wykazały, że gatunek ma wpływ na wartość odżywczą i zawartość związków bioaktywnych w owocach jagodowych. Najwyższą zawartość suchej masy, flawonoidówogółem i antocyjanów stwierdzono w owocach maliny czarnej. Owoce jeżyny kanadyjskiej zawierały największą zawartość witaminy C. Najwyższą zawartość polifenoli ogółem zaobserwowano w owocach jeżyny zwyczajnej. Natomiast w owocach malinojeżyny stwierdzono najwyższą zawartość kwasów fenolowych ogółem i kwercetyny.
Podsumowując, owoce jagodowe mogą stanowić dobre źródło przeciwutleniaczy w diecie i mogą zapobiegać chorobom powodowanym przez wolne rodniki. Omówione krzewy owoców jagodowych są łatwe w uprawie i mogą być hodowane w systemie rolnictwa ekologicznego.
***Słowa kluczowe**: owoce jagodowe, składniki bioaktywne, antyoksydanty, polifenole, rolnictwo ekologiczne*

1. Introduction

In general, fruit consumption is increasing. There are many health benefits resulting from the consumption of fruit. Fruits contain many valuable nutrients, which are involved in many metabolic reactions occurring in the human body. Many of them exhibit antioxidant properties, which include the ability to neutralize reactive oxygen species. These include vitamin C and polyphenol compounds such as phenolic acids, anthocyanins and flavonoids. Polyphenols are the largest group of natural antioxidants that are primarily responsible for inhibiting the formation of free radicals, thereby preventing the occurrence of many diseases. This is because polyphenols bind to metal ions which are catalysts for free radical reactions [12]. Polyphenols are organic phenolic compounds containing at least two hydroxyl groups attached to the aromatic ring. More than 8,000 polyphenol compounds have been isolated from various natural products, including flavonoids and phenolic acids. Each group is then subdivided into subgroups depending on the chemical structure of the basic carbon skeleton [15]. Polyphenols are naturally occurring in plants, but are not produced by the body, and should also be supplied with food. Berry fruits are especially rich in these compounds. Berry fruit contains many important dietary components: vitamins, minerals, polyphenols and fibre. The overwhelming body of research has now firmly stated that the dietary intake of berry fruits has a positive and profound impact on human health, performance and disease. Berry fruits are known as possessing outstanding antioxidative power. The antioxidant capacity of berry fruit was shown to be influenced by several factors with cultivar variability being one of the most important. Antioxidants occured in berry fruit exhibit anti-atherosclerotic, antitumor and antimicrobial features. They eliminate reactive oxygen species, scavenge free radicals, causing the chelation of metal ions and the inhibition of enzymes from the group of oxidases. Thanks to this the human body is protected against oxidative stress and the development of related diseases [5].

Rubus is a large and diverse genus of flowering plants in the rose family, Rosaceae, subfamily Rosoideae, with 250–700 species. *Rubus* represents one of the most diverse genera of plants, comprising 12 subgenera of which four have high value as fruiting species. This diversity is reflected in the wide range of fruit types and pigmentation found within the genus. *Rubus* species are widely distributed globally as wild and cultivated species and genotypes, *Rubus* includes species found in Europe, Asia, and North America,. Wild grown *Rubus* species are mostly found in forest edges. Of the cultivated *Rubus* the most popular is the red raspberry of the subgenus Idaeobatus, which is distributed throughout the temperate regions of Europe, Asia and North America as two species, R *idaeus* L and R *strigosus* Michx. Fruit *Rubus* are widely recognized fruits for their nutritional quality and potential health benefits. Fruit *Rubus* in particular, are known to demonstrate strong antioxidant capacity, mainly as a result of their high levels of anthocyanins and other phenolic compounds [10].

The intensification and expansion of modern agriculture is amongst the greatest current threats to worldwide biodiversity. Over the last quarter of the 20th century, dramatic declines in both range and abundance of many species associated with farmland have been reported in Europe, leading to growing concern over the sustainability of current intensive farming practices. Purportedly sustainable farming systems such as organic farming are now seen by many as a potential solution to this continued loss of biodiversity and receive substantial support in the form of subsidy payments through EU and national government legislation. The purpose of organic farming is not only to produce high-quality food but also to protect natural environment and ensure the well-being of farm animals. Organic farming is based on the controlled production methods which are conducive to biodiversity and do not cause soil and ground water pollution because of the ban on agro-chemicals [6].

2. Material and methods

The experimental material included the fruits of individual cultivars Rubus: *raspberry*, *tayberry*, *black raspberry, Rubus canadensis*, *Rubus idaeus Rubus fruticosus.* The experimental material was composed of the fruits obtained from Polish Academy of Sciences Botanical Garden, Center for Biological Diversity Conservation in Powsin.

The content of dry matter, vitamin C and polyphenols was measured in fruits.

In fruits the content of dry matter (by scale method), vitamin C (by spectrophotometric method) as well as polyphenols (by HPLC method) has been determined. The obtained results were statistically elaborated with post-hoc Tukey test (p=0,05).

3. Results

Nutritional value and content of bioactive compounds in berry fruit are shown in Table 1.

Table 1. The content of dry matter (g/100 g FW), vitamin C (mg/100 g FW) and polyphenols (mg/100 g FW) in examined berry fruits
Tab. 1. Zawartość suchej masy (g/100 g ś.m.), witaminy C (mg/100 g ś.m.) oraz polifenoli (mg/100 g ś.m.) w badanych owocach jagodowych

Examined compounds	Cultivars						p-value
	Raspberry	Tayberry	Black raspberry	*Rubus canadensis*	*Rubus idaeus*	*Rubus fruticosus*	
dry matter	17,85±1,17b	14,26±1,01a	23,49±1,05c	18,46±0,78b	16,26±0,90ab	16,42±1,40ab	<0,001
vitamin C	60,01±5,25c	38,81±5,13a	47,80±4,27ab	64,17±2,06c	55,80±2,94bc	61,68±6,48c	0,001
total polyphenols	107,44±3,61a	172,25±4,50b	990,30±48,59c	83,36±1,43a	294,75±7,78b	255,34±20,91b	<0,001
total phenolic acids	48,47±1,25b	85,98±3,76d	70,88±5,61c	11,49±0,65a	51,02±3,89b	71,01±4,54c	<0,001
gallic	3,31±0,17b	2,74±0,77b	9,78±0,35c	2,69±0,33b	0,64±0,01a	0,54±0,05a	<0,001
chlorogenic	28,91±1,65b	30,79±0,51b	40,44±5,16c	5,62±0,66a	42,50±3,76c	8,86±1,24a	<0,001
caffeic	1,62±1,03b	-	-	1,04±0,09b	0,68±0,19ab	1,38±0,19b	0,01
p-coumaric	9,87±0,42b	49,82±3,79d	14,55±1,32c	0,52±0,21a	6,96±0,05b	58,98±3,10e	<0,001
benzoic acid	0,78±0,11b	0,77±0,06b	2,60±0,48d	1,59±0,35c	0,22±0,02a	1,22±0,01bc	<0,001
cinnamic acid	-	-	-	-	-	-	
Ellagic acid	3,95±0,35c	1,84±0,06b	3,48±0,42c	-	-	-	<0,001
total flavonoids	12,83±0,38a	12,82±0,77a	32,92±2,52c	22,01±0,80b	15,39±0,73a	21,36±1,75b	<0,001
quercetin-3-O-rutinoside	5,19±0,34a	5,94±0,77ab	11,99±0,96c	17,01±0,63d	7,12±0,11b	10,05±1,23c	<0,001
glycoside-3-O-quercetin	0,48±0,01a	0,52±0,07a	13,43±0,34d	0,45±0,07a	3,09±0,28b	4,49±0,40c	<0,001
glycoside-3-O-kempferol	1,35±0,16b	n.w.±0	n.w.±0	n.w.±0	n.w.±0	n.w.±0	<0,001
myristectin	3,65±0,32ab	3,87±0,52ab	5,19±0,93c	3,10±0,15a	3,24±0,46a	4,69±0,15bc	0,007
quercetin	1,68±0,07ab	2,18±0,16b	1,79±0,42b	1,02±0,08a	1,65±0,66ab	1,81±0,18b	n.s
kaempferol	0,47±0,02c	0,28±0,02a	0,50±0,03c	0,40±0,02b	0,27±0,01a	0,31±0,03a	<0,001
total of anthocyanins	46,13±2,13a	73,44±7,04a	886,49±44,08d	49,86±1,03a	228,33±7,32c	162,97±14,64b	<0,001
glycoside-3,5-di-O-dolphinidine	34,23±0,72a	63,20±8,12a	728,25±35,40c	27,96±0,29a	174,48±13,40b	138,63±12,00b	<0,001
galactoside-3,5-di-O-peonidine	3,37±0,29a	2,84±0,32a	58,67±7,80d	9,29±0,69ab	22,08±2,55c	11,18±2,61b	<0,001
glycoside-3,5-di-O-cyanidine	7,93±1,48a	7,39±0,79a	99,57±4,82c	11,96±1,80a	31,69±3,76b	10,99±0,78a	<0,001
glycoside-3,5-di-O-malinidine	0,59±0,11b	-	-	0,64±0,08b	0,06±0,001a	2,15±0,20c	<0,001

*data are presented as the mean ± SD with ANOVA p-value; ** n.s. (statistically not significant); values labeled with the same letter are not significantly different (Tukay's honestly significant difference test, P=0.05)

Source: own work / Źródło: opracowanie własne

Dry matter content. The highest content of dry matter were found in black raspberry fruit. The content of dry matter in fruits mainly depends on the method of soil fertilization. Too high dose of nitrogen used in the later phases of the growth may reduce the dry matter content in the fruit [9].

Vitamin C content. *Rubus canadensis* fruit contained the highest content of vitamin C. The high content of vitamin C in fruits can be explained by the fact that the level of vitamin C increases if the plant is grown under the low nitrogen availability conditions [9].

Polyphenols content. The highest content of total polyphenols was observed in fruits of *Rubus idaeus*. In contrast, the highest content of total phenolic acids and quercetin was found in tayberry fruit. Black raspberry fruits were characterized by the highest content of total flavonoids and anthocyanins. Polyphenols constitute a large class of compounds present in plants. Experimental research has demonstrated that each plant species is characterized by the presence of a limited number of compounds. Within each species, the nature of these compounds can vary from organ to organ. Factors contributing to the variability in polyphenols distribution include cultivar and genetics, geographical origin, maturity, climate, position on trees, and agricultural practices [1].

4. Disscusion

In their experiment, Skupień et al. (2012) analyzed the content of biologically active compounds (vitamin C and polyphenols) in raspberry fruits of different cultivars (Polana, Polka and Pokusa). Raspberry fruit cultivar Pokusa contained higher content of vitamin C (22,88 mg/100 g) and polyphenols (244,7 mg of gallic acid/100 g). In contrast, raspberry fruit cultivar Polana was characterized by the lowest content of vitamin C (17,62 mg/100 g) and polyphenols (186,9 mg of gallic acid/100 g) [12].

In another research, Fijol-Adach et al. [3] studied the effect of the organic and conventional system on the quality of strawberry fruit. The result showed that strawberries cultivar Elkat from organic production contained significantly higher content of L-ascorbic acid (123 mg/100 g of fresh weight) compared with conventional strawberries (57 mg / 100 g of fresh weight). Organic strawberries also contained higher levels of polyphenols, flavonoids and anthocyanins than conventional strawberries [3].

Research of Wojdyło on organic strawberry fruits cultivar Senga Sengana and Elkat showed lower content of bioactive poly-phenol compounds compared to their conventional counterparts, which determined their higher antioxidant activity. The total content of individual compounds depended not only on the cultivation system but also on the cultivar. Strawberry cultivar Senga Sengana had 20-30% more polyphenolic compounds than Elkat strawberries [13]. Three cultivars of blackcurrant: Ben Lomond, Ojebyn and Titania were selected for the research. The jams were made of the fruits and then analytical tests were carried out in which vitamin C, phenolic acids, flavonols and anthocyanins. The cultivation method had a significant influence on the contents of phenolic acids, flavonols and vitamin C in currants jams. The cultivation method also affected the accumulation of anthocyanins in the tested products. However, taking into account the cultivar there was no relationship between the content of anthocyanins and the cultivar. The highest content of phenolic acids was contained in jams from currants cultivar Ojebyn. Flavonol content was the hightest of jams made from Titania fruit, while most vitamin C contained jams from the Ben Lomond cultivar. Differences in the content of vitamin C and phenolic acids and flavonols were dependent on both the cultivation of raw materials and cultivars [7].

In a study by Sablani et al. there was compared the content of anthocyanins and total phenolic acids in raspberries and berries of organic and conventional cultivation. The raspberries cultivar Meeker and blueberries cultivar Duke and Rek were the study material. The type of cultivation system had a significant effect on the anthocyanin content of the fruit. The anthocyanin content in the blueberries of the cultivar Reka was higher (1.19 g / kg of fresh weight) than in conventional blueberries (0.997 g / kg of fresh weight). In contrast, both Duke blueberries from organic farms and ecological raspberries were characterized by lower anthocyanin content than conventional fruits. Results related to the total phenolic content of the fruit showed that raspberries and both types of blueberries of organic origin contained higher amounts of this compound compared to the conventional ones [10].

In conducted research, Klamkowski et al. [8] analized responses of three raspberry cultivars (Beskid, Laszka, Latham) to water deficiency. It was examined by evaluating selected physiological parameters. Plants were subject to two different water regimes: optimal irrigation (control), and reduced irrigation. Leaf water potential in all cultivars was decreased as a result of limited water availability. Genotypes differed in their response to water deficiency. Under water shortage conditions, the rate of CO2 assimilation was the highest in cultivar Latham and Laszka. On the other hand, the severe inhibition of photosynthesis was observed in 'Beskid'. Taking all data into consideration it was concluded that cultivar Latham and Laszka appeared to be more drought resistant which was reflected by enhanced physiological parameters [8].

The review by Gryszczyńska et. al. [4] suggested an association between consumption of polyphenol-rich berry fruits and their prophylactic role. The antioxidant activity of berry fruits depending on the cultivar is also discussed. *Elliot Nero* fruit contained the highest content of total polyphenol compounds but was characterized by the lowest content of l-ascorbic acid. The highest content of l-ascoribc acid was found in *Ribes nigrum* fruit (table 2) [4].

Table 2. Total content of polyphenol compounds and concentration of l-ascorbic acid in selected cultivars of berry fruits [4]

Tab. 2. Całkowita zawartość związków polifenolowych i stężenie kwasu l-askorbinowego w wybranych odmianach owoców jagodowych [4]

Cultivar	Total of polyphenol compounds [mg/100 g FW]	L-ascorbic acid [mg/ 100 g FW]
Rubus fruticosus	397,4 ±5,9	13,1±0,1
Rubus idaeus	140,6±0,9	15,5±0,7
Ribes nigrum	535,5±10,2	108,1±2,5
Ribes rubrum	501,6±4,2	51±1,9
Elliot Nero	690,2±8,8	13,1±0,5

The aim of study conducted by Bobinaite et al. [2] was to assess the level of some bioactive comounds in 19 raspberry cultivars. The content of total phenolics ranged from 278,6 (Pokusa) to 714,7 mg/100 g (Bristol). The total anthocyanins content varied from 2,1 (yellow Beglianka) to 325,5 mg/100 g (black Bristol). The radical scavenging capacity of the tested raspberry cultivars was highly correlated with their total phenolics content [2].

5. Conclusions

1. The cultivar has an impact on the nutritional value and the content of bioactive compounds in the examined *Rubus* fruit.
2. The examined fruits were characterized by statistically significant differences in the content of biologically active compounds.
3. The highest content of dry matter (23,49 g/100 f FW), total flavonoids (32,92 mg/100 g FW) and total anthocyanins (886,49 mg/100 g FW) was found in black raspberry fruit.
4. *Rubus canadensis* fruit were contained the highest content of vitamin C (64,17 mg/100 g FW) and tayberry fruit were characterized by the lowest content of vitamin C (38,81 mg/100 g FW).
5. The highest content of total polyphenols was observed in fruits of *Rubus idaeus.* (294,75 mg/100 g FW) and the lowest content of this compounds was found in *Rubus Canadensis* fruit (83,36 mg/100 g FW).
6. The highest content of total phenolic acids (85,98 mg/100 g FW) and quercetin (2,18 mg/100 g FW) was found in tayberry fruit.

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