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REVIEW ARTICLE

ORGANIC FOOD AND HEALTH

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ABSTRACT

The popularity of organic foods grows systematically. In the last decade, several critical reviews and meta-analysis concerning organic food consumption and their effect on some chosen health problems have been published. The aim of the work was to present the current state of knowledge regarding the influence of organic food consumption on human health. On average, organic food of plant origin is characterized by a trace presence of pesticides, a lower content of nitrates and an increased content of polyphenols and vitamin C. Organic products of animal origin contain more beneficial for health unsaturated fatty acid. Organic dairy products, in contrast to meat products, are characterized by a higher content of protein and saturated fatty acids, however, the differences more result from the length of the grazing period and access to fresh forage than to the production system. Although generally, the consumption of organic food does not provide a significant nutritional advantage compared to a conventional diet, regular and frequent consumption of organic products generally reduces the risk of overweight and obesity, both for women and men, as well as non-Hodgkin lymphoma in case of women. Besides those, consumption of organic fruits and vegetables, as well as dairy products significantly reduces the risk of pre-eclampsia in pregnancy and eczema in infants, respectively. Positive effect on selected health problems probably results from a reduced amount of pesticide residues and an increased secondary plant metabolites intake which characterize organic food. This review showed that there is a need for further, especially, large cohort studies concerning the effect of organic food consumption on specific diseases development.

Key words: *organic foods, composition, pesticides, nutrients, heath, cancer*

STRESZCZENIE

Popularność żywności ekologicznej systematycznie rośnie. W ostatniej dekadzie opublikowano kilka prac przeglądowych i metaanaliz dotyczących konsumpcji żywności ekologicznej i ich wpływu na wybrane problemy zdrowotne. Celem pracy było przedstawienie aktualnego stanu wiedzy na temat wpływu konsumpcji żywności ekologicznej na zdrowie człowieka. Przeciętnie, żywność ekologiczna pochodzenia roślinnego charakteryzuje się śladową zawartością pestycydów, niższą zawartością azotanów i podwyższoną zawartością polifenoli i witaminy C. Ekologiczne produkty pochodzenia zwierzęcego zawierają więcej korzystnych dla zdrowia nienasyconych kwasów tłuszczowych. Ekologiczne produkty mleczne, w przeciwieństwie do produktów mięsnych, charakteryzują się wyższą zawartością białka i nasyconych kwasów tłuszczowych, jednak różnice wynikają bardziej z długości okresu wypasu i dostępu do świeżej paszy niż rodzaju produkcji. Chociaż ogólnie spożywanie żywności ekologicznej nie zapewnia znaczącej przewagi żywieniowej w porównaniu z konwencjonalną dietą, regularne i częste spożywanie produktów ekologicznych zmniejsza ryzyko wystąpienia nadwagi i otyłości, zarówno u kobiet, jak i mężczyzn, a także chłoniaka nieziarniczego w przypadku kobiet. Poza tym spożywanie ekologicznych owoców i warzyw znacznie zmniejsza ryzyko stanu przedrzucawkowego u kobiet w ciąży, a w przypadku produktów mlecznych egzemy u niemowląt. Pozytywny wpływ na wybrane problemy zdrowotne prawdopodobnie wynika ze zmniejszonej ilości pozostałości pestycydów i zwiększonego spożycia metabolitów wtórnych roślin, które charakteryzują żywność ekologiczną. Przegląd ten wykazał potrzebę dalszych, zwłaszcza dużych badań kohortowych dotyczących wpływu spożywania żywności ekologicznej na rozwój określonych chorób.

Słowa kluczowe: *żywność ekologiczna, skład, pestycydy, składniki odżywcze, zdrowie, nowotwory*

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INTRODUCTION

Organic food is produced from plant raw materials obtained without the use of artificial fertilizers and pesticides, and from animal raw materials in the production of which animals are bred without the use of antibiotics and live in conditions close to natural. Besides those, the applied raw materials for consumption and food production cannot come from genetically modified organisms and their processing excludes the use of radiation and most food additives [12]. Organic food production is becoming more and more popular and is growing systematically at a rate of several percent per year [22]. Still, it is a minority of food available on the market. A good example is the European Union in which organic farming area is 7.5% in a total utilized agricultural area [13]. Proponents of organic food are convinced that it is more beneficial to health and tastier. In recent years, several meta-analyses and cohort studies have been published that allow drawing more solemn conclusions about the impact of eating organic food on human health. The aim of the work was to review recent research related to this topic.

DIFFERENCES IN THE COMPOSITION OF RAW MATERIALS OF PLANT ORIGIN

Nutritional composition of plant raw materials depends on growing conditions, a season of the year, application of fertilizers and plant protection products. Since plant materials produced in the organic system are obtained without the use of mineral fertilizers and pesticides, their composition has been compared many times to those obtained in the conventional system. The most commonly comparable ingredients, in this case, include pesticides, nitrates, toxic metals and broadly understood secondary metabolites such as vitamin C, carotenes and polyphenols. Some researchers go further and try to find differences also in the content of mycotoxins and microbial contaminants [16].

By definition, pesticides should not be used in organic production. However, a control analysis carried out in the European Union showed that 6.5% of organic product samples contain pesticide residues (44% of conventional produce food samples). The presence of pesticide residues is one thing, and the exceedance of maximum residue levels is the other. In this case, consumers of organic food may also feel calmer because exceeding the permissible levels of pesticide residues was found 6 times more often in products obtained conventionally compared to organic food (1.2 vs 0.2 % of samples) [10].

Nitrates are a natural component of plant material and their quantity depends on such factors as species, variety, part of the plant, fertilization, soil type and pH, time of cultivation and harvest [15]. Many reviews showed that the content of nitrates in raw materials obtained organically is 15-50% lower, compared to conventional raw materials, although this difference is not always statistically significant [6]. A separate issue is the effect of consumed nitrates on human health and here this dependence is even more difficult, especially that usually the average diet of non-organic products does not exceed the harmful level of nitrate consumption [17, 33].

When analysing the content of toxic metals, the vast majority of analysed products contained acceptable levels of lead or cadmium [17, 30, 31]. However, the differences between organic and conventional products are not always clear-cut. *Staniek and Krejpcio* [27] found that the cadmium content in organic cereals, vegetables and fruit was higher than in the conventional counterparts. On the other hand, lead level in most organic vegetables and fruits was lower in comparison with conventional products. Different results found *Zaccone* et al. [34] showing that significantly higher heavy metal input to soil provided by addition the organic fertilizer significantly increased the content of Pb, Zn and Ni, simultaneously decreasing the content of Cd, Cr and Cu in semolina samples. Lower concentration of Cd in organic products was confirmed in meta-analyses based on 343 peer-reviewed publications carried out by *Barański* et al. [2].

The content of vitamin C in organic fruits and vegetables is in most cases higher than in the case of those obtained by the conventional method [3] while the content of secondary metabolites such as carotenes that are not involved in defence against diseases and pests is no different [6] although there are some single studies where the content of carotenoids in organic samples was higher than in conventional counterparts [18, 19].

Another example of secondary metabolites is phenolic compounds. *Cebulak* et al. [8] showed a 19% higher content of polyphenolic compounds in organic broccoli compared to those conventionally grown. Very similar results were obtained by *Hallmann* et al. [19] who analysed the effect of processing on the concentration of bioactive compounds in organic vs. conventional pickled bell pepper. The conventional pickled bell pepper fruits were richer in phenolic acids, while organic samples contained significantly more flavonoids and carotenoids. Such individual results are also confirmed by meta-analyses [26]. Artificial nitrogen fertilizers used in conventional production increase the yield although they reduce the content of phenolic compounds in contrast to natural fertilizers (with more difficult access to nitrogen), which affect a higher content of phenolic compounds, and thus greater resistance to pests and diseases, while giving a lower yield [6].

In addition to the above, the content of other ingredients was also subject to comparative analysis. *Polak-Śliwińska* et al. [24] showed significantly lower content of patulin and 5-HMF in fruit and vegetable juices made from organic and conventional raw materials although in none of the samples the maximum permissible content has been exceeded. Analysis of aflatoxin and ochratoxin A in dried fruits also showed a lower probability of finding mycotoxins in organic than conventional products [14]. Analysis of several studies concerning detecting *Escherichia coli* in organic and conventional fruits, vegetables and grains showed no significant difference [26].

An additional argument raised by enthusiasts of organic food is the difference in taste with a clear indication in favour of organic products, although other authors do not confirm this. *Zhao* et al showed no significant differences between the taste of traditionally and organically produced tomatoes, cucumbers, onions, lettuce and spinach [35]. An interesting experiment was also carried out by *Apaolaza* et al. [1] proving that the label made the same wine taste better if consumers were convinced that they were drinking an organic product.

DIFFERENCES IN THE COMPOSITION OF RAW MATERIALS OF ANIMAL ORIGIN

Palupi et al. [23] carried out a meta-analysis comparing 29 studies concerning the nutritional quality of conventional and organic dairy products. It was shown that concentration of some pro-healthy ingredients like α-linolenic acid, total *omega*-3 fatty acid, cis-9,trans-11 conjugated linoleic acid, trans-11 vaccenic acid, eicosapentaenoic acid, and docosapentaenoic acid and *omega*-3 to -6 ratio is significantly higher in organic products. On the other hand, conventional products contained less fat, saturated and monounsaturated fatty acids. No significant differences were observed for the content of α-tocopherol and β-carotene.

A few years later, meta-analyses based on 170 published studies carried out by Średnicka-Tober et al. [29] showed that there were no significant differences in total saturated and monounsaturated fatty acids concentrations between organic and conventional milk. However, the results concerning unsaturated fatty acids were in agreement with *Palupi* et al. [23] meta-analysis. *Średnicka-Tober* et al. [29] also showed, in contrast to *Palupi* et al. [23] that organic milk has significantly higher α-tocopherol concentrations.

In order to run an organic farm, it is necessary to fulfil a lot of requirements. However, there are still some farmers who run their farms in a more traditional way but they do not try to get organic producer certification. This was the topic of a study carried out by *Butler* et al who analysed fatty acid and fat-soluble antioxidant concentrations in milk from high- and low-input conventional and organic systems. Milk from both the low-input organic and non-organic systems (10 and 5 farms, respectively) had significantly higher concentrations of nutritionally desirable fatty acids and antioxidants (conjugated linoleic and α-linolenic acids, α-tocopherol and carotenoids) compared with milk from the conventional high-input (10 farms) system. The differences resulted from the stage and length of the grazing period and more detailed analysis showed that concentration of antioxidants and conjugated linoleic acid was in some cases higher in milk obtained from low-input non-organic than that from organic cows [7].

Analysis of differences in the composition of organic and non-organic meat was carried out by *Średnicka-Tober* et al. [28]. In a meta-analysis based on sixty-seven studies, they showed that organic meat contains a slightly lower concentration of monounsaturated fatty acids and 23% higher polyunsaturated fatty acids (PUFA), especially, n-3 PUFA (47%). Authors estimate that bearing in mind average meat fat consumption in European Union those who consume only organic meat intake 17, 22 and 21 % more PUFA, n-3 PUFA and n-6 PUFA, respectively, and similar values of saturated fatty acids [28].

Meta-analysis concerning contamination of organic and conventional animal origin products with bacterial pathogens showed insignificant differences in case of chicken, pork, raw milk and eggs, however, in most analysed works risk for isolating antibiotic-resistant bacteria in organic products was lower than in nonorganic products [26].

THE EFFECT OF ORGANIC FOOD CONSUMPTION ON HUMAN HEALTH

Although organic food has been known for a long time, research on the impact of its consumption on health for many years was not very spectacular. *Dangour* et al. [9] in their systematic review analysed 98,727 articles identifying 12 relevant among were 6 clinical trials, 1 cohort study, and 1 cross-sectional study. The number of subjects in clinical trials was usually small (6-66 subjects) and duration was short (1-30 days). Among all analysed studies only cohort study involving 2764 infants aged 0–2 y carried out by *Kummeling* et al. [21] showed that consumption of strictly organic dairy products (more than 90 % of organic products in a diet) was associated with a significantly lower risk of eczema in the analysed group. However, the conclusion of this systematic review was a lack of evidence for nutrition-related

health effects that result from the consumption of organic food [9].

Kesse-Guyot et al. [20] in a cohort study involving 54 311 adult participants analysed the effect of consumer attitude and frequency of use of 18 organic products on the risk of overweight and obesity. Applying multivariate models, after accounting for confounders such as level of plant foods, sweet and alcoholic beverages, processed meat or milk consumption, they found that compared to non-consumers of organic products, regular consumers of organic foods showed 42 and 36% lower probability of overweight in women and men, respectively, and in case of obesity, 48 and 62% lower probability in women and men, respectively. In the discussion of the results, authors indicate pesticide residues as factors responsible for an increased risk of having excessive weight.

In 2014, an outstanding scientific work concerning a large prospective study of women in the United Kingdom and analysis of organic food consumption and the incidence of cancer was carried out by *Bradbury* et al. [5]. The authors investigated the relationship between the frequency of consumption of organic food and cancer incidence in 623 080 middle-aged women within 9.3 years' period. Statistical analysis showed that consumption of organic food was not associated with a reduction in the incidence of all cancer when the groups of never (30%) vs usually/always (7%) eating organic food were compared. Similar results obtained after analysis of most of 17 individual cancer sites or types, however, organic food consumers had a 9% higher risk of breast cancer and 21% lower risk of non-Hodgkin lymphoma than those who never consumed organic food. The authors indicate pesticide residues as a likely factor differentiating these two food groups, however, in case of breast cancer, they suppose that this slightly risk increase in women consuming organic food can result from that they are more likely to attend breast cancer screening and therefore are more likely to be diagnosed with breast cancer [5].

Another impressive cohort study (28,192 pregnant women) was carried out by *Torjusen* et al. [32] who analysed the risk of pre-eclampsia and organic vegetable consumption. Women who often or mostly consumed organic vegetables had a 24% lower risk of pre-eclampsia than those who reported rare or lack of such consumption. As it was in the above described studies, the authors suppose that lower exposition on pesticide residues when organic vegetables are consumed can be the main factor affecting the obtained results. The potential mechanism involved in this phenomenon concerns inflammation. Since the low intake of pesticide residues and additionally, secondary metabolites present at a higher level in organic plants, with their positive influence on gut microbiota, decrease inflammation perhaps this decreases the risk of pre-eclampsia.

Quite disturbing results obtained *Rauh* et al. [25], *Bouchard* et al. [4] and *Engel* et al. [11] analysing prenatal exposure to organophosphate pesticides and their effect on cognitive development of children. In their cohort studies involving from 265 to 404 children and their mothers, they found that prenatal exposure to organophosphates is negatively associated with cognitive development. Children born by mothers with a high level of organophosphate pesticide metabolites found in urine during pregnancy had an average deficit of 7.0 IQ points compared with those who were born by mothers with the lowest pesticide prenatal exposure. Fortunately, children's urinary pesticides metabolites concentrations were not associated with cognitive scores. Trying to understand the mechanisms involved in this phenomena authors indicate more vulnerable foetal nervous systems being under unique processes occurring during this stage of development [4].

Very interesting prediction proposed *Brandt* at al. [6] who assumed that 12% increased intake of biologically active compounds present in organic fruits and vegetables is like 12% increased consumption of fruits and vegetables. They applied a mathematical model to calculate the health outcome of this increased consumption and estimated the potential increase in life expectancy. Assuming that a woman switched from conventional to organic products without changing the amount consumed per day she would live 17 days longer. The same calculation for a man gives 25 days' longer life.

Although in a perfect world we probably all would like to consume organic food, it is not realistic at present due to its high prices and problems with common availability, and looking from a global perspective, due to low production efficiency and the high number of inhabitants of the Earth. There is still a need for research on the impact of organic food consumption on specific diseases because, as this review has shown, there are plenty of gaps to fill. To the best of author's knowledge, there are no meta-analyses, critical reviews and especially large cohort studies concerning the influence of organic food intake on the development of cancer in men, overweight and obesity in children, as well as the effect of organic food consumption of animal origin on the development of cardiovascular diseases. For this reason, further research is necessary to fulfil these lacks.

CONCLUSIONS

Although the results from individual studies are not always consistent, statistically speaking, organic raw materials of plant origin contain less pesticides, nitrates, toxic metals as well as more vitamin C and

polyphenols. In case of animal origin products, it is expected to find more unsaturated fatty acid and in organic dairy products, additionally, a higher content of protein and saturated fatty acids, however, more important here is the length of the grazing period and access to fresh forage than a production system. Although a diet based on organic food significantly reduces exposure to pesticides and increase access to antioxidants, it generally does not provide a significant nutritional advantage compared to a conventional diet. Nonetheless, some large cohort studies showed that the systematic, consumption of organic products reduces the risk of overweight and obesity for both sexes, as well as non-Hodgkin lymphoma in the case of women. Besides, the consumption of dairy products significantly reduces the risk of eczema in infants, and organic fruits and vegetables, pre-eclampsia in pregnancy. Many studies suggest that the lower morbidity of these diseases by organic food consumers is the result of lower intake of pesticide residues and higher intake of antioxidants. Since there are still many unanswered questions concerning the effects of organic food consumption on the development of numerous diseases, farther research, especially large cohort studies are necessary to be carried out.

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Conflicts of interest
The author declares no conflict of interest.

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