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COMPARISON OF TOTAL POLYPHENOL CONTENTS AND ANTIOXIDANT ACTIVITY IN CRUCIFEROUS VEGETABLES GROWN IN DIVERSIFIED ECOLOGICAL CONDITIONS

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ABSTRACT

Background. The aim of this study was to compare total polyphenol contents and antioxidant activity of three species of cruciferous vegetables grown under diversified ecological conditions for three consecutive years.
Material and methods. Methanol extracts were prepared to be used to determine (spectrometrically) the content of total phenolics, using the Folin-Ciocalteau reagent and antioxidant activity by identifying the sample's ability to extinguish an $ABTS^{•+}$ free radical.
Results. All these species of cruciferous vegetables contained similar total polyphenols amounts regardless of its origin. Only red cabbage from organic farms was characterized by significantly higher antioxidant activity compared to vegetables purchased from local retailers in Cracow and similar or those cultivated near the steelworks. In white cabbage from farms located in a former steelworks protection zone a higher antioxidant activity was found than in organically grown vegetables and similar to that in vegetables available in retail. Brussels sprouts was characterised by a similar antioxidant activity regardless of its origin.
Conclusions. On the basis of the present study, it cannot be concluded that organically grown cruciferous vegetables generally have higher contents of health-promoting secondary metabolites in comparison with the conventionally cultivated ones.

Key words: $ABTS^{•+}$ free radical, antioxidant activity, cruciferous vegetables, diverse ecological conditions, total polyphenols

INTRODUCTION

Numerous epidemiological studies clearly indicate the importance of fruit and vegetables as the richest potential source of natural antioxidants and emphasise the need to increase the proportion of these products in diet [Kim et al. 2003, Liu et al. 2002]. A prominent role in this process is played by the popular cruciferous vegetables, which contain several bioactive compounds and which not only act as antioxidants, but also have other health-promoting properties [Patras et al. 2011, Sikora et al. 2008]. They are among the most important dietary vegetables consumed in Europe and all over the world owing to their availability at local markets, cheapness and consumer preference [Kusznierewicz et al. 2008]. Phytochemicals from cruciferous vegetables induce detoxification enzymes, scavenge free radicals, alleviate inflammation,

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stimulate immune functions, decrease the risk for cancers, inhibit malignant transformation, and regulate the growth of cancer cells [Herr and Büchler 2010].

The actual available data only reveal the conclusion that a frequent intake of vegetables of the cruciferous family lowers the risk and may lead to a weaker metastasis of tumors in some persons [Forman et al. 2006, Herr and Büchler 2010].

Reactive oxygen species (ROS), which include free radicals, are considered to be a major cause of the initiation and promotion of cancer [Bergamini et al. 2004]. These unstable molecules are by-products of normal metabolism. Their contents increase in the body during infection, inflammation and exercise, and following exposure to exogenous sources: pollution, smoking, certain medications and radiation, including UV radiation [Lobo et al. 2010]. The ability of free radicals to induce cancer-causing DNA mutations and to oxidize and modify critical regulatory proteins, lipids and other cellular molecules makes them crucial factors in cancer development [Borek 2005].

Antioxidants are chemical compounds that detoxify reactive oxygen species and prevent them from causing damage to cellular macromolecules and organelles through multi-mechanisms [Conklin 2000, Zhou and Yu 2006]. Fruits and vegetables are good dietary sources of natural antioxidants for humans and consumption of them has been strongly associated with the reduced risk of chronic diseases, such as cardiovascular disease, cancer, diabetes, Alzheimer's disease, cataracts and age-related functional decline and other health benefits [Cohen et al. 2000, Knekt et al. 2002, Zhang and Hamauzu 2004].

Consumers generally perceive organic foods to be healthier and safer for themselves and environment [Crinnion 2010]. There is a considerable number of scientific data indicating that organic vegetables and fruits contain more compounds with antioxidant properties compared to products from conventional farms, which is decisive for their greater biological value, but according to the latest review the health benefits of consuming organic compared to conventional foods are unclear [Dangour et al. 2009, Hoefkens et al. 2010, Warman and Havard 1997].

Studies investigating the effect of organic food consumption on animal and human health are scarce. Few studies have shown some differences in effect of organic and conventional feed or diet on the immune status, reproductive health, growth and weight development, and the plasma antioxidant status [Benbrook et al. 2008, Finamore et al. 2004, Huber 2007, Kummeling et al. 2008]. However, much more controlled clinical human trials will be needed to further investigate health impacts of organic versus conventional diets on human health [Hoefkens et al. 2010].

The aim of the present study, which was consumer-research study in nature, was to compare total polyphenol contents and antioxidant activity in cruciferous vegetables cultivated in areas around a steelworks, on organic farms and those bought in retail for three consecutive years. The hypothesis to be verified through research was that statistically, total polyphenol contents and antioxidant activity in cruciferous vegetables from areas around a steelworks, organic farms and random retailers differ significantly independent of the climate and agro-technical conditions.

MATERIAL AND METHODS

Material

The study was done on three species of cruciferous vegetables: the white head cabbage 'Stone head' *variety*, the red head cabbage 'Langedijker' *variety*, and the 'Dolores F1' Brussels sprouts *variety*. The experiment lasted three years, from 2005 to 2008. Vegetables came from three different sources:

- 15 conventional farms from five different locations around the ArcelorMittal Poland SA. steelworks (Malopolskie Voivodeship), each of the farms producing vegetables for commercial purposes, located straight to the east of the emission source (western winds prevail in that territory),
- five organic farms holding "Agro Bio Test" Certificates (Malopolskie and Świetokrzyskie Voivodeships, located straight 50 kilometers from the ArcelorMittal Poland SA. steelworks and sources of possible contamination),
- unknown method of cultivation (conventional/organic/integrated), of recognizable varieties, obtained from five different retailers in Cracow (Malopolskie Voivodeship).

Seedlings of the above vegetables were all grown by Polan, a Cracow-based cultivation and seed production firm, and were planted out at the turn of June and

July for three consecutive years in the above locations. The last group of tested vegetables was purchased randomly from five different retailers in Cracow.

The Cracow region has been an environmentally threatened area for a number of years. According to the Report on the Condition of the Environment in Malopolska Voivodeship in 2009 [Raport... 2010], dust and gas emissions from industrial sources still rank this region among the most polluted ones in Poland, despite the ongoing effort to reduce the pollution load. ArcelorMittal Poland SA Unit in Cracow (formerly T. Sendzimir Steel Works, TSSW) has remained under the constant scrutiny of the Voivodeship Inspectorate for Environmental Protection (VIEP) since it was counted among the enterprises causing the greatest environmental nuisance due to emission of chemical pollutants [Raport... 2005, 2010].

Vegetables came from random suppliers reflected the situation of a potential consumer who buys vegetables at the consumer market. It cannot therefore be established what type of vegetable farms they came from.

The subject study was conducted regardless of the climate or agro-technical conditions because it was consumer-type research in nature.

Fresh vegetables were stored in a cold room at +4°C, from where they were taken directly to a laboratory. Two specimens of white and red cabbages and eight Brussels sprouts, with the biggest and with the smallest diameter, were sampled at each farm and from five different retailers. The plants of each vegetable were cut vertically into four or eight pieces (sub-samples) after removing inedible parts (outer leaves and stalks). Next, the sub-samples of plants were crumbled and mixed thoroughly. The material so prepared provided a representative average sample, which was used for analyses of dry matter. Additionally, the fresh material was used to prepare methanol extracts necessary to determine the content of polyphenol and antioxidant activity.

Analytical methods

The fresh material was crushed using a homogenizer and next was used to prepare methanol extracts (5 g of raw vegetables in 80 mL of 70% methanol solution). In each case, fresh plant materials were extracted by shaking at room temperature for 2 hours, and solution was centrifuged, filtered and then the extracts were stored at –20°C [Pellegrini et al. 2003]. They were used to establish the polyphenol content, using the Folin-Ciocalteau reagent. The method involved colorimetric determination of coloured products that formed when phenolic compounds reacted with the Folin-Ciocalteau (Sigma) reagent [Poli-Swain and Hillis 1959]. The content of total phenolics in the extracts was determined spectrometrically according to the Folin-Ciocalteu procedure and calculated as chlorogenic acid equivalents (CGA) (in terms of milligrams) per 100 g of fresh or dry weight, based on a standard curve.

Methanol extracts were also prepared to be used to determine (spectrometrically) antioxidant activity by identifying the sample's ability to extinguish an $ABTS^{\bullet+}$ free radical [Re et al. 1999]. The method involved colorimetric determination of the amount of the colored solution of $ABTS^{\bullet+}$ free radical which was reduced by the antioxidants present in the test product. Values obtained for each sample were compared to the concentration-response curve of the standard trolox solution and expressed as micromoles of Trolox equivalent per gram of fresh or dry weight.

The dry matter of the prepared samples of vegetables was determined according to PN-90/A-75101/03. The determination principle comprised determining the decrease in mass upon removal of water from the product during thermal drying at the temperature of 105°C, under normal pressure conditions.

For each simple the chemical analyses were done in two or three replicates, the relative error not exceeding 5%. The mean values presented in the tables were calculated based on 45 repetitions (15 farms × 3 years) for each vegetable species from farms around the ArcelorMittal Poland SA steelworks; on 15 repetitions (5 farms × 3 years) for vegetable species from organic farms; and on 15 repetitions (5 farms × 3 years) for vegetable species from retail stores.

Statistical analysis

All data are mean values ±SD (standard deviation). To check the significance of differences between the contents of polyphenol and antioxidant activity in cruciferous vegetables depending on their source ANOVA single-factor was performed. The significance of differences was evaluated using Duncan's test, with the critical significance level of $p \leq 0.05$. All calculations were done by Statistica v. 8.1 (StatSoft Inc.).

RESULTS AND DISCUSSION

A comparison of contents of the components in vegetables grown around the steelworks, vegetables from organic farms and vegetables from retailers was performed either on a fresh or dry mass basis. These data were then compared with the results obtained by other authors based on the contents of the subject components reported on a unit fresh weight basis for vegetables with (some) exceptions.

Dry mass

Table 1 presents dry mass contents in white cabbage, red cabbage and Brussels sprouts grown under diversified environmental conditions.

All the three vegetable species under review (Table 1) cultivated on farms holding “Agro Bio Test” certificates were demonstrated to have a clearly higher dry mass content ($p \leq 0.05$) compared with vegetables cultivated near the steelworks. Vegetables from eco-farms and from retailers in Cracow showed a similar dry mass content.

Total polyphenols

The total content values of polyphenolic compounds in vegetables are converted to chlorogenic acid equivalents and presented in Table 2. When the values were reported per unit of fresh weight (Table 2), the total contents of polyphenols in all the cruciferous species under review from all the three locations were similar ($p > 0.05$).

Three cruciferous species examined contained similar total amounts of polyphenols on a dry weight basis, independent of their origin (Table 2). Only in white head cabbage cultivated near the steelworks, the total content of polyphenols was insignificantly higher ($p > 0.05$) compared with organic vegetables and was similar to commercially available vegetables. The differences in the proportion were 12 and 11%, respectively.

Kähkönen et al. [1999] proved that the method of determination of total polyphenols using FC reagent is highly error-susceptible due to the compound’s ability to react not only with polyphenols but also with vitamin C, some alkaloids, proteins and other compounds specified in literature. It does not provide a full picture of the quality and quantity of phenolic compounds in extracts from the plant under investigation. This should be taken into consideration when evaluating the results.

Halvorsen et al. [2002] after examining 32 vegetables from several different countries listed red cabbage on the third position and Brussels sprouts on the eighth position in terms of total polyphenol content, which corresponds to these studies. Regardless of the origin

Table 1. Content of dry mass in white cabbage, red cabbage and Brussels sprouts grown in diversified ecological conditions

Sources of vegetables	Dry mass, g/100 g		
	white cabbage	red cabbage	Brussels sprouts
From closest vicinity of the steelworks	6.63 ±0.59 a	8.16 ±0.21 a	14.8 ±0.69 a
From organic farms	7.55 ±0.20 b	9.33 ±0.21 b	16.0 ±0.62 b
From a selected market	7.35 ±0.20 b	9.35 ±0.40 b	15.7 ±0.52 b

Mean values ±standard deviation.
Differences between values signed with the same small letters are non-significant ($p \leq 0.05$).

Table 2. Content of total polyphenols (in fresh and dry mass) in white cabbage, red cabbage and Brussels sprouts grown in diversified ecological conditions

Sources of vegetables	Total polyphenols					
	white cabbage		red cabbage		Brussels sprouts	
	mg CGA/ 100 g f.m.	mg CGA/ 100 g d.m.	mg CGA/ 100 g f.m.	mg CGA/ 100 g d.m.	mg CGA/ 100 g f.m.	mg CGA/ 100 g d.m.
From closest vicinity of the steelworks	59.8 ±3.1 a	875.5 ±83.1 a	249.1 ±8.97 a	2 960.0 ±191.7 a	209.0 ±27.1 a	1 291.3 ±81.2 a
From organic farms	59.7 ±3.1 a	784.2 ±49.9 a	242.7 ±24.4 a	2 989.0 ±199.8 a	214.6 ±16.3 a	1 373.8 ±97.8 a
From a selected market	58.4 ±6.0 a	791.3 ±85.8 a	260.3 ±29.2 a	2 853.8 ±306.4 a	222.7 ±16.2 a	1 399.8 ±115.4 a

Mean values ±standard deviation.
Differences between values signed with the same small letters are non-significant ($p \leq 0.05$).

source of the analyzed vegetables it was red head cabbage characterized by the highest polyphenol content, then Brussels sprouts and the lowest content was observed in white head cabbage.

Other authors claim that the total content of polyphenols in red head cabbage ranged from 134.7 to 257.0 mg/100 g f.w., which corresponds in general to our results given in Table 2 [Heo and Lee 2006, Leja et al. 2005, Podsędek et al. 2004, Podsędek 2007, Proteggente et al. 2002].

The total content of polyphenols in Brussels sprouts as presented in this paper (Table 2) corresponds to the data published by a number of researchers, and fluctuated from 68.8 to 740.0 mg/100 g f.w. [Brat et al. 2006, Cieślik et al. 2005, 2006, Kaur and Kapoor 2002, Podsędek 2007, Souci et al. 2000].

Phenolic compounds, including their subcategory, flavonoids, are present in all plants and have been studied extensively in cruciferous vegetables. The total polyphenol content ranges from 4% in white and Italian cabbage to 39% in red cabbage [Chun et al. 2004, Karadeniz et al. 2005]. Anthocyanin pigments found in red cabbage (23 of them have been identified so far) are acylated derivatives of cyanidine, and their content in this species varies from 25 to 495 mg/100 g f.w. [Sosnowska 2007].

As in other plant products, the content of polyphenolic compounds in vegetables is contingent on a number of factors, among them climate, agronomy, maturation phase, harvest time, storage conditions, temperature, tissue damage, genetic factors and varietal diversity [Hallmann and Rembiałkowska 2007, Martinez-Valverde et al. 2002, Ninfali and Bacchiocca 2003]. This study was conducted for 3 years, because only the average value of the various evaluated parameters of the successive iterations obtained in such a long period of time may be an objective value that is representative independently of the resultant influence of all interfering factors climatic and agro-meteorological.

According to Borowska [2003], the concentration of phenolic acids during maturation can rise or drop while storage markedly reduces it. Polyphenolic compounds having complicated structure and properties, extraction conditions and testing methods are equally important. Large disproportions between total polyphenol contents reported by different authors may result from differing methods of extraction of polyphenolic compounds from raw material. Differing calculation methods and reference standard are another reason for discrepancies.

Young et al. [2005] measured the content of nine major phytochemical compounds in lettuce, collards and pak choi and found that organic production resulted in a higher concentration of phytochemicals in pak choi, but not in lettuce or collards.

Whereas in the study of Søltoft et al. [2010] onions, carrots, and potatoes were cultivated in two-year field trials in three different geographical locations, comprising one conventional and two organic agricultural systems. In onions and carrots, no statistically significant differences between growth systems were found for any of the analyzed polyphenols.

Hallmann and Rembiałkowska [2006] demonstrated that red onion when grown organically contained more flavonoids compared with conventional methods. Some research also showed a slightly yet significantly higher content of polyphenol in organic potatoes or tomatoes [Hajslová et al. 2005, Hamouz et al. 2005, Mitchell et al. 2007], as well as in the study of Asami et al. [2003], where antioxidant levels in sustainably grown corn were 58.5% higher than conventionally grown corn.

The higher content of these compounds in mostly organic products as found in our experiments is explained by the Growth-Differentiation Balance Hypothesis (GDBH), which says that organically grown plants, which have limited access to easily assimilable nitrogen, produce more valuable bioactive compounds, including phenols, than plants grown conventionally [Caris-Veyrat et al. 2004]. Brandt and Mølgaard [2001] and Heaton [2001] also showed that it was natural for plants cultivated organically to contain more polyphenols and other secondary metabolites. Opposite tendencies indicative of higher contents of polyphenols in conventional products were observed by Caris-Veyrat et al. [2004] and Anttonen and Karjalainen [2006].

On the other hand plants in the event of mechanical, heat or water stress produce typically polyphenolic compounds. This is accordance with our results on white cabbage (Table 2, d.m.). This situation is often accompanied by oxidative stress, in the defeat of which the phenolic compounds assist the plant [Mikołajczyk 2007]. Cultivation of crops for human or livestock consumption on heavy metal-contaminated soils can potentially lead to the uptake and accumulation of these metals in the edible plant parts with the resulting risk to human and animal health. In the eighties, scientists from the Agricultural University in Cracow conducted research on agricultural crops located in the vicinity of the steelworks that showed significantly high level of contamination of selected vegetables and berries with heavy metals, nitrates and nitrites. Based on the results it was stated that there are meaningful reasons to eliminate some species of vegetables and berries from cultivation in this area [Curzydło 1986, Leszczyńska 2002, Międzobrodzka et al. 1986].

In another paper by Kapusta-Duch et al. [2011], that comprises the same research, the following conclusions have been reached: dry mass of different cruciferous vegetable species cultivated on ecological farms contained generally significantly lower lead amounts in comparison with farms located in the closest steelworks neighbourhood and those purchased at local markets. It cannot be unequivocally stated that the origin of vegetables was influenced by their cadmium content.

Cruciferous vegetables are among the most important dietary vegetables consumed in Poland and other European countries, owing to their availability at local markets, low cost, and consumer preference [Kusznierewicz et al. 2008]. Since they are consumed in large quantities and frequently, cruciferous vegetables supply significant amounts of protective components, such as minerals, micronutrients, vitamins, antioxidants, phytosterols, and dietary fiber, but they are also the main source of cadmium, lead, and other contaminants (28-31%) in the daily diet [Amr and Hadidi 2001]. The roots of many plants exposed to heavy metals exude high levels of phenolics [Winkel-Shirley 2002]. Cruciferous vegetables can accumulate high amounts of cadmium and lead from heavy metal-contaminated soils, which are of great concern because of their toxicity to human health and other organisms [Kabata-Pendias 2001]. However, quite recently the interest in the function of individual phenolic compounds against oxidative stress derived from heavy metals exposition increased [Márquez-García et al. 2009, Tung et al. 2007].

Antioxidant activity

The antioxidant activity of compounds in cruciferous vegetables is summarised in Table 3. On a fresh weight basis, all the three cruciferous species (Table 3) under investigation demonstrated comparable antioxidant activity values, independently of their origin.

Calculations on a dry weight basis (Table 3) showed that only red cabbage from eco-farms had a significantly higher ($p \leq 0.05$) antioxidant activity in comparison

Table 3. Antioxidant activity of white cabbage, red cabbage and Brussels sprouts (in fresh and dry mass) grown in diversified ecological conditions

Sources of vegetables	Antioxidant activity					
	white cabbage		red cabbage		Brussels sprouts	
	μmole Trolox/ g f.m.	μmole Trolox/ g d.m.	μmole Trolox/ g f.m.	μmole Trolox/ g d.m.	μmole Trolox/ g f.m.	μmole Trolox/ g d.m.
From closest vicinity of the Steelworks	3.83 ±0.10 a	56.4 ±5.7 b	27.4 ±1.5 a	337.8 ±16.8 a. b	18.3 ±1.06 a	113.1 ±11.9 a
From organic farms	3.66 ±0.29 a	48.3 ±4.2 a	26.8 ±1.2 a	367.4 ±33.1 b	19.0 ±0.80 a	123.4 ±7.4 a
From a selected market	3.84 ±0.13 a	51.6 ±3.8 a. b	28.5 ±1.7 a	325.0 ±24.6 a	19.2 ±0.65 a	118.9 ±4.4 a

Mean values ±standard deviation.
Differences between values signed with the same small letters are non-significant ($p \leq 0.05$).

with the cabbage from Cracow retailers (the difference was 13%) and similar activity as red cabbage from the steelworks area (the difference was 9%).

Organic Brussels sprouts returned similar activity values as commercial vegetables and vegetables cultivated near the steelworks. In addition, white head cabbage from the steelworks area was characterized by a significantly higher ($p \leq 0.05$) antioxidant activity (by 16%) than the same species from eco-farms, and by a similar activity as vegetables purchased from retailers.

Regardless of the vegetable origin, the largest antioxidant activity was observed in red head cabbage, likewise in case of total polyphenols. Brussels sprouts was placed on the second position and white head cabbage could be found on the last position with an extensive discrepancy between analysed species.

The antioxidant activity in Brussels sprouts as measured in this work (Table 3) is slightly higher than literature data, fluctuating from 3.04 to 15.8 μmol Trolox/g f.w. [Cieślik et al. 2005, Borowska 2003, Podsędek 2007, Szajdek and Borowska 2004].

The number of publications on the antioxidant activity is considerably lower than works discussing the content of analyzed raw material ingredients with antioxidant effects, as well as publications concerning the antioxidant activity of vegetables grown in different ecological conditions. This type of studies is mostly based on comparing fruit, especially berries.

Kusznierewicz et al. [2006] reported a lower antioxidant activity in fresh organically grown cabbage vs. conventional technologies. According to Ren et al. [2001] juices from organic spinach, Welsh onion and Chinese cabbage had 50-120% higher antioxidant activity than juices from conventionally produced vegetables. Prędka and Gronowska-Senger [2009] studied antioxidant properties of selected vegetables (cabbage, boiled potatoes, raw and cooked carrots) from organic and conventional system of cultivation. Antioxidant properties of selected vegetables were independent on the method of cultivation.

The wide range of antioxidant capacity variability given above is wide and may be indicative of impacts of cultivating conditions. The differences in antioxidant capacity may also result from the application of free radicals of different nature (e.g. $ABTS^+$ and DPPH) [Bartoszek et al. 2007].

Modulation of the quality of the phenolic compounds could affect the antioxidant capacity, since different chemical structures have distinct radical scavenging properties. The formation of novel substances, such as products of the Maillard reaction, could also increase the antioxidant capacity [Faller and Fialho 2009, Manzocco et al. 2001].

The total antioxidant potential of a vegetable is determined by factors such as its species; variety; tissue type; climate and environmental conditions during the vegetation period; plant maturation phase; storage temperature and duration; and thermal processing [Hazzani 1998]. The total antioxidant potential of vegetable extracts also depends on the type and polarity of extraction solvent, isolation methods, purity of active substances, methodology and the substrates used [Meyer et al. 1998]. All these impacts may be the reasons why the cruciferous vegetables used in the presents study and research projects referenced vary with respect to antioxidant capacity.

CONCLUSIONS

After the impact of water dilution of the components was eliminated and dry mass content in vegetables was found to vary depending on their place of growing, the following conclusions were drawn based mainly on values per unit of dry weight.

Three cruciferous species examined contained similar total amounts of polyphenols, independent of their origin. Only red cabbage from eco-farms had a significantly higher antioxidant activity in comparison with the cabbage from Cracow retailers and similar activity as red cabbage from the steelworks area. Organic Brussels sprouts returned similar activity values as commercial vegetables and vegetables cultivated near the steelworks. In addition, white head cabbage from the steelworks area was characterised by a significantly higher antioxidant activity than the same species from eco-farms, and by a similar activity as vegetables purchased from retailers.

Most likely it was due to strong protective plants' response exposed to prolonged stress and increased production of compounds with a protective effect. Plants from heavily polluted areas exhibit changes in physiological and biochemical traits.

Studies investigating different phytochemicals and antioxidant activity in organic and conventional foods have had conflicting results, because it can vary not only among cultivars but also based on the specific substance that is being analysed. This study also does not give a definitive answer to the consumer.

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PORÓWNANIE ZAWARTOŚCI POLIFENOLI OGÓŁEM I AKTYWNOŚCI ANTYOKSYDACYJNEJ W WARZYWACH KAPUSTOWATYCH UPRAWIANYCH W ZRÓŻNICOWANYCH WARUNKACH EKOLOGICZNYCH

STRESZCZENIE

Wstęp. Celem pracy było porównanie zawartości polifenoli ogółem oraz aktywności antyoksydacyjnej wybranych gatunków warzyw kapustowatych, uprawianych przez trzy kolejne lata, w zróżnicowanych warunkach ekologicznych.
Materiał i metody. Polifenole ogółem oznaczono metodą Folina-Ciocalteau'a, a aktywność przeciwutleniającą metodą z wykorzystaniem wolnych rodników $ABTS^{\bullet+}$.
Wyniki. Wszystkie analizowane gatunki warzyw kapustowatych charakteryzowała zbliżona zawartość polifenoli ogółem, niezależnie od ich pochodzenia. Kapusta głowiasta czerwona, pochodząca z upraw ekologicznych, charakteryzowała się istotnie większą aktywnością antyoksydacyjną w porównaniu z warzywami zakupionymi na placach targowych Krakowa i zbliżoną w stosunku do kapusty z upraw zlokalizowanych w byłej strefie ochronnej Huty im. Tadeusza Sendzimira (aktualnie ArcelorMittal Poland S.A.). W kapuście głowiastej białej, pochodzącej z upraw zlokalizowanych w sąsiedztwie huty, stwierdzono istotnie większą aktywność antyoksydacyjną w stosunku do warzyw ekologicznych oraz zbliżoną w porównaniu z warzywami rynkowymi. W kapuście brukselskiej natomiast nie stwierdzono istotnych różnic w aktywności antyoksydacyjnej, w zależności od jej pochodzenia.
Wnioski. Na podstawie pracy nie można stwierdzić, że ekologiczne warzywa kapustne na ogół charakteryzują się większą zawartością polifenoli ogółem oraz aktywnością antyoksydacyjną w porównaniu z uprawianymi metodami konwencjonalnymi.

Słowa kluczowe: wolny rodnik $ABTS^{\bullet+}$, aktywność antyoksydacyjna, warzywa kapustowate, zróżnicowane warunki ekologiczne, polifenole ogółem

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