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NUTRITIVE AND HEALTH-PROMOTING VALUE OF ORGANIC VEGETABLES

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ABSTRACT

In recent years in Poland we may observe a considerable development of organic vegetable production. Increased interest in organic products results from an opinion of the consumers on their high quality and health safety. However, results of research comparing nutritive value and contents of biologically active compounds in vegetables from organic and conventional farms are ambiguous. Most studies confirm higher contents of certain vitamins and antioxidants in organic vegetables, as well as their lower contents of nitrates and pesticide residue in comparison to vegetables grown in the conventional manner. There are also reports which did not confirm such differences or showed opposite trends. Research results at present do not make it possible to formulate a general conclusion on a higher health-promoting value of organic vegetables in comparison to those grown by conventional farming methods. It is necessary to continue research in order to explain the effect of organic raw materials on human health in a more comprehensive manner.

Key words: bioactive components, sensory examination, nitrates, pesticides, pathogenic bacteria

INTRODUCTION

Organic farming is developing dynamically in Europe and worldwide [Eurostat 2010]. Similar trends may also be observed in Poland. In the last decade the number of organic farms and the area of organic farming have increased over ten-fold. In 2011, organic farming in Poland has covered the area of approx. 574 thousand ha, with an over two-fold increase in comparison to that in 2009. Organic crop production in 2010 reached the level of approx. 710 thousand ton, at an increase in relation to the previous year amounting to almost 60%. In 2011 there were 23,860 organic food producers in Poland and the number was almost two-fold higher than in 2008 [www.organic-europe.net].

Organic farming is a system of farming and crop production, in which no mineral fertilizers or synthetic herbicides are used. In organic cultivation proper crop rotation is used, including structure-forming plants, which increase the amount of organic matter in soil, such as e.g. legumes. Natural manures produced on the farm, such as compost, farmyard manure or green manure, are used along with natural-origin mineral fertilizers, e.g. dolomites, basalt and kainite. In order to provide plant protection against pests, diseases and weeds mechanical and cultivation measures are applied. The focus is on appropriate succession and planting of different crops together as well as extensively applied biological plant protection, using natural enemies of pathogens and biological preparations such as e.g. plant extracts [Tyburski and Żakowska-Biemans 2007].

Organic food is produced following principles of organic farming and is monitored at the stage of

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production, storage, processing and distribution. Consumers are interested in organic products, because they care for their health. For many people organic food is a synonym of high quality and safety [Meier-Ploeger 2005]. Research results have confirmed that organic vegetables and fruits generally have more advantageous health-promoting properties than those coming from commercial, conventional farms [Gąstoł et al. 2009, Hallmann et al. 2008, Lima and Vianello 2011]. However, some studies have not proved a straightforward relationship between nutritional value of organic vegetables and human health [Huber et al. 2011]. According to Stracke et al. [2011], the diet with addition of organically or conventionally produced vegetables had no effect on basic hematological parameters.

Typically organic products contain more nutrients, including sugars and organic acids, vitamin C, as well as flavonoids and anthocyanins exhibiting antioxidant properties [Hallmann and Rembiałkowska 2007 a, Kazimierczak et al. 2011]. In turn, their contents of compounds with adverse or harmful effects, such as residue of pesticides and mineral fertilizers, particularly nitrates and nitrites, are lower in comparison to conventionally grown vegetables [Gonzalez et al. 2010].

In order to meet increasing demand for high quality products, many vegetable producers, particularly on small farms, decide to grow them using organic methods. For producers and processing firms this creates prospects for development taking advantage of the increased demand for such food [Myczko et al. 2009]. In 2010 in Poland there were almost 2800 farms producing organic vegetables. The area cropped to certified vegetable production was almost 1900 ha, while over 1700 ha were at the stage of transition to start organic farming production [www.ijhars.gov.pl].

NUTRIENT CONTENTS IN ORGANIC VEGETABLES

Numerous studies, conducted both worldwide and in Poland, have concerned nutritive value of vegetables produced using conventional and organic methods [Szafirowska and Elkner 2008, Ordonez-Santos et al. 2009, Gonzalez et al. 2010, Hallmann et al. 2010]. Most recorded results confirmed higher nutrient contents in organic vegetables. Crops grown organically, in case of which organic fertilization is applied, target their metabolism to produce carbon compounds, thus producing more sugars, phenolic compounds and vitamin C. In contrast, plants fertilized using mineral fertilizers produce more nitrogen compounds, including amino acids, peptides, proteins and alkaloids [Pither and Hall 1990].

Organic vegetables typically have higher dry matter contents than those produced conventionally. This pertains especially to leaf and root vegetables [Lairon 2011]. Particularly pronounced differences are observed in case of leaf vegetables, exhibiting a tendency to accumulate water in their cells at the application of mineral fertilization. Savoy cabbage grown organically was found to contain by 50-69% more dry matter than in case of conventional cultivation [Schuphan 1974]. Similar results were observed for red beet, where the difference in dry matter content was 23% to the advantage of organic farming [Kazimierczak et al. 2011]. The trend towards high dry matter contents in fruits was also found in organic growing of peppers [Hallmann et al. 2009] and tomato [Caris-Veyrat et al. 2004, Hallmann and Rembiałkowska 2008] as well as potatoes [Rembiałkowska 2000].

However, some studies did not confirm the above mentioned trends. Rembiałkowska et al. [2005] and Toor et al. [2006] did not find significant differences in dry matter contents in tomatoes grown in the organic and conventional cultivation systems. Similar results were recorded by Hallmann and Rembiałkowska [2007 b] for red onion cultivars, as well as Rembiałkowska and Hallmann [2007] in their study on carrot. No differences were observed in terms of dry matter contents in cabbage and carrot [Masamba and Nguyen 2008] and in Chinese cabbage [Lima et al. 2009] coming from both types of cultivation systems.

Dry matter content in vegetables is associated with their keeping quality. Some research results confirm that organic vegetables exhibit superior keeping quality in comparison to vegetables from conventional farming systems [Brandt and Molgaard 2001]. This is explained by the reduction of enzymatic activity, slowed down respiration, rotting and degradation processes resulting from the typically lower water content in organic vegetables [Szafirowska-Walendziak 2007].

Nawrocki et al. [2011] used proteome analysis for comparison of cabbage and carrot grown in conventional and two organic systems. The authors confirmed that proteins of conventionally grown vegetables varied from organically grown vegetable to a large extend. The number of proteins which differed between the conventional and organic growing system was 7 and 4 times higher (for cabbage and carrot, respectively) than the number of proteins which differed between the two organic systems.

Numerous authors investigated sugar content in vegetables coming from organic and conventional farming systems. Recorded results were inconclusive. Some studies showed that raw materials from organic farms contain higher levels of total sugars and reducing sugars than vegetables from conventional farming. Results confirming this thesis were obtained for tomato [Hallmann and Rembiałkowska 2007 a], peppers [Hallmann et al. 2007], red onion varieties [Hallmann and Rembiałkowska 2007 b] and red beets [Jabłońska--Ceglarek and Rosa 2003]. Also Elkner and Kosson [2009] obtained total sugar contents higher by approx. 10% in organic beets. In turn, in a study by Kazimierczak et al. [2011], organically grown red beets contained by almost 30% more reducing sugars, while there were no differences in the total sugar contents between beets from both growing systems. In contrast, Kosson et al. [2010] found no differences in the contents of reducing sugars and total sugars in string beans coming from organic and conventional farming systems.

Literature sources present results of very few studies on contents of minerals in organic vegetables. Schuphan [1974] showed that organically grown spinach, potatoes, carrot and cabbage contained more iron (+77%), potassium (+18%), calcium (+10%) and phosphorus (+13%), at a lower sodium content (–12%) in comparison to vegetables coming from conventional growing systems. In other studies conducted in western Europe in case of organic vegetables higher contents were recorded for iron (spinach, savoy cabbage, carrot), magnesium (savoy cabbage, carrot, potato, leek, lettuce), phosphorus (potatoes, celery, carrot, savoy cabbage, spinach), potassium (carrot, potatoes, spinach, savoy cabbage) and calcium (potatoes, carrot, savoy cabbage, spinach) (Rembiałkowska 2000]. Also Masamba and Nguyen [2008] in organic cabbage, carrot and lettuce recorded calcium contents higher by 12-16%, while potassium contents higher by 2-17%.

CONTENTS OF BIOACTIVE COMPOUNDS IN ORGANIC VEGETABLES

Studies conducted by many authors focused on contents in organic vegetables of such bioactive compounds as vitamin C, carotenoids and phenolic compounds, including anthocyanins [Hallman and Rembiałkowska 2008, Masamba and Nguyen 2008, Halmann et al. 2008, 2009, Lima et al. 2009, Lima and Vianello 2011]. It was shown that organic growing methods result in an increase in the contents of antioxidants by 30% in relation to conventionally grown products [Benbrook 2005]. As it was shown by Borguini and Torres [2006] and Chassy et al. [2006], tomato fruits from organic culture contained more vitamin C than those coming from conventional culture. Studies conducted in Poland showed higher contents of vitamin C in fruits of tomato [Hallmann and Rembiałkowska 2008], sweet peppers [Hallmann et al. 2009] and beet roots [Sikora et al. 2008] grown organically in comparison to those from conventional farming. In turn, Masamba and Nguyen [2008] showed no differences in the contents of vitamin C between cabbage and lettuce coming from both growing systems. Also a 6-year study by Fjelkner-Moding et al. [2000] showed no differences in vitamin C content expressed in terms of dry matter in vegetables grown organically and conventionally. In turn, in a study by Rembiałkowska et al. [2003] organic tomatoes contained considerably less vitamin C than conventionally grown tomatoes.

The group of antioxidants contained in vegetables includes carotenoids. Results of numerous studies indicate differences in their contents between vegetables coming from conventional and organic growing systems. Hallmann et al. [2007], when determining carotenoid contents in fruits of peppers found higher contents of lutein and β-carotene, by 20% and 30%, respectively, in organic peppers, while the content of licopene was slightly higher in peppers grown in the conventional farming system. Hallmann and Rembiałkowska [2008] reported an over 50% higher content of β-carotene in organic tomatoes, while the content of licopene was by 16% higher in conventionally grown tomatoes.

There are numerous reports in available literature that vegetables from organic cultures contain more phenolic compounds in comparison to conventionally grown vegetables. Chassy et al. [2006] stated higher contents of flavonoids in organic tomatoes. In a study by Michell et al. [2007] a two-fold higher content of quercetin and kempferol was recorded in organic tomatoes. In turn, Ren et al. [2001] stated many times higher (from 1.3 to 10.4-fold) contents of quercetin and caffeic acid in such organically grown vegetable species as spinach, Chinese cabbage, garlic and peppers. A study by Hallmann et al. [2007] showed an almost two-fold higher content of rutin in fruits of organically grown peppers in comparison to those grown in the conventional farming system. Hallmann and Rembiałkowska [2006] stated higher contents of flavonoids in organic onion, while Kazimierczak et al. [2011] in organic red beets when compared to those grown in the conventional cultures. In turn, Kosson et al. [2010] showed that organically grown peppers contained more ascorbic acid, β-carotene, flavonoids and especially phenolics in comparison to conventionally grown peppers. The above mentioned trends were not observed in a study by Rembiałkowska and Hallmann [2008], in which higher contents of polyphenolics were recorded in conventionally grown peppers than in organic vegetables.

The typically higher content of phenolic compounds, alkaloids and glycosides in organic raw materials probably results from the fact that at the absence of synthetic herbicides in farming plants activate their own defense mechanisms synthesizing the above mentioned compounds. Phenolic compounds are referred to as natural pesticides [Amor et al. 2008]. Moreover, in organic systems, poor in readily available nitrogen, plants produce intensively first of all carbon compounds, i.e. simple and complex sugars, as well as secondary metabolites containing no nitrogen, including phenolic compounds, certain pigments and vitamins [Coley et al. 1985].

NUTRITIVE VALUE OF PROCESSED PRODUCTS FROM ORGANIC RAW MATERIALS

The use of good quality raw materials is essential to obtain processed products with a high nutritive value. Many studies, both conducted in Poland and other European countries, have been devoted to the nutritive value of processed vegetable products obtained from organic raw materials. Some of them were characterized by higher contents of dry matter, vitamin C, pigments and antioxidants in relation to processed products from conventionally grown vegetables. In organic tomato juice dry matter content was found to be by over 2% higher in relation to juice from conventional farming production [Hallmann and Rembiałkowska 2008]. Higher content of dry matter was also recorded in fresh carrot juice pressed from organic raw material in relation to the conventional juice [Sikora et al. 2009]. Gyorene et al. [2006] stated higher content of vitamin C in processed products from organic raw materials. In a study by Hallmann et al. [2009] pickled peppers from organically grown vegetables were characterized by higher contents of β-carotene and phenolic compounds in comparison to conventionally grown peppers.

Investigations conducted by Świderski et al. [2009] concerned antioxidant properties of vegetable juices produced from organic raw materials. Organic tomato juices were characterized by lower contents of dry matter and polyphenolic compounds in comparison to juices produced from conventionally grown vegetables, while carrot juices, both organic and conventional, contained similar amounts of polyphenolic compounds. Tested organic juices were characterised by higher antioxidant activity than juices from conventionally grown vegetables. In a study by Hallmann and Rembiałkowska [2011] juice produced from organic carrot had higher contents of vitamin C, lutein and caffeic acid in comparison to juice from conventionally grown vegetables. Also Robak [2010] showed higher contents of rutin and chlorogenic acid in tomato juice from organic fruits in comparison to juices pressed from conventionally grown fruits. In turn, Caris-Veyrat et al. [2004] stated higher contents of vitamin C in organic tomato juices.

SENSORY EXAMINATION OF ORGANIC VEGETABLES AND PROCESSED PRODUCTS

Sensory attributes frequently determine the selection of a product. Due to higher contents of dry matter in organic vegetables their superior sensory quality is also frequently reported. Many studies stated that they are characterized by better taste, aroma and consistency in comparison to conventionally grown raw materials [Rembiałkowska 2004, Hallmann and

Rembiałkowska 2006]. In other studies sensory examination showed no differences between organically and conventionally grown raw materials [Zhao et al. 2007].

Jahansson et al. [1999], when conducting sensory examination of fresh tomatoes stated that vegetables coming from organic farms were characterised by better fruit coloring and a sweet taste, but at the same time they were bitterer in comparison to conventionally grown tomatoes. Also Heeb et al. [2005] stated that organic fertilization resulted in an improvement of sweet and acid taste of tomatoes. Thybo et al. [2006] showed that organically grown tomatoes were characterized by darker flesh and mealiness of fruits, higher acidity and overall quality in the first year of the study. In contrast, in the second year of the study conventionally grown vegetables received higher scores. In turn, in a study by Ordonez-Santos et al. [2009] no significant differences were found in quality attributes between tomatoes from organic and conventional farming systems. In a study by Zhao et al. [2007] lettuce, spinach, tomatoes, cucumbers and onion coming from organic and conventional farming systems were subjected to sensory examination. Overall quality evaluation showed no significant differences between organically and conventionally grown vegetables. Only aroma of conventionally grown tomatoes received higher scores than organic tomatoes.

Quality of juices produced from organically and conventionally grown tomatoes was analysed by Hallmann and Rembiałkowska [2008]. Juices from conventionally grown vegetables received higher scores in the sensory examination than organic juice in terms of aroma, colour, taste and overall quality. Also thickness of the juice and detectability of fruit particles proved to be better in case of juice from conventionally grown fruits. These results were consistent with a statement by Slimestad and Verheul [2005], who gave higher scores for sensory attributes of tomato juice pressed from conventionally grown vegetables. Completely different results were obtained in a study by Hallmann et al. [2010]. They stated that juices from organic tomatoes were characterized by superior color, thickness and detectability of fruit particles, intrinsic tomato and sweet taste as well as overall quality in comparison to juice from conventionally grown juice.

Kosson et al. [2010] analysed results of sensory evaluation of processed products from peppers as well as spring beans coming from organic and conventional farming systems. Red peppers pickled in vinegar marinade, coming from organic culture, were characterized by a more intensive intrinsic pepper taste than processed products from conventionally grown peppers. In turn, processed products from conventionally grown peppers were characterized by a more intensive sweet and fruity taste. However, preserves from peppers from both types of farming did not differ in terms of the overall quality evaluation scores. In turn, preserves from conventionally grown yellow string beans received higher scores in the overall quality of the product than those of organic farming. Green string beans in the tomato processed product produced from an organic raw material received higher scores in the overall quality appraisal than conventionally grown string beans.

CONTENTS OF HARMFUL COMPOUNDS IN ORGANIC VEGETABLES

Vegetables grown organically should have lower contents of compounds considered harmful for human health, which results from the specific character of this type of production. In studies concerning nitrate contents in organically and conventionally grown vegetables highly differentiated results were recorded [Magkos et al. 2003, Gonzalez et al. 2010]. Some studies confirmed that organic vegetables have lower nitrate contents than vegetables grown conventionally [Pussemier et al. 2006], while other studies showed an opposite trend [De Martin and Restani 2003, Guadagnin et al. 2005]. Woese et al. [1997] when summing up results of 41 tests comparing nitrate contents in vegetables from conventional and organic farming systems stated that a higher nitrate level was characteristic of conventionally grown leafy and root vegetables. Worthington [2001] when comparing results of analyses conducted on 176 samples showed that in 72% cases the content of nitrates was higher in conventionally grown vegetables, while in 24% cases this content was higher in organic vegetables. As it results from a report by Heaton [2001], 14 comparative studies confirmed lower contents of nitrates in organic raw materials, while in two no significant differences were shown in this respect. Malmauret et al. [2002] obtained high nitrate contents in conventionally grown spinach, while Elmadfa [2001] showed an opposite trend. Lima et al. [2009] showed that the content of nitrates was significantly higher in leaves of Chinese cabbage coming from organic culture. It results from the statements presented above that consumers buying organic vegetables do not always receive a product with a lower nitrate content.

Organic vegetables should not contain detectable amounts of pesticides. The body of data on the residue of these substances in vegetables is insufficient to formulate decisive conclusions that organic raw materials are free from pesticides [Borguini and Torres 2006]. Rossetto et al. [2009] reported the presence of pesticides in leaves and skin of conventionally grown beets. Winter and Davis [2006] showed that the residue of pesticides is detected less frequently and in smaller amounts in organic food, and for this reason it poses less of a hazard for human health than products of conventional farming. The cooking process considerably reduces the level of pesticide residue in organically grown vegetables. According to Nagayama [1996], some pesticide residue penetrates from raw vegetables to water, in which they are cooked, while residue of other pesticides may remain in processed products. For this reason cooking of vegetables, even those coming from organic cultures, may be an effective method to reduce their contents.

The problem of pesticide residue in raw vegetables and juices is particularly crucial in case when they are components of children's diet. Curl et al. [2003] stated higher contents of pesticides in the urine of children consuming food produced conventionally in comparison to those typically eating organic products. Lu et al. [2006] observed a decrease in the contents of pesticides, such as malathion and chlorpyrifos, in the systemic fluids of children after the introduction of organic products to their diet.

THREAT OF MICROBIOLOGICAL CONTAMINATION IN ORGANIC VEGETABLES

Due to the application of large doses of farmyard manure and composts in organic farming there is an increased risk of microbiological contamination of these products, mainly with *Escherichia coli* and mycotoxins, as well as parasites. According to Williams [2002], the use of farmyard manure and limited application of fungicides and antibiotics in organic production may lead to increased contamination of these products by microorganisms and their metabolites. In order to minimize the risk of development for such pathogens as *Salmonella enterica*, *Salmonella typhimurium* and *E. coli* 0157:H7 it is necessary to determine the proper time interval between the application of manure and the harvest of vegetables [Natvig et al. 2002]. Maintenance of a 120-day interval provides an assurance that roots and leaves of vegetables are free from *S. enterica* and *S. typhimurium* [Lima and Vianello 2011].

In the opinion of Loncarevic et al. [2005], as a result of the application of farmyard manure field-grown vegetables may be contaminated with species pathogenic to humans, such as *E. coli*, *Salmonella* spp. and *Listeria monocytogenes*. On the other hand, very few studies have been reported in available literature clearly confirming contamination of organically grown vegetables with microorganisms posing a hazard to human health. Loncarevic et al. [2005] did not show the presence of *E. coli* 0157 or *Salmonella* in plant samples. In turn, Oliveira et al. [2010] reported contamination of organic lettuce by *E. coli* and *L. monocytogenes*.

Apart from the proper application of manure in cultivation practice the process of vegetable washing before the consumption is equally important. Intensive washing makes it possible to reduce or almost completely eliminate pathogenic bacteria. It is believed that proper washing of vegetables is of key importance for human health even in case when vegetables are consumed in the cooked form [Natvig et al. 2002].

Fungal toxins constitute another potential threat to human health. Mycotoxin contents in food produced conventionally and organically have been analyzed in many studies. Highly varied results have been reported, on the basis of which it is not possible to definitely state that a specific farming method leads to a reduced risk of mycotoxin contamination [Magkos et al. 2003]. A comparison of mycotoxin contents in plants grown in the organic and conventional farming systems does not yield a clear indication that conventionally produced raw materials are more or less safe in this respect in comparison to organic vegetables. Although the presence of deoxynivalenol (a vomitoxin) has been detected both in conventionally produced and organic food, its content was higher in organic raw materials [Malmauret et al. 2002].

CONCLUDING REMARKS

Despite the considerable number of studies conducted to date and concerning biological value of organic vegetables we may not present a clear hypothesis that they are in every case more valuable than those grown conventionally. There is a need to continue research in this field to determine unambiguously the effect of organic vegetables on the human organism. Most research results published to date confirmed lower contents of pesticides, hormones and nitrates in organic vegetables at higher contents of certain vitamins. This provides the justification for the statement that organic vegetables may be potentially used as health-promoting food. This is a thesis which needs to be confirmed by further studies. Consumers should be provided complete information on the biological vale of organic raw materials so that they could make educated decisions when choosing between organic and conventionally grown vegetables. This is particularly important in a situation when the market prices for organic products are typically much higher than those of vegetables grown in the conventional farming system.

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WARTOŚĆ ODŻYWCZA I ZDROWOTNA WARZYW POCHODZĄCYCH Z UPRAW EKOLOGICZNYCH

STRESZCZENIE

W ostatnich latach obserwuje się w Polsce znaczny rozwój ekologicznej produkcji warzyw. Wzrost zainteresowania produktami ekologicznymi wynika z przeświadczenia konsumentów o ich wysokiej jakości oraz bezpieczeństwie dla zdrowia. Jednak wyniki badań, porównujących wartość odżywczą oraz zawartość związków biologicznie czynnych w warzywach z upraw ekologicznych i konwencjonalnych, nie są jednoznaczne. Większość badań potwierdza w warzywach ekologicznych większą zawartość niektórych witamin oraz związków o charakterze przeciwutleniaczy, a także mniejszą zawartość azotanów oraz pozostałości pestycydów w porównaniu z warzywami uprawianymi konwencjonalnie. Istnieją również doniesienia, które nie potwierdzają takich różnic lub wykazują tendencje odwrotne. Uzyskane wyniki badań uniemożliwiają obecnie sformułowanie ogólnego wniosku o wyższych walorach zdrowotnych warzyw ekologicznych w porównaniu z konwencjonalnymi. Konieczne jest kontynuowanie badań w celu pełnego wyjaśnienia wpływu surowców ekologicznych na zdrowie człowieka.

Słowa kluczowe: składniki bioaktywne, ocena sensoryczna, azotany, pestycydy, bakterie chorobotwórcze

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